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ENVIRONMENTAL EVALUATION
RESIDUALS MANAGEMENT FACILITY PLAN

For The City Of Phoenix
91st Avenue Wastewater Treatment Plant
23rd Avenue Wastewater Treatment Plant

Phase C- EFFLUENT DISCHARGE ASSESSMENT

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Phase C - Effluent Discharge Assessment

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SECTION 1

INTRODUCTION

PURPOSE AND SCOPE

This assessment evaluates the environmental effects of discharging 91st Avenue and 23rd Avenue Wastewater Treatment Plant effluent into the Salt River. Issues and concerns related to water resources, riparian vegetation and wildlife, flood hazards, and insects are specifically addressed. As identified throughout the Final Environmental Impact Statement for the Point Source Metro Phoenix 208 Wastewater Management Plan (USEPA, 1979), these concerns include:

- Potential degradation of surface and groundwater quality due to effluent discharge
- The impacts of effluent discharge on the maintenance of riparian vegetation, which provides wildlife habitat and is reported to cause increases in floodwater spreading
- The impacts of effluent discharge on present nuisance insect problems
- Public health impacts associated with the effluent

These issues are assessed in the context of two separate conditions of effluent discharge which were selected by the City of Phoenix. The conditions are based on effluent projections as described in Appendix C (Greeley and Hansen, 1980).

EFFLUENT DISCHARGE CONDITIONS

Two effluent discharge conditions were compared in order to determine the effects of effluent in the area downstream of the 91st Avenue Wastewater Treatment Plant. The first condition considers the impacts of the effluent

discharge assuming total effluent reuse and, therefore, minimum discharge into the Salt River. Under this condition, the only effluent discharged to the Salt River would be 6.52 mgd to meet an existing non-contractual commitment to the Arizona Game and Fish Department. The assessment of this condition reflects the impacts of minimum discharge on the area downstream of the 91st Avenue Plant.

The second condition of discharge assumes that the existing reuse commitments would be fulfilled and the remaining unused effluent would be discharged into the Salt River. Under this condition, discharge to the Salt River would decrease from 90 mgd annual average flow in 1980 to approximately 20.2 mgd annual average flow of effluent in 1986, and then increase to 35.2 mgd by the year 2000. This condition further assumes that the Arizona Nuclear Power Project (ANPP) will use only enough effluent for three units at the Palo Verde Nuclear Generating Station and will allow the unused portion of their contracted effluent to be discharged into the Salt River. The minimum effluent discharge of approximately 20.2 mgd in 1986 was selected for evaluation in this report because maximum impacts are to be expected under this low flow condition.

The discharge point into the river for either condition is assumed to be at the outfall of the existing effluent channel. A further discussion of projected flows and estimated quantities of effluent discharge into the Salt River is provided under "Physical Factors" in Section 2. A description of existing effluent reuse commitments is provided under "Institutional Arrangements," also in Section 2.

Effluent discharged from the 23rd Avenue Wastewater Treatment Plant is accounted for in this assessment as part of the baseline river flow of the Salt River

entering the project area southeast of the 91st Avenue Plant. The effects of effluent discharged to the Salt River from the 23rd Avenue Plant on the area upstream of the 91st Avenue Plant project area are not evaluated in this report; however, the effects of 23rd Avenue Plant effluent on riparian vegetation have been addressed in the 23rd Avenue Plant Upgrade Interim Report No. 1 (Greeley and Hansen, October 1979). Surface water quality, groundwater quality and the relationship of these factors to public health are addressed in the draft Effluent Disinfection Facility Plan for the 23rd Avenue Wastewater Treatment Plant (Greeley and Hansen, December 1979) and in the above mentioned Interim Report No. 1 (Greeley and Hansen, October 1979). Insect problems associated with the 23rd Avenue Plant and its discharges are being addressed in the "Insects and Odors" appendix to the 23rd Avenue Plant Upgrade Interim Report No. 2, to be completed in March 1980.

PUBLIC CONCERNS ASSOCIATED WITH EFFLUENT DISCHARGE

Public concerns regarding the impact of effluent discharge into the Salt River have been well documented. In general, these concerns include insect problems attributable to the effluent, the impact of effluent on support of riparian vegetation, and the impact of effluent on surface and groundwater quality, which could potentially affect public health.

Residents in the vicinity of the 91st Avenue Plant have historically noted insect problems (USEPA, 1979). Typical nuisance insects of this area include *Psorophora confinnis* and *Culex pipiens* mosquitoes and non-biting midges of the genus *Chironomus* (bloodworms) (ABE/CDM, 1980).

A recent study (ABE/CDM, 1980) found that although Psorophora confinnis mosquitoes are probably the major nuisance insect species in the project area, they were not found to be associated with treatment plant effluent. Common breeding sites include poorly leveled or drained yards and pastures, tailwater ponds, desert ponds, dammed washes, and other areas where water stands for more than three days. This assessment focuses primarily on the effects of effluent discharge on Culex pipiens mosquitoes and midges, the insect species which are most related to the effluent.

Another public concern involving effluent discharge is the degree to which it supports downstream riparian vegetation. Both adverse and beneficial impacts of vegetation have been ascribed to the effluent. Effluent presently flows through the Base and Meridian Wildlife Area, which is located east of 115th Avenue and managed by the Arizona Game and Fish Department for preservation of valuable wetland vegetation and wildlife habitat. Further downstream, however, residents of the Holly Acres area who have had their homes and land recently flooded believe that the effluent supports riparian vegetation, particularly saltcedar, which they believe is the dominant factor in the spreading of floodwater on their properties.

The impact of effluent discharge on surface and groundwater quality is of major concern to the Gila River Indian Community and other residents of the project area who live near the 91st Avenue Plant or effluent channel. These residents are primarily concerned that effluent-impacted groundwater may contaminate their potable water supply wells and that open access to the effluent channel is a public safety hazard. Mitigation of these public concerns associated with the plant is addressed in the 91st Avenue Plant Expansion Draft Facility Plan.

PROJECT AREA

The project area corresponds with that of the 91st Avenue Plant Expansion Draft Facility Plan. As depicted on Plate 1-1, the area includes the land within a two-mile wide corridor along the Salt River channel from 83rd Avenue to the Buckeye Canal headgate about 7.5 miles downstream. Much of the project area is within the 100 year floodplain of the Salt and Gila Rivers.

The 91st Avenue Plant is located on the north bank of the Salt River just east of 91st Avenue and south of Broadway Road. The plant is surrounded on the west, north and east by low density rural/agricultural development with some rural subdivisions of residential housing such as Holly Acres, two to four miles west, and others five to ten miles northwest of the plant. In addition, the Maricopa Colony of the Gila River Indian Community is located on the south bank of the Salt River channel about one mile south of the plant location.

The project area lies entirely within the Gila River drainage basin. Flows of the Salt and Verde Rivers, which converge east of the Phoenix metropolitan area, are controlled by six dams and reservoirs that distribute the joint flows to various canals at the Granite Reef Diversion Dam for irrigation.

Discharge of treated effluent from the 23rd and 91st Avenue Wastewater Treatment Plants helps to support the flow of the Salt River. As described under "Physical Factors" in Section 2, effluent discharge from the 23rd Avenue Plant has been accounted for in this assessment as part of the baseline river flow entering the project area southeast of the 91st Avenue Plant. The flows of the Salt River combine with irrigation tailwaters and normal stormwater runoff of the Gila River just downstream of the plant. These combined flows

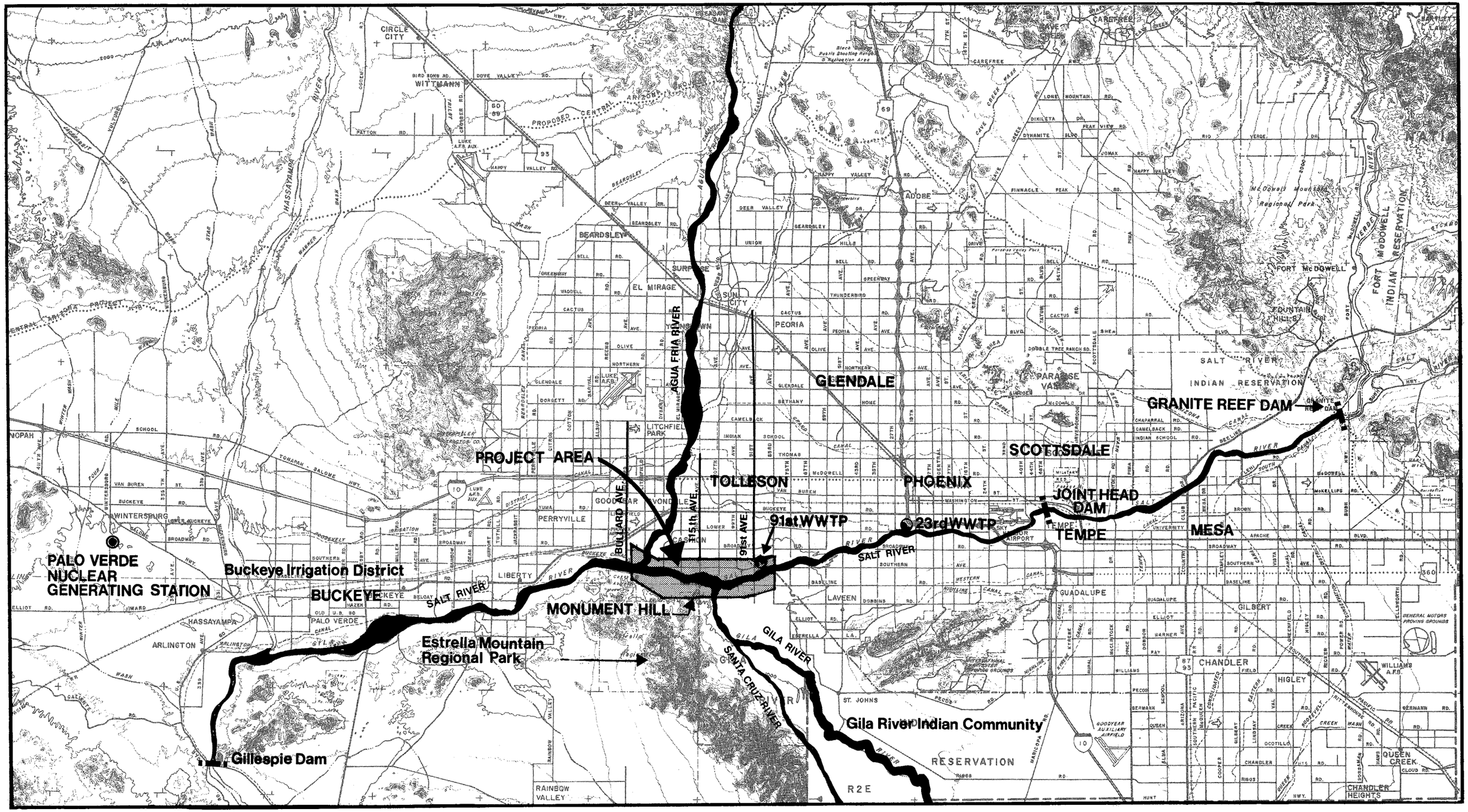

Plate 1-1
Project Area Location

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and the existing groundwater table maintain a significant riparian habitat, including the Base and Meridian Wildlife Area. At a location between Litchfield Road and Bullard Avenue, the Buckeye Canal diverts the majority of the flow for irrigation purposes.

METHODOLOGY

GENERAL: The assessment of the two effluent discharge conditions was undertaken in several steps. These steps included:

- Determination of needs for relevant environmental information on the present and past environmental conditions within the project area. This information centered on surface water, groundwater, vegetation, flooding, and insects.
- Development and evaluation of environmental information. Detailed information was developed for each of the five categories listed above. Information includes present and past conditions and the environmental factors which influence those conditions. Present conditions were quantified to the extent possible for use as a baseline in the discharge assessment.
- Determination of relationships among surface water, groundwater, vegetation, flooding, and insects. Based on the above, the relationships among those factors were identified and quantified to the extent possible.
- Assessment. Using as baselines the information developed for each category and the relationships determined among them, the impacts of the discharge of effluent were assessed under the two conditions.

The following discusses the assumptions and environmental information developed to assess the impacts of the two effluent discharge conditions and explains how the information was used to determine impacts.

SURFACE WATERS: Basic information on surface water quality and quantity in the project area was developed for the assessment of effluent discharge impacts.

Information on the quality of the surface flow in the project area was needed to address the impact of effluent discharge in terms of public health.

Annual average flows and seasonal surface flow fluctuations of the Salt River excluding 91st Avenue Plant effluent were determined to establish that which is referred to as the baseline river flow. Both the baseline river flow and effluent from the 91st Avenue Plant were used to address possible impacts on riparian vegetation. This included fluctuations in quantities of effluent discharged to the surface waters under existing effluent reuse commitments and the effects of seasonal variation in the amount of irrigation tailwater present in the project area.

The baseline river flow was determined using existing information sources. Because information on quantities of irrigation tailwater was not directly available, a range of tailwater contribution to surface baseline river flow was derived on the basis of irrigable acreages. Seasonal changes in tailwater flow were determined based on monthly percentages of total irrigation water supplied to agricultural lands.

Total surface water flows under each effluent discharge condition were determined by adding the effluent discharge flow for the first and second discharge conditions to the baseline river flow. A comparison between the two provides the net change in total surface flow expected under the two conditions.

A comparison of surface water flows under the two discharge conditions was made for 1986 when the effluent for Units 1, 2, and 3 of the Palo Verde Nuclear Generating Station would be required. The MAG 208 Final EIS (USEPA, 1979) states that urbanization will continue in the region, resulting in conversion

from agricultural to urban land use. Projection of the baseline river flow which is predominated by irrigation tailwaters was not attempted past 1986 because of the uncertainty of future irrigable acreage but was assumed to be constant to the year 2000.

GROUNDWATER: Information on groundwater quality and quantity was necessary to address the issue of the potential effects of effluent discharge in the project area. Dr. Kenneth Schmidt, a groundwater quality expert, was contracted to determine these effects (Appendix B). The relationships between the groundwater levels and geological conditions, the effects of flooding and river surface flows on groundwater recharge, and the effect of groundwater levels on the support of riparian vegetation were then determined.

VEGETATION: Information on riparian vegetation in the project area was required in order to address issues concerning maintenance of riparian wildlife habitat and to address the concern that riparian vegetation results in increased floodwater spreading in the project area. This included identification of the riparian species in the area and the environmental conditions required for their establishment and survival. Present and historical information on density and distribution was developed based on literature searches, examination of aerial photographs and field investigations. The key to the evaluation of riparian vegetation in the project area was the determination of relationships between surface water and groundwater conditions and the establishment and survival requirements for riparian species. Conclusions and assessment of future vegetative growth under the two effluent discharge conditions were then prepared.

FLOODING: Several factors were required to assess the potential for increased flooding under the two conditions of effluent discharge. These included information on historical flood flows, effects of vegetation on flooding, historical changes in the river channel and floodplain, and information on flood profiles under varying flood flow conditions. An element of the flooding assessment included an investigation of changes in the river channel and recent flood intensities in order to address possible causes of floodwater spreading. In this assessment, the largest recent flooding events were compared with the floodplain frequency map to determine probable areas of inundation. The assessment of flooding associated with the two conditions of effluent discharge was then performed.

INSECTS: The information necessary for the assessment of insect problems associated with the two conditions of effluent discharge was based on Appendix G of the 91st Avenue Wastewater Treatment Plant Expansion Draft Facility Plan. The impacts of the two effluent discharge conditions on insects were then determined.

SUMMARY: There are presently several studies underway which relate to some of the major issues and concerns addressed in this assessment. The analysis and conclusions presented in this assessment have been based on existing information and documents. These are cited in the list of references. Quantified conclusions concerning certain impacts were not possible based on the information presently available. These are noted in the text and summarized in Section 4, "Issues to be Resolved."

SECTION 2

ENVIRONMENTAL ASSESSMENT

PHYSICAL FACTORS

The factors addressed in this portion of the assessment are essentially related to the project area water resources. These physical factors are of primary importance in determining the relationship between vegetative growth and the surface and groundwater characteristics. The specific physical factors included in this analysis are surface water quantity, surface water quality, geology, groundwater quantity, and groundwater quality.

SURFACE WATER QUANTITY: The 91st Avenue Wastewater Treatment Plant started discharging effluent in 1958; by 1962 the effluent flow had increased to about 4 mgd. From 1964 to 1965 effluent discharge increased from approximately 5 mgd to 23 mgd. Presently, about 100,000 acre-feet per year (approximately 90 mgd) of effluent is discharged from the plant to the Salt River channel about three miles upstream of the Salt-Gila River confluence. This flow combines with the project area average annual baseline river flow of approximately 42,000 to 57,000 acre-feet. The combined waters flow westward in the channel, past the Salt-Gila River confluence and beyond the confluence of the Agua Fria River. At about this point, a majority of the flow is diverted into the Buckeye Canal and used for irrigation by the Buckeye Irrigation Company.

The flow of the river is maintained by several surface and groundwater inflows other than plant effluent. One contribution of stream flow in the project area is the upstream Salt River flow, as indicated in Table 2-1. This net

TABLE 2-1

ESTIMATED UPSTREAM WATER SUPPLY TO THE PROJECT AREA (Acre – Feet/Year)

UPSTREAM WATER SUPPLY: (Above 91st Avenue Outfall)		
INFLOW -	23rd Avenue Effluent[1]	41,800
	Tailwater (NE¼24-T1N-R2E)[1]	1,500
	Rainfall[2]	200
	Underflow[2]	100
	Groundwater Inflow[2]	300
	Subtotal	43,900
OUTFLOW -	Diversion[1]	250
	Evapotranspiration[1]	3,900
	Groundwater Recharge[1]	33,400
	Subtotal	37,550
	NET AVERAGE FLOW*	6,350

* Not Including Flood Flows

SOURCE:

[1] Halpenny and Clark, 1977.
[2] USEPA, 1979.

inflow of approximately 6,300 acre-feet per year is expected to be relatively continuous and uniform from month to month, as opposed to being seasonally variable. This is due to the rather consistent discharge of effluent from the 23rd Avenue Plant. The baseline river flow of the project area (i.e. excluding 91st Avenue Plant effluent) exhibits a larger seasonal fluctuation than the upstream reach because it depends more on rainfall and the variable contribution of irrigation tailwaters and the Gila River. These flows are presented in Table 2-2.

Gila River flow fluctuations result from stormwater runoff and, to some extent, growing season irrigation demands. Data pertaining to Gila River flows at the confluence of the Salt River were derived from a ten-year composite of flows (13,400 acre-feet/year averaged over 1968-1977) from USGS gauging stations located upstream of the Salt-Gila confluence on the Gila River near Laveen (#9-4890) and the Santa Cruz River near Laveen (#9-4795). Rainfall data analysis was based on monthly percentages of the area's annual average precipitation of 7.48 inches, which provides an average of 1,400 acre-feet/year of rainwater to the river channel. These flows join with various relatively constant river waters, mainly groundwater underflow of 3,500 acre-feet/year from the Gila River bed upstream of the Salt-Gila confluence and general groundwater inflow to the stream which contributes 1,700 acre-feet/ year (Halpenny and Clark, 1977).

Other than effluent, the major contributor of flows to the river is irrigation tailwater. The actual locations of the points of discharge have been identified. (Halpenny and Clark, 1977.) Because actual flow measurements for

TABLE 2-2
ESTIMATED WATER SUPPLY IN THE PROJECT AREA (Acre-Feet/Year)

PROJECT AREA BASE FLOW:		
INFLOW -	Upstream Water Supply (Table 2-1)	6,350
	Other Effluent[1]	800
	Upper Gila River Discharge[2,3]	13,400
	Rainfall[1]	1,400
	Underflow[2]	3,500
	Groundwater Inflow[1]	1,700
	Irrigation Tailwater[4]	15,000 - 30,000
	AVERAGE FLOW*	42,150 - 57,150
91st AVENUE PLANT EFFLUENT:		
INFLOW -	Annual Average (90 mgd)	100,000

* Not Including Flood Flows.

SOURCE:

1 USEPA, 1979.
2 Halpenny and Clark, 1977.
3 USGS Gauging Station (#9-4890, #9-4795) (10-year average, 1968-1977).
4 Field Reconnaissance and Data Analysis.

these tailwaters are not available, an estimate of the most probable range of tailwater flows was made for this assessment. Based on aerial photograph interpretation and topographical slopes, approximately 22,000 and 10,000 acres of irrigable land border the north and south banks of the Salt River, respectively, and supply tailwaters to the project area. To determine a yearly contribution of tailwaters, it was assumed that 5-10 percent of the total land would be left fallow. Therefore, it would be expected that approximately 30,000 acres per year of land would be available for irrigation. Through a monitoring program of eleven irrigation districts in California, Merrill et al (1979) determined that in terms of field supply and return flow measurements a range of 0.5 to 1.0 acre-feet/year of tailwater would be expected per acre of irrigated lands. Based on this interpretation, the range of expected annual tailwater flow from the previously stated acreages would be about 15,000 to 30,000 acre-feet/year. This range should be considered as the maximum expected flow. The data supplied in Table 2-3 for irrigation tailwater flows was assessed for expected monthly discharge volumes for a typical growing season. These monthly flow determinations were derived from a monthly percentage of the total annual flows in the Grand Canal below Power House and the Tempe Crosscut Canal (Salt River Project, 1970-1978). The percentages were applied against the total acreage of irrigable land and the expected runoff, as previously described, to predict the monthly contribution of irrigation tailwaters to the baseline river flow.

The accumulation of these various flows (Table 2-3) without effluent creates a flow in the river that is heavily influenced by seasonal fluctuations (Figure 2-1). The present effluent discharge added to the river provides a

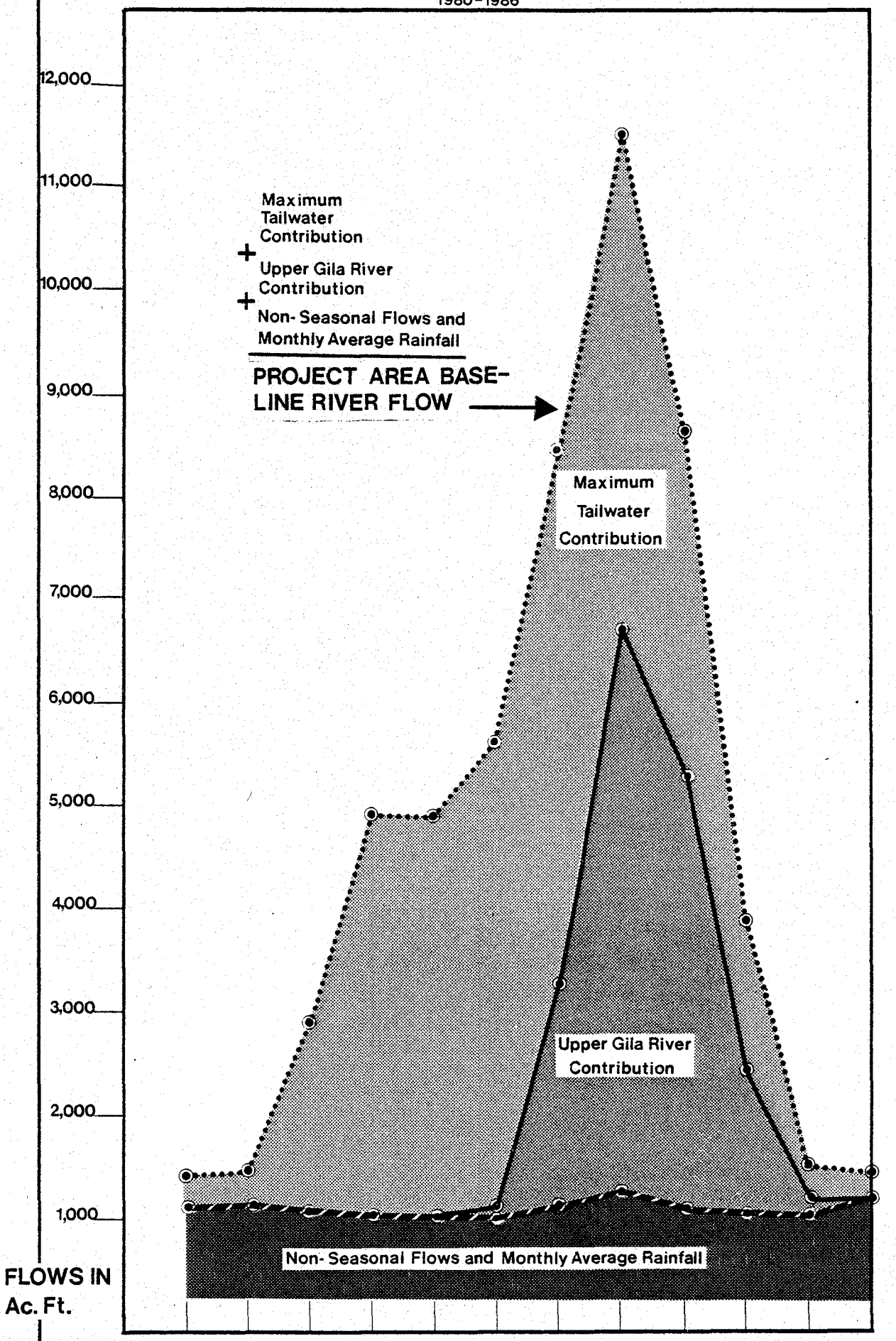
TABLE 2-3
PROJECT AREA
MONTHLY AVERAGE BASELINE FLOW

MONTH	NON-SEASONAL FLOWS (ac.-ft./month)	AVG. ANNUAL RAINFALL (ac.-ft./month)	UPPER GILA RIVER FLOWS (ac.-ft./month)	IRRIGATION TAILWATER-RANGE (ac.-ft./month)	BASELINE RIVER FLOW (ac.-ft./month)	BASELINE RIVER FLOW (mgd)
Jan.	1030	135	NF	150- 300	1315-1465	14.1- 15.7
Feb.	"	160	NF	150- 300	1340-1490	14.4- 15.0
Mar.	"	130	NF	900-1800	2060-2960	22.1- 31.7
Apr.	"	60	NF	1950-3900	3040-4990	32.6- 53.5
May	"	20	NF	1950-3900	3020-4970	32.4- 53.3
June	"	20	100	2250-4500	3400-5650	36.5- 60.6
July	"	145	2200	2550-5100	5925-8475	63.5- 90.9
Aug.	"	250	5500	2400-4800	9180-11,580	98.4-124.2
Sept.	"	130	4200	1650-3300	7010-8660	75.2- 92.9
Oct.	"	95	1300	750-1500	3175-3925	34.0- 42.1
Nov.	"	90	100	150- 300	1370-1520	14.7- 16.3
Dec.	"	165	NF	150- 300	1345-1495	14.4- 16.0
Yearly Flows	12,350 Af/yr, Af/yr Source 6,350 Upstream water supply 800 Other effluent 3,500 Underflow 1,700 Groundwater inflow 12,350 Af/yr. 1,030 Af/month	1400 Af/yr Based on monthly averages	13,400 Af/yr. Based on mthly. averages 10-yr. averages NF - Gila not flowing	Range: Af/yr. 15,000-30,000 Based on 0.5-1.0 Af of run-off per acre irrigated	Range: Af/yr. 42,180-57,180 Does not include discharge from the 91st Avenue Plant AF/month ÷ 93.25 = mgd Expected flow per year 1980 - 1986	

Figure 2-1

PROJECT AREA BASELINE RIVER FLOW

1980-1986



uniform contribution of flow which essentially maintains a high flow in the river when the seasonal discharges are reduced.

The 91st Avenue Plant presently adds approximately 90 mgd of effluent to the Salt River channel flow. In this arid region, this effluent has proven to be a valuable resource. The 91st Avenue Plant is in the process of being expanded as identified in the MAG 208 Plan. The effluent, including the projected flows to 120 mgd, is already subject to reuse commitments as follows:

- Up to 30,000 acre-feet per year (approximately 26.8 mgd) to Buckeye Irrigation Company for restricted agricultural irrigation.
- Up to 7,300 acre-feet per year (approximately 6.52 mgd) to the Arizona Game and Fish Department for a wildlife management area in the Salt River bed near 115th Avenue (not a contracted allocation).
- 1,200 acre-feet per year (approximately 1.07 mgd) to the U.S. Water Conservation Laboratory for the laboratory's research facilities at Flushing Meadows. However, these facilities were washed out by 1978-79 floodwaters and there are no plans to reactivate the project.
- Up to 140,000 acre-feet per year (approximately 125 mgd) to the Arizona Nuclear Power Project. The Multi-cities/ANPP contract specifies that the effluent may be used at the Palo Verde Nuclear Generating Station (PVNGS) or any other power generating facility ANPP may choose.

The plant effluent is currently discharged along the north bank of the Salt River where it eventually mixes with the baseline river flow as previously described. The river water flows to Buckeye Heading where the majority is diverted and used for irrigation. As a result of this discharge two reuse commitments are satisfied: 1) effluent allocated to AGFD which flows through the downstream riparian habitat, and 2) the effluent drawn off by the Buckeye Irrigation Company for restricted agricultural irrigation.

As indicated in Table 2-4, discharge of all effluent from the plant into the Salt River is expected to continue until about 1983 when Arizona Nuclear Power Project (ANPP) is scheduled to bring the first power generating unit commercially on line. Buckeye Irrigation Company has made arrangements to have its supply of effluent conveyed through the same pipeline that ANPP would use for its allotment. Therefore, the BIC flow and the effluent required by the ANPP commitment would be removed from the river.

The increasing use of effluent by ANPP as the remaining units are brought on line would significantly change the quantity of plant effluent discharged to the river. The flows in Table 2-4 indicate the remaining effluent as an annual average. However, when the flows are assessed on a monthly basis the discharge is shown to be seasonally variable. The cooling water demand for Palo Verde Nuclear Generating Station (PVNGS) would be the highest during the summer months and would decline during the colder seasons. Table 2-5 indicates the monthly requirements as each power generating unit becomes operational (Appendix C, Greeley and Hansen, 1980). Monthly fluctuations in the baseline river flow would serve to offset the seasonal demands of cooling water for ANPP, which would tend to produce a more uniform flow in the river through 1986. Figure 2-2 indicates this offsetting effect of reduced effluent discharged under the seasonally higher requirements of PVNGS and the simultaneous increase in the baseline river flow caused by agriculture uses.

The baseline river flows, (i.e. without effluent) were determined based on the existing conditions, specifically in terms of present land uses. According to the MAG 208 Final EIS (USEPA, 1979), the region is expected to continue to

TABLE 2-4

EFFLUENT REUSE PROJECTIONS FOR THE 91st AVENUE TREATMENT PLANT

(120 mgd - Annual Average Flow Basis)

Year	Estimated Projected Flow (mgd)	EFFLUENT REUSE COMMITMENT			DISCHARGE TO SALT-GILA RIVER (5,6)		ADDITIONAL EFFLUENT REQUIRED TO MEET REUSE COMMITMENTS(7)
		AGFD (mgd)	BIC (mgd) (1)	PVNGS (mgd) (2,3)	With Units 4&5 (mgd)	Without Units 4&5 (mgd)	With Units 4&5 (mgd)
1980	90	6.52	26.81	-		90	
1981	93	"	"	-		93	
1982	95	"	"	-		95	
1983	98	"	"	20.7 (Unit 1)		50.5	
1984	101	"	"	38.7 (Units 1&2)		35.5	
1985	103	"	"	38.7 (Units 1&2)		37.5	
1986	105	"	"	58.0 (Units 1,2,3) (4)		20.2	
1988	110	"	"	77.3 (Units 1-4)	6.52	25.2	.63
1990	120	"	"	96.6 (Units 1-5)	"	35.2	9.93
1995	120	"	"	96.6 (Units 1-5)	"	35.2	9.93
2000	120	"	"	96.6 (Units 1-5)	"	35.2	9.93

AGFD-Arizona Game and Fish Dept./BIC-Buckeye Irrigation Co./PVNGS-Palo Verde Nuclear Generating Station

1. BIC water expected to be drawn off PVNGS pipeline.
2. Only PVNGS Power Generating Units 1,2 and 3 have been approved to date.
3. Greeley and Hansen, 1980.
4. Assumes average annual requirement of 19.3 mgd for each of units 4 & 5.
5. Includes 6.52 mgd committed to AGFD.
6. Assumes Flushing Meadow allocation available for reuse.
7. Based on per unit requirements. ANPP is contractually allowed up to approximately 125 mgd annual average supply of effluent.

TABLE 2-5

REDUCTION IN PLANT EFFLUENT DUE TO COMMITMENTS AND CORRESPONDING DISCHARGE TO THE RIVER

Month	Plant Effluent Flows, mgd 91st Ave. *	Effluent Commitments PVNGS/BIC mgd *	Plant Effluent Flows mgd to the River
1980			
January	83.4		83.4
February	86.2		86.2
March	88.0		88.0
April	88.0		88.0
May	88.9		88.9
June	88.9		88.9
July	91.6		91.6
August	93.4		93.4
September	98.9		98.9
October	97.0		97.0
November	92.5		92.5
December	90.7		90.7
1983			
January	90.2	-	90.2
February	93.1	-	93.1
March	95.1	-	95.1
April	95.1	-	95.1
May	96.0	48.9	47.1
June	96.0	50.2	45.8
July	99.0	49.9	49.1
August	100.9	49.9	51.0
September	107.8	48.5	59.3
October	104.9	47.8	57.1
November	100.0	40.4	59.6
December	98.0	44.7	53.3
1984			
January	92.5	39.9	52.6
February	95.5	40.2	55.3
March	97.5	46.3	51.2
April	97.5	46.9	50.6
May	98.5	71.0	27.5
June	98.5	73.6	24.9
July	101.5	73.0	28.5
August	103.5	73.0	30.5
September	109.5	70.2	39.3
October	107.5	68.8	38.7
November	102.5	54.0	48.5
December	100.5	62.6	37.9
1986			
January	96.6	53.0	43.6
February	99.8	52.4	47.4
March	101.9	65.8	36.1
April	101.9	67.0	34.9
May	102.9	93.1	9.8
June	102.9	97.0	5.9
July	106.1	96.1	10.0
August	108.2	96.1	12.1
September	115.5	91.9	23.6
October	112.4	89.8	22.6
November	107.1	67.6	39.5
December	105.0	80.5	24.5

SOURCE:

*Greeley & Hansen, 1980

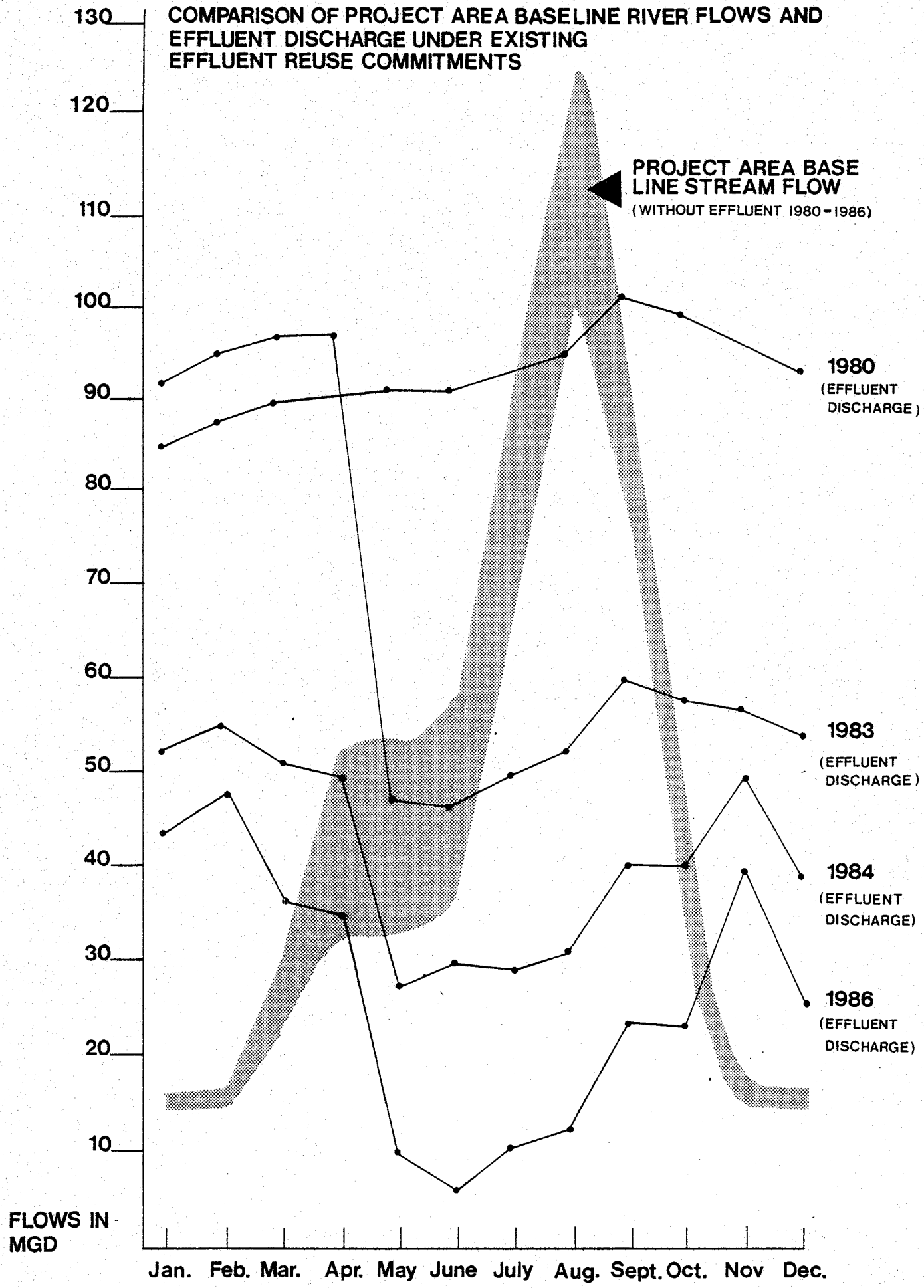

COMPARISON OF PROJECT AREA BASELINE RIVER FLOWS AND EFFLUENT DISCHARGE UNDER EXISTING EFFLUENT REUSE COMMITMENTS
PROJECT AREA BASE LINE STREAM FLOW
(WITHOUT EFFLUENT 1980-1986)
1980 (EFFLUENT DISCHARGE)
1983 (EFFLUENT DISCHARGE)
1984 (EFFLUENT DISCHARGE)
1986 (EFFLUENT DISCHARGE)
130
120
110
100
90
80
70
60
50
40
30
20
10
FLOWS IN MGD
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov
Dec.

Figure 2-2

grow in population. This would result in a continuation of the present trend of conversion from agricultural land to urban development. The contribution of irrigation tailwater to the baseline river flow after 1986 is difficult to predict and could not be quantified for this assessment. Because these reduced flows of irrigation tailwaters cannot be quantified, flows were assumed to remain constant to the year 2000 for this study.

The quantity of plant effluent discharged to the Salt River is expected to change with time. As discussed previously, the effluent has become a valuable resource and its effective reuse is of significant interest. The main focus of this assessment is to determine the effects of two possible effluent reuse conditions on the maintenance of surface water flows in the river for the entire year. The two effluent conditions consist of: 1) the discharge of only the 6.52 mgd for AGFD with total reuse of the remaining effluent, and 2) allocations of effluent to the existing reuse commitments through 1986 with the unused portion being discharged to the river.

A general reduction in the existing relatively consistent flow of effluent discharged into the Salt River would be expected from either effluent discharge condition. As a result, channel flow characteristics would shift in both effluent discharge conditions to a more seasonally variable flow, primarily because on an annual basis the total river flow would have a higher proportion of irrigation tailwaters. The difference between the two effluent conditions would be expected to be the greatest during the winter when the seasonal baseline river flow is at its lowest, causing plant effluent discharge to be most dominant. The river flows under the two effluent conditions are provided in Table 2-6 and represented in Figure 2-3.

TABLE 2-6
PROJECT AREA RIVER FLOW UNDER THE EFFLUENT REUSE CONDITIONS (1986)

MONTHS	91st AVENUE PLANT UNUSED EFFLUENT - 1986[1] (mgd)	BASELINE RIVER FLOW[2] (mgd)	SECOND CONDITION BASELINE FLOW AND EFFLUENT FLOW[3] (mgd)	FIRST CONDITION BASELINE FLOW AND 6.5 mgd OF EFFLUENT DISCHARGE[4] (mgd)
Jan.	43.6	14.1- 15.7	57.7- 59.3	20.6- 22.2
Feb.	47.4	14.4- 16.0	61.8- 63.4	20.9- 22.5
Mar.	36.1	22.1- 31.7	58.2- 67.8	28.6- 38.2
Apr.	34.9	32.6- 53.5	67.5- 88.4	39.1- 60.0
May	9.8	32.4- 53.3	42.2- 63.1	38.9- 59.8
June	5.9	36.5- 60.6	42.4- 66.5	43.0- 67.1
July	10.0	63.5- 90.9	73.5-100.9	70.0- 97.4
Aug.	12.1	98.4-124.2	110.5-136.3	104.9-130.7
Sept.	23.6	76.2- 93.9	98.8-116.5	82.7-100.4
Oct.	22.6	34.0- 42.1	56.6- 64.7	40.5- 48.6
Nov.	39.5	14.7- 16.3	54.2- 55.8	21.2- 22.8
Dec.	24.5	14.4- 16.0	38.9- 40.5	20.9- 22.5

[1] From Table 2-5. Assumes effluent commitments to PVNGS and BIC by pipeline.

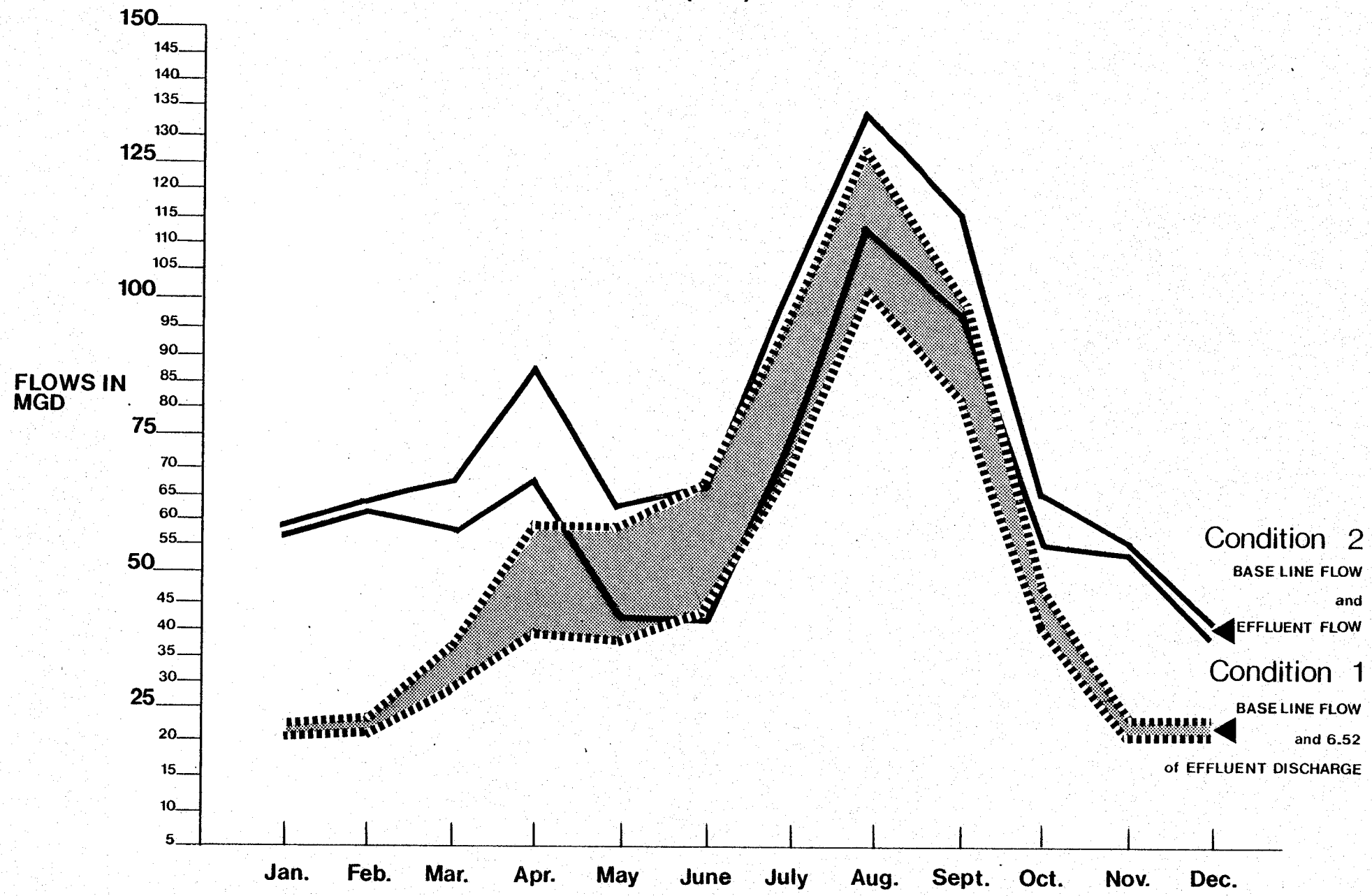
[2] From Table 2-1.

[3] River flow under second effluent discharge condition - assumes 20.2 annual average discharge into the Salt River.

[4] River flow under first effluent discharge condition - assumes 6.52 annual average discharge into the Salt River.

FIGURE 2-3

COMPARISON OF PROJECT AREA RIVER FLOWS UNDER THE EFFLUENT REUSE CONDITIONS*
(1986)



*Refer to Table 2-6 for Summary Table.

As indicated, the first condition (6.52 mgd only) would provide for the lower annual average river flow of the two conditions. This low flow would be most noticeable from November through March. The impacts that would be expected on the downstream ecosystem are discussed in the section on biological factors.

SURFACE WATER QUALITY: In general, the discharge of treatment plant effluent to any typical receiving stream results in the addition of several pollutants which reduce water quality. These pollutants are Biochemical Oxygen Demand (BOD) which lowers the dissolved oxygen, elevated levels of ammonia (NH_3), and chloramine toxicity due to disinfection. However, in this case the receiving stream is predominantly irrigation tailwaters which contain pollutants of their own, such as a high total dissolved solids (salinity) content along with a slight elevation in pH and total suspended solids (SS). Combining these discharges ultimately dilutes the various constituents specific to each discharge. For example, the irrigation tailwaters are characterized by a high concentration of salinity, whereas the effluent salinity content is low. Therefore, the mixing of the two flows reduces the overall level of salinity in the river water. This would also occur for the other various pollutants previously stated. The effects of the low salinity effluent on the recharge and the dilution of high salinity groundwater would be about the same as that described for surface water. The BOD and ammonia of the effluent is usually contained in the surface soil and would not reach the groundwater. No significant change is expected under either effluent condition.

GEOLOGY: The project area is located in an area of particular geological interest. The available data indicates a significant relationship between the area's geomorphology, surface water flow and depths to groundwater in this segment of the river. The subsurface geology is such that the basement rocks in the project area are arranged in fault-block sequences; mountain units are bounded by faults and are uplifted with respect to the nearby rocks. Conversely, the sediment-filled valleys are the bordering blocks; they are bounded by faults and lowered with respect to the surrounding rocks (Graf, 1980). Specific to the project area, this is characterized by the ridge of mountains which runs parallel to the southern border of the river channel. This ridge of mountains essentially starts at Monument Hill (115th Avenue) and extends to the butte which is topped by the Goodyear Survey Mark (adjacent to the Agua Fria River). The lowered portion of the fault is evidenced by the sediment-filled valley, which begins along the river channel and continues north through the project area.

Several distinct geologic units are found in the project area. The subsurface geology was derived from wells drilled throughout the area; the wells are located on Plate 2-1. The uppermost material beneath the majority of the area is Recent alluvium. This unit is comprised of coarse-grained deposits (primarily boulders, gravel, and sand) up to 200 feet thick, and is a prolific aquifer. The next distinctive unit ranges in depths from about 180 to 270 feet below land surface. This unit is comprised primarily of clay and silt and may be comparable to the "Middle Fine-Grained Unit" of the U.S. Bureau of Reclamation (1977). Because of its low permeability, this unit is a poor water producer.

It could be concluded that relatively impermeable geologic materials are present at relatively shallow depths near the Gila River west of Monument Hill. The subsurface geologic structure between Monument Hill and the Estrella Mountain Regional Park is such that shallow groundwater levels are favored. Hardrock either crops out at the land surface in this area or is present at relatively shallow depth, forming a boundary to the groundwater system south of the Gila River. In this southern part of the project area, near the mountain front, a substantial amount of water can be produced from the conglomerate layer (Appendix B; Schmidt, 1980).

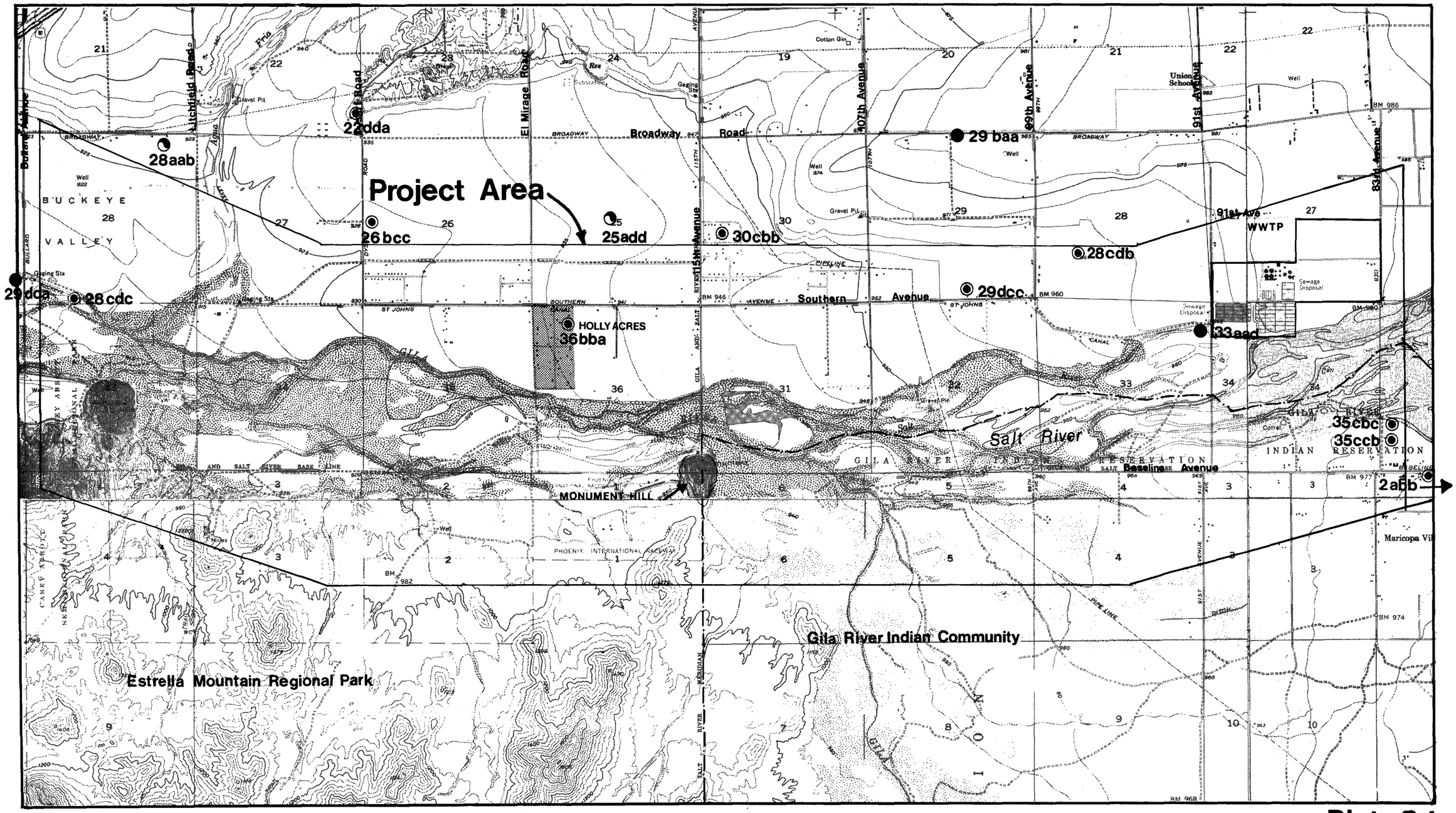
GROUNDWATER QUANTITY: The project area has historically been underlain by relatively shallow groundwater levels as compared to other parts of the Salt River Valley. This is largely due to the subsurface geologic structure, sources of groundwater recharge such as flood flows and other discharges, along with the relatively small amount of pumpage (Schmidt, 1980).

Halpenny and Greene (1975) reported on a water balance investigation of the Salt and Gila Rivers between 23rd Avenue and Gillespie Dam. By the end of the 1950's, flow in the Gila River at the Buckeye Heading had decreased to the point where water was present only after storms. Groundwater levels along the channel began to decline up through 1965 due to expanded pumpage and a decrease in stream flow. However, west of 115th Avenue, water levels did not fall significantly below the Gila River channel. Well data near 91st Avenue and the Salt River indicate that the groundwater level exceeded 40 feet in the early 1950's. After 1965, several sources of recharge became important in the project area. These include periodic flood flows and relatively continuous discharges

of effluent and other water in the channel of the Salt River. The combined effect of these sources has been to substantially raise water levels in the area from 1965 to the present, as indicated by hydrogeologic studies of wells in the area shown on Plate 2-1 and 2-2 (Appendix B; Schmidt, 1980).

Groundwater levels presented in the hydrograph on Figure 2-4 indicate that in the short term, water levels in wells in the project area fall during drought periods and rise during wet periods. During wet periods, two predominant factors control the depth to groundwater. First, there is direct recharge during flood flows. Second, pumpage is usually decreased substantially at the time of flood flows because of abundance of available canal water. These factors combine to produce a rather marked response in water levels following flood flows, which is expressed on Figure 2-4. In the long term, there has been a gradual rise in water levels since the mid-1960's in the project area, and this is attributed to recharge from effluent and the prevalence of more runoff in the Salt and Gila Rivers than occurred in previous decades.

Information regarding depth to water beneath the channel of the Salt and Gila Rivers in the project area is scarce because of a lack of measurements for wells which tap only the Recent alluvium. However, extrapolation of measurements from wells to the north and south of the Gila River near the Agua Fria River confluence suggests that groundwater levels beneath the western part of the project area have been at or near the elevation of the river channel (less than five feet deep) since the mid-1960's. East of Monument Hill, however, depth to water has often ranged from 10 to 20 feet beneath the Salt River channel (Schmidt, 1980).



Source: Schmidt, 1980

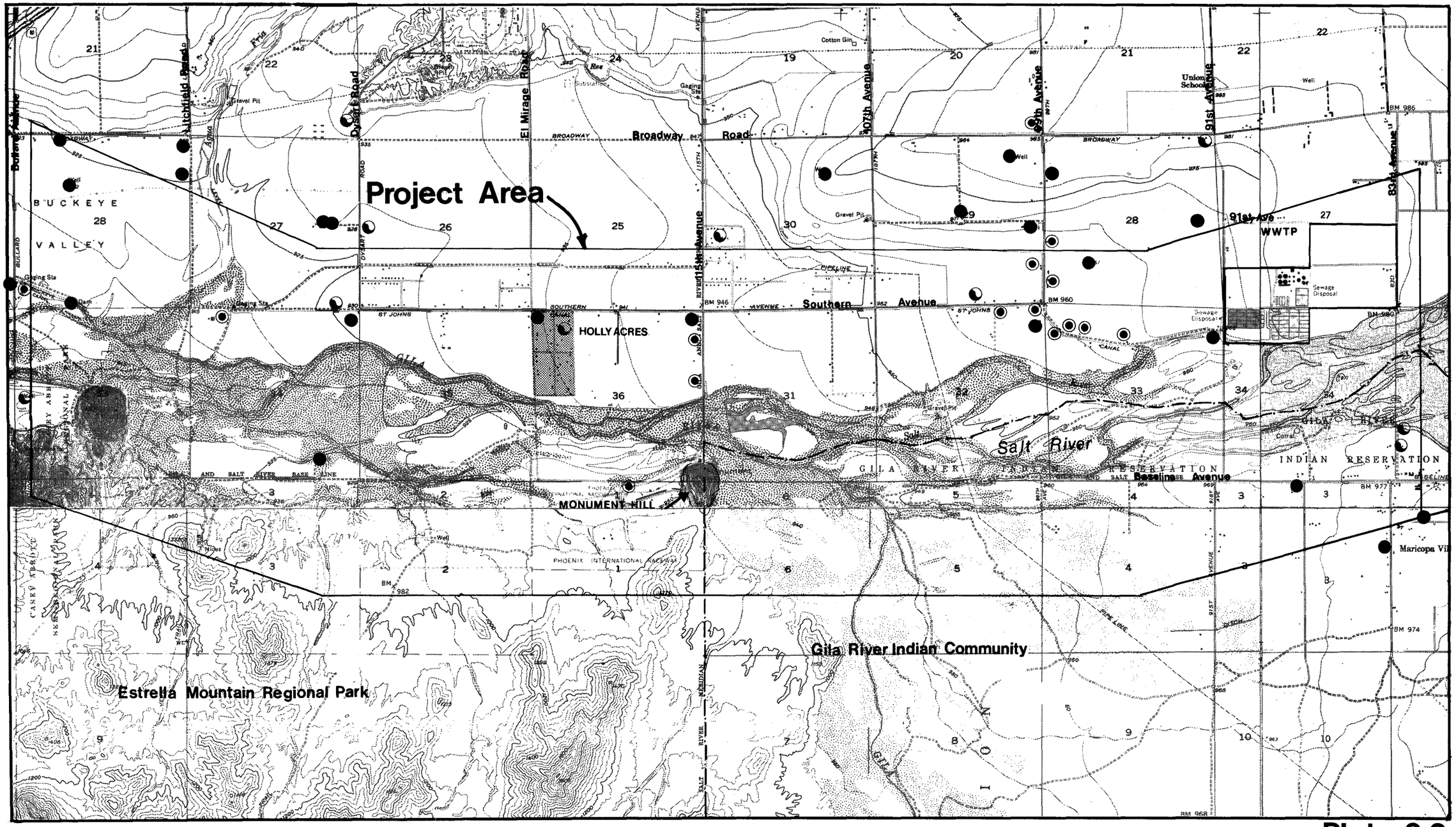
N

Scale: 1"=2700'

- Subsurface Geology
- Water Levels
- Chemical Quality

Plate 2-1
Location Of Selected Wells With Hydrogeologic Records

arthur beard engineers, Inc. / CAMP DRESSER & McKEE INC.



Source: Schmidt, 1980

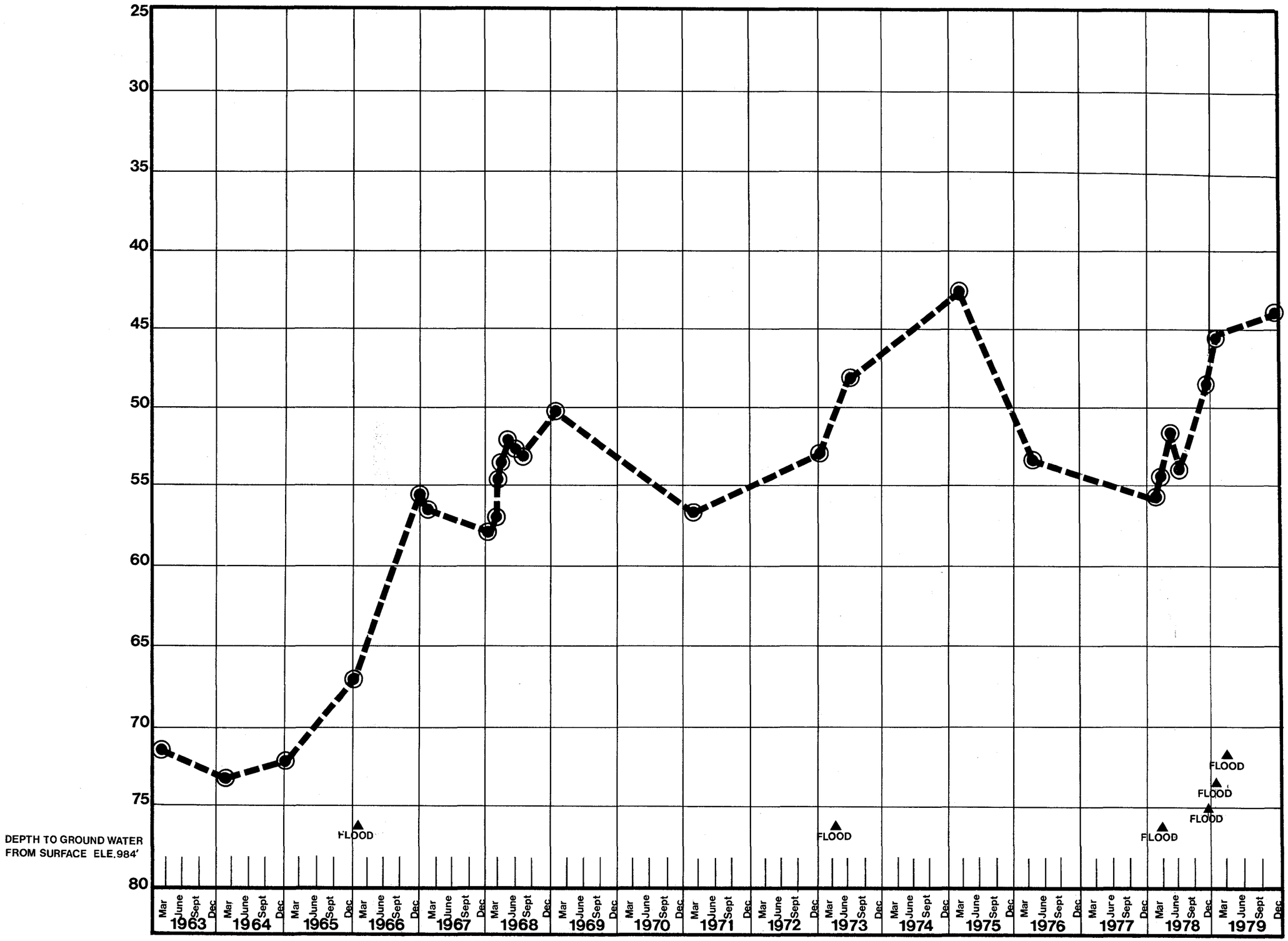
N

Scale: 1"=2700'

◉ Domestic or
● Irrigation
◐ Public Supply Stock

Plate 2-2
Location Of Selected Wells In The Project Area

arthur beard engineers, Inc. / CAMP DRESSER & McKEE INC.



Flood–occurences of flood recharge

source, Schmidt 1980

Figure 2–4

Ground Water Depths In Response To Flood Flows

A comparison of the project area geomorphology and available well data indicates that this segment of the river channel within the project area is characterized by two groundwater regimes, with the east and west separation occurring at 115th Avenue. This is based on the fact that the western part exhibits typically high groundwater levels, as previously stated, and the levels in the eastern part respond more readily to recharge as a result of lower groundwater levels (Figure 2-4). The depth to water beneath the channel is important because it partially controls the amount of recharge that can occur from water in the channel. In general, the deeper the water level, the more storage space there is for recharge.

This analysis (Schmidt, 1980) indicates that the eastern basin groundwater level is more dependent on recharge, with the primary sources of recharge to the groundwater in the project area being:

1. Seepage of flood waters from the floodplains of the Salt, Gila, and Agua Fria Rivers.
2. Seepage of effluent and irrigation tailwater from the channels of the Salt and Gila Rivers.
3. Deep percolation of irrigation return flow.

In comparison, for the present discharge rate of about 100,000 acre-feet per year, recharge of 91st Avenue Plant effluent in the project area is probably about 8,000-10,000 acre-feet per year, while for the 1965-66 flood flows, an estimated 15,000-20,000 acre-feet were recharged in the project area, primarily east of Monument Hill. These calculations and a review of water-level measurements for wells in the project area indicate that flood flows have three primary impacts on groundwater recharge (Schmidt, 1980):

1. They supply direct recharge.
2. They clear the channel of the organic mat formed by the effluent discharge, the removal of which temporarily greatly enhances the seepage of effluent and other surface water from the stream channel.
3. They coincide with periods of abundant canal water, which results in minimal pumpage.

The difference between the two effluent conditions would primarily affect the eastern part, where the depth to groundwater is such that larger recharge would occur. Under the first condition, with only 7,300 acre-feet per year of effluent discharge, an estimated 1,500 acre-feet per year of recharge, would be expected from 91st Avenue Plant effluent. The majority of this recharge would take place in the eastern portion as a result of the lower groundwater level, which provides a greater recharge potential. The recharge capabilities in the western part would be less, because of a high groundwater level which reduces storage availability. During dry periods, water levels could decline at a rate of several feet per year in excess of that normally expected during such periods. Under the second condition, with the remaining committed effluent discharged, an estimated 4,000 to 8,000 acre-feet per year of recharge from 91st Avenue Plant effluent would be expected to occur, the majority of which would be in the eastern part of the project area. Recharge from other sources of water would continue. Water levels would probably decline slightly on the long term under this alternative; however, the precise magnitude of this decline is unknown, but a rate less than one foot per year is likely. The rate and degree of groundwater level decline would be offset as a result of recharge by floods or other large discharges (Appendix B; Schmidt, 1980).

Plate 2-2 shows selected well locations and use of the area groundwater, with the most predominant use being for irrigation.

GROUNDWATER QUALITY: The chemical quality of groundwater in the shallowest strata of the project area is poor. Schmidt (1978) assessed the regional groundwater characteristics of several chemical constituents (Table 2-7). In general, groundwater to the north of the project area exhibits a decrease in the salinity content with an increase in nitrate.

Wells north of the Salt and Gila Rivers and on a down gradient from recharge of flood water and effluent appear to have relatively low salinity water. An example is the well at Holly Acres which is about one-half mile from the river channel. Water from this well had a low nitrate content and a total dissolved solids content of about 800 mg/l in 1979 (Schmidt, 1980).

Numerous other chemical analyses for trace elements have been performed on samples of water from public supply wells in the project area. The only constituent found in amounts exceeding the USEPA drinking water limits is iron. The limit for iron is based on aesthetic, not health concerns, and is recommended only. Much of the groundwater in the Recent alluvium, which is the major aquifer in the area, is considered "marginal" to "unstable" for domestic use and irrigation, due to high salinity, chloride, and hardness. Therefore, much of the drinking water in the project area is reportedly supplied by bottled water. The reduction of the low salinity effluent from possible recharge could tend to increase the total dissolved solids content of the groundwater in the area, particularily in the eastern part. However, this would be expected to be reduced as a result of the contribution of flood flows.

TABLE 2-7
CHEMICAL ANALYSIS FOR WATER FROM WELLS IN THE PROJECT AREA

Constituent (mg/l)	(A-1-1)				(B-1-1)			
	28 cdb	29 dcc	30 cbb	35 ccb	22 dda	26 bcc	28 cdc	36 bba
Calcium	216	465	120	30	126	69	108	42
Magnesium	72	185	63	14	39	39	70	19
Sodium	639	640	342	259	312	264	272	200
Carbonate	0	0	0	0	0	0	0	0
Bicarbonate	422	239	156	127	134	151	400	118
Sulfate	348	620	212	118	195	93	261	78
Chloride	1070	1830	760	344	636	624	656	356
Nitrate	26	11	11	3	4	2	23	< 1
Fluoride	-	< 0.2	0.3	0.9	0.2	0.3	0.3	0.6
Total Hardness ($CaCO_3$)	770	1920	559	133	580	336	546	183
Iron	-	0.1	< 0.1	< 0.05	0.2	0.44	-	< 0.1
Manganese	-	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	-	< 0.05
Chromium	-	< 0.01	0.01	-	< 0.01	< 0.01	-	< 0.01
Arsenic	-	< 0.01	< 0.01	-	< 0.01	< 0.01	-	< 0.01
pH	7.6	7.4	7.6	7.8	-	7.8	7.6	8.0
Electrical Conductivity (micromhos @ 25°c)	4320	-	-		2130	1850	3730	-
Total Dissolved Solids	2580	4250	1730	840	1512	1078	1772	790
Date	11/08/68	04/05/79	04/02/79	06/77	08/22/76	08/11/76	07/77	04/05/79
Perforated Interval (feet)	50-140	-	410 T.D.	389-407	500 T.D.	-	55-421	176 T.D.
Lab	SRP	ADHS	ADHS	ATL	ADHS	ADHS	U of A	ADHS

Data from MAG 208 program and files of Arizona Department of Health Services, Maricopa County Health Department, and Bureau of Indian Affairs.

Schmidt, 1980

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Potential well contamination, which is of concern to the Gila River Indian Community, was not found to be correlated to the effluent from the 91st Avenue Plant. However, monitoring of wells is necessary to determine other possible sources and constituents of contamination.

BIOLOGICAL FACTORS

RIPARIAN VEGETATION: Riparian vegetation in the project area has a history closely related to groundwater fluctuations. The historical description below of both the groundwater and the riparian vegetation is presented as a basis for understanding present conditions and future impacts. The three major riparian species to be considered are saltcedar (*Tamarix chinensis*), cottonwood (*Populus fremontii*) and willow (*Salix spp.*). Information is based on photographic evidence, research articles and field reconnaissance. The historical discussions are followed by a description of the existing vegetation in the eastern and western groundwater areas. The future impacts on vegetation under the two effluent discharge conditions are then assessed for the eastern and western parts of the project area.

Groundwater History. Groundwater levels in the project area are high compared to other parts of the Salt River Valley (Appendix B; Schmidt, 1980). Groundwater was close to the surface under the Salt River channel in 1920 (Halpenny and Greene, 1975), but because of increased pumpage and decreased streamflow, groundwater levels declined through 1965. West of 115th Avenue, however, the decline under the channel was not significant. This is largely due to the presence of relatively impermeable geologic materials at shallow depths. After 1965, several sources of recharge became important in the project

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area. These include periodic flood flows and relatively continuous discharge of sewage effluent and other waters in the channel of the Salt River.

History of Riparian Vegetation. Prior to the 1920's, riparian vegetation in the project area probably consisted primarily of cottonwood and willow with small bosques of mesquite, all of which are native species (Horton and Campbell, 1974). The earliest account of saltcedar (an introduced, exotic species) on the Gila River was around 1900. Saltcedar was apparently common in the river bottom near Tempe in 1901, and by 1902 saltcedar could be seen along the Gila River around Gila Bend, but it did not appear to be well established (Robinson, 1965).

Heavy growth of saltcedar was reported at Gillespie Dam on the Gila River in 1929. During the same year, it was reported as a nuisance along unlined laterals of the Roosevelt Irrigation District in the Buckeye area and "jungles" of it were reported along the Gila River (Robinson, 1965).

Photographs taken in 1941 (Maricopa County Flood Control District - MCFCD) show fairly dense saltcedar growth in most of the area. West of the Agua Fria-Gila River confluence, the saltcedar growth consisted of large trees covering about 80 percent of the channels with few open spaces. From this point east to the Salt-Gila River confluence, the bed of the channel had approximately 60 percent coverage with a few widely dispersed clumps of saltcedar and several open areas. The Salt-Gila River confluence east to 91st Avenue had comparatively sparse coverage consisting of riparian tree species along the low flow channels, with little growth outside the channel. From photographs taken in 1941 and later, cottonwood and willow did not occur in dense stands, but were generally dispersed along low flow channels throughout the area.

Partial photographic records from 1949 (U.S. Army Corps of Engineers) indicate an increase in the areal extent of riparian vegetation. The area from the Salt-Gila River confluence to 91st Avenue remained relatively the same, but west of the confluence there was a slight increase in extent and density of vegetation. Soil Conservation Service (SCS) aerial photographs from 1954 indicate only a slight reduction in growth along the Salt River from 91st Avenue to the Salt-Gila River confluence.

In the late 1950's an extensive thinning of vegetation began to occur. Photographic records of 1959 (MCFCD) show a general reduction in areal extent of riparian vegetation. West of the Agua Fria-Gila River confluence, dense growth occurred along the low flow channel only, with about 20 percent coverage outside the channel. From this point to the Salt-Gila River confluence, a similar reduction was evident. Dense growth occurred only along the low flow channels, with the area outside the channel exhibiting many open spaces and some scattered growth. By this time, the area from the Salt-Gila River confluence east to 91st Avenue was practically barren. Very little vegetation was present, even along the channel. The vegetation was essentially the same in SCS photographs from 1964.

Comparison of the 1964 photographs with 1978 and 1979 photos indicates a general trend toward increasing density and coverage throughout the project area.

Some general conclusions can be drawn from the above information. First, saltcedar growth in the project area probably started during the 1920's and coverage was probably heaviest in the late 1940's. In the 1950's, a reduction

in the extent of coverage began to occur, and probably continued until about 1967, when a gradual reversal began. The extent and density of riparian vegetation has apparently been slowly increasing from the late 1960's to the present.

These changes in the extent and density of vegetation, especially saltcedar, are largely dependent on gross groundwater fluctuations. The fluctuations in turn largely depend on flood flow, effluent and other recharge, and pumping rates. Prior to 1965, there was a 25 year period without flood flows, accompanied by increasing groundwater pumpage and decreased streamflow. A simultaneous reduction in vegetation occurred during the same period of decreased groundwater levels.

The 91st Avenue Treatment Plant commenced operation in 1958. With approximately 0.1 mgd annual average flow being discharged, the effluent did not travel far. By early 1962, however, effluent discharges increased to about 4 mgd annual average flow and reached the Buckeye Heading six and one-half miles downstream (Halpenny and Greene, 1975). During this period, however, the vegetation in the stretch from 91st Avenue to the Buckeye headgate continued to decrease. Increases in vegetation did not begin until about 1967, after the flood of December 1965-January 1966. Effluent discharge from the 91st Avenue Plant increased to approximately 23 mgd annual average flow in 1965 (Halpenny and Greene, 1975). The increase in groundwater level from recharge of these flows was probably the primary factor in increased vegetative growth. The low groundwater levels prior to 1965 allowed greater recharge capacity. Several sources of recharge became important in the project area, as previously mentioned. These include periodic flood flows and relatively continuous discharge

of effluent and other waters which supported new vegetation. In general terms, the riparian vegetation has been increasing in areal extent and density since the late 1960's.

Because the project area has value for wildlife, much of the river bed from 91st Avenue to 115th Avenue has been proposed as a natural area by the Arizona State Parks Board. The proposal involves 1,120 acres of land and will require a voluntary, cooperative agreement among all of the landowners prior to becoming a registered natural area. A natural area status does not impose any legal restrictions on the land, but recognizes the site as a special area in which management and protection of resources are encouraged. The purpose of the establishment of the natural area is to help maintain riparian vegetation at this site and add some impetus to control illegal disturbances such as trash dumping.

The site of the proposed natural area includes a segment of the Salt River and riparian habitat between 91st and 115th Avenues in the eastern part of the project area. The southern boundary is adjacent to the northern edge of the Gila River Indian Community (Smith and Bender, 1973).

Current ownership of the river bed within the project area is varied. The southern half of the river bed between 91st Avenue and 107th Avenue is owned by the Gila River Indian Community, with the remaining land divided among private, state and municipal ownerships. However, west of 107th Avenue to the Buckeye Heading, the majority of the land is either owned by the Arizona Game and Fish Department (AGFD) or designated as State Trust Land. A portion of this land within the proposed natural area is currently managed by the AGFD as the Base

and Meridian Wildlife Area, located in the Salt River channel just east of 115th Avenue. The AGFD had constructed several ponds that were managed as waterfowl resting areas and were important to migratory as well as resident wetland wildlife. The earthen dams constructed for this purpose were washed out during the recent floods and no plans have been made to replace them.

Existing Vegetation. The project area contains a groundwater regime that is comprised of two groundwater parts, as described in "Physical Factors." The division between the eastern and western groundwater parts extends northward from Monument Hill at approximately 115th Avenue. Because the difference in groundwater level between the eastern and western areas results in contrasting vegetative distribution, these areas are discussed separately.

o Eastern Part - At present, surface flow and depth to groundwater appear to influence both areal extent and species composition of riparian vegetation in this area. This area is characterized by deeper groundwater levels than those found in the western area, although at present they are relatively high due to recent flooding and other recharge; levels are approximately ten feet near 115th Avenue and generally range from 10-20 feet beneath the Salt River channel upstream to about 91st Avenue. In general, the groundwater level declines about seven feet per mile upstream from 115th Avenue to an approximate depth of 70 feet at the 23rd Avenue Plant (Schmidt, 1980).

The relatively deep water table of the eastern part of the groundwater regime is unattainable by many plant species. Table 2-8 shows the maximum root depths for mature cottonwood, willow, and saltcedar. Cottonwood roots are not known to reach down farther than 25-30 feet, while willow does not extend below

TABLE 2-8
ROOT DEPTHS AND EVAPOTRANSPIRATION RATES

Species	Location	Depth to Water Table	Maximum Root Depth	Average Tree Height	Evapotranspiration Rate (acre feet/acre/year)	Source
Cottonwood	Safford Valley, AZ	7 ft.	25-30 ft.	no data	6.0 (100% volume density)	Gatewood et al. 1950 and Turner, 1951
	San Luis Rey River, CA	4 ft.			5.2 (100% volume density)	Muckel et al. 1945
		3 ft.			8.1 (100% volume density)	
Willow	Safford Valley, AZ	7 ft.	< 15 ft.	no data	6.0 (100% volume density)	Gatewood et al. 1950 and Turner, 1951
	Winnemucca, NV	4 ft. (Alkali conditions)			3.03 (less than 100% volume density)	Robinson, 1970
	Safford Valley, AZ	∧ 7 ft.		13 ft.	7.2 (100% volume density)	Gatewood et al. 1950 and Turner, 1951
	Safford Valley	4.0		13 ft.	9.2 (100% volume density)	Gatewood et al. 1950
Tamarisk or Saltcedar	Safford Valley	8.0	30-60 ft.	13 ft.	7.0 (100% volume density)	
	23rd Avenue to Gillespie	Taken into account		Taken into account	5.5 (75-100% areal density)	Water Resource Associates, 8/75
	23rd Avenue to Gillespie	Taken into account		Taken into account	4.5 (50-75% areal density)	
	23rd Avenue to Gillespie	Taken into account		Taken into account	2.9 (25-50% areal density)	
	23rd Avenue to Gillespie	Taken into account		Taken into account	1.0 (10-25% areal density)	

15 feet to groundwater (Robinson, 1958), and seven feet is more likely (Zimmerman, 1969). Unlike cottonwood and willow, the roots of saltcedar may reach relatively deep groundwater levels of approximately 30-60 feet (Water Resource Associates, 1975). However, these depths are for established trees. Younger trees and seedlings require shallow groundwater and/or surface flows.

As a result, between 91st and 115th Avenues, willow and cottonwood trees are primarily restricted to areas adjacent to surface water flow. No willow trees exist away from the surface flow. Saltcedar is found growing in dense stands near surface water and also in areas not watered by surface flows. These latter areas are characterized by dry surface soil and, as discussed, a relatively deep water table (approximately 10-20 feet).

Although the minimum surface flow necessary for the maintenance of riparian vegetation in this area is not known, these flows directly impact adjacent vegetation and help to maintain higher groundwater levels.

A report is presently being completed by the U.S. Fish and Wildlife Service on the stream flow effects on maintenance of cottonwood for the Verde River. Further studies would be necessary to determine a theoretical minimum flow essential for maintaining riparian tree species in this area. These studies would include a tree count, densities, a determination of evapotranspiration rates for individual species, percolation rate of a surface water flow, depth to water table and surface water evapotranspiration rates. Table 2-8 presents evapotranspiration rates calculated for several arid areas. The rates show considerable variation both between species and areas depending on several factors. Therefore, an accurate determination of the rates for this project area would require site specific analysis.

o Western Part - In general, the vegetation in the western part of the project area appears to be supported more by readily accessible groundwater than by surface flow. The subsurface geologic characteristics of this portion of the project area favor shallow groundwater levels. As a result, the western part is characterized by groundwater levels at or near the elevation of the Gila River channel. These levels have remained relatively shallow because of comparatively small amounts of pumpage and continued flows for recharge to the groundwater (Schmidt, 1980).

In this area, willow and cottonwood trees are found growing near the surface water flow. Saltcedar stands are extensive in areas away from the surface flow and include relatively large willow trees. Just east of Bullard Avenue, individual willow trees are found growing throughout the river channel in areas devoid of surface flow. The existence of these willows in the absence of surface flow reflect high groundwater levels in that willow roots have been found to descend to groundwater only seven feet or less in most cases (Zimmerman, 1969). It may be concluded that once the willow is established and surface flows diminish, the willow's maintenance becomes dependent on a shallow groundwater table. Overall, the vegetation appears to be supported more by groundwater levels than by surface flow. However, as noted previously, surface flow is a factor in the maintenance of groundwater levels.

Future Vegetation. The future of riparian vegetation in the project area will depend on both groundwater levels and surface flows. Issues of public concern deal with both the maintenance of riparian habitat and the impacts of effluent discharge on that habitat.

The impacts of the two effluent discharge conditions on riparian habitat are addressed in the following discussion. The first condition of effluent discharge reflects the impacts of minimum discharge assuming only 6.52 mgd of effluent for AGFD discharged into the Salt River. The second effluent condition assumes discharge into the river of the remaining effluent not used for existing effluent reuse commitments. This condition would result in effluent discharge to the river decreasing from 90 mgd annual average flow in 1980 to approximately 20.2 mgd annual average flow in 1986 based on flow projections provided in the 91st Avenue Plant Expansion Draft Facility Plan. Annual average flow then increases to about 35.2 mgd by the year 2000.

The reduction in effluent discharge which will occur under either condition will affect the eastern and western parts of the project area differently because of the unequal groundwater levels in each area. The minimum monthly flow expected to occur in 1986 under the first discharge condition is 20.6 mgd (minimum baseline river flow of 14.1 mgd plus effluent discharge of 6.5 mgd). It is expected that surface flow should not terminate within the project area.

- Eastern Part - Due to the relatively deep groundwater levels, vegetation in the eastern area depends on surface flow to a greater extent than in the western area where groundwater is higher and more accessible to the vegetation.

Under the first condition, the reduction in annual average stream flow due to total effluent reuse may impact vegetation adjacent to the surface water due to a general reduction in soil saturation. Therefore, vegetation which depends on surface flow, such as cottonwood and willow, may be expected to thin and

become distributed in closer proximity to the river channel. Much of the salt-cedar located in the eastern part has been noted as primarily supported by groundwater and, therefore, is not expected to be significantly impacted by the reduction in stream flow.

Based on a report by Turner (1974), a significant change in the establishment of riparian vegetation is not expected to occur as a result of seasonal fluctuations in effluent discharge due to the commencement of reuse allocations. Turner states that "In terms of physiologic requirements for water, the establishment of riparian species is not directly related to the amount of stream discharge." If the alluvium is fully saturated, an increase in flow from 50 cubic feet per second to 5,000 cubic feet per second is unimportant to riparian seedling establishment. More important to the vegetation is the duration of flow during critical growth periods such as germination and seedling establishment in the spring and summer (Turner, 1974).

As depicted in Figure 2-3, under the first condition monthly average flows are expected to remain constant or increase throughout the spring, which corresponds to the period of germination and seedling establishment. Cottonwood produces seeds from mid-March to mid-April. A high groundwater level and bare, sandy soil, especially nearby deposited alluvial soil appear to be optimal for germination and seedling development (Ohmart, 1977); willow apparently requires similar conditions for seedling establishment and germination (personal communication, Ohmart, 1980). During the summer and fall when the water requirements of vegetation are the greatest, the seasonal fluctuation of the baseline river flow will result in the greatest monthly flows. Lowest monthly flows will occur in the winter (November through March), when water requirements of vegetation are

at the lowest point. As a result, the seasonal variability in surface flow is not expected to significantly alter the germination, seedling establishment, or maintenance of the cottonwood, willow, or aquatic organisms in the eastern portion of the project area. Aquatic organisms should be maintained during low winter flows since those flows are not expected to terminate before Buckeye Heading.

Similarly, in this area saltcedar is not expected to be impacted by the seasonal variation in surface flow. Saltcedar produces seeds from mid-April to October, with peak distribution of viable seeds in June and July (Merkel et al, 1957). Germination occurs on water, generally in less than 24 hours. Very moist conditions are required for satisfactory germination and seedling establishment and for the first two to four weeks of growth. The combination of warm, moist, bare soil, especially that left by receding surface flows, is ideal for saltcedar establishment (Horton et al, 1960). These conditions, which are favorable for the germination of saltcedar, should not be significantly affected by variation in seasonal flows due to a discharge of 6.52 mgd.

In general, the greatest impacts in the eastern area under the first condition should result from the expected reduction in soil saturation due to a decrease in average annual stream flow. As a result, a thinning of river channel vegetation (cottonwood and willow) may be expected to occur. Seasonal variation in stream flow should not significantly affect the cottonwood, willow, or saltcedar.

Under the second effluent discharge condition, the reduction in annual average flow from the current 90 mgd to approximately 20.2 mgd should result in

impacts similar to those noted above for the first condition. Based on annual average flow, the reduction in yearly surface water quantity could result in decreased soil saturation and a thinning of the vegetation associated with the river channel (cottonwood and willow). The thinning of vegetation is not expected to be as great as that which could occur under the first condition due to the relatively greater stream flow and area of saturated soil occurring in the second condition. Saltcedar is not expected to be significantly affected by the reduction of annual average stream flow in the eastern area because of its ability to reach the lower groundwater table once established.

Seasonal variation in surface flows under the second condition will result in a greater quantity of water available for vegetation during the spring months relative to the available amount in the first condition (see Figure 2-3). The relatively greater surface flow in the spring could result in more germination and seedling establishment of cottonwood and willow along the river channel over that expected in the 6.52 mgd discharge condition due to the larger area of saturated soil.

In summary, within the eastern area, the second effluent discharge condition could result in a thinning of cottonwood and willow and a redistribution of that vegetation to a closer proximity to the river channel due to an expected reduction in soil saturation over present conditions. However, these impacts are not expected to be as extreme as the effects of the first effluent discharge condition. Seasonal variation in stream flows could enable more germination and seedling establishment of river channel vegetation (cottonwood and willow) than the first effluent condition due to greater surface flows in

the spring. Saltcedar should not be significantly impacted by either the reduction in annual average flow or the seasonal variability in surface flow under the second condition.

o Western Part - Vegetation in the western part is supported by groundwater to a greater extent than in the eastern part. Currently, groundwater levels are shallow, 5 feet or less, and are expected to remain shallow unless some new large-scale pumpage is developed (Schmidt, 1980). As with the eastern area, the groundwater level in the western area is recharged by flood flows, effluent and other flows. Based on root depths, the groundwater level in the western area is high enough to support cottonwood, willow, or saltcedar. As a result, these vegetative types could be maintained in portions of the western part where surface water does not exist.

Under the first effluent condition (effluent discharge reduced to 6.52 mgd), based on annual average stream flow, the existing vegetation west of approximately 115th Avenue is not expected to be significantly affected. The reduction in surface flows associated with a loss of effluent in this area would probably not appreciably affect the survival and growth of present riparian vegetation because of the shallow depth to groundwater. Both established native and exotic tree species can effectively obtain water for maintenance and growth from the present groundwater.

In general, throughout the western part, an annual reduction in surface flow west of 115th Avenue would not necessarily preclude cottonwood and willow seedling establishment. If the groundwater remains high, low sandy spots would continue to provide conditions necessary for seedling establishment.

The seasonal variation in surface flows is not expected to affect the germination, seedling establishment, or maintenance of cottonwood, willow, saltcedar or aquatic organisms in the western part of the project area. Aquatic organisms should be maintained during low water flows since those flows are not expected to terminate before Buckeye Heading. As discussed under "Eastern Part" monthly average flows are expected to remain constant or increase throughout the spring enabling germination and seedling establishment. The increased flows occurring in spring or summer could be beneficial to the growth and reproduction of the riparian tree species in the area because this is a period of active growth for them. Most riparian species are deciduous (drop their leaves in the winter) and would have a reduced water requirement during the winter months. In the absence of a drop in groundwater as a result of new pumping, there should be sufficient water present during spring and summer to allow maintenance and new growth of riparian vegetation from 115th Avenue to the Buckeye Heading.

The effects of the second effluent discharge condition on vegetation in the western area are expected to be similar to those of the first condition. In general, the second effluent condition would probably not appreciably affect the survival and growth of present riparian vegetation. The shallow depth to groundwater enables both established native and exotic tree species to effectively obtain water for maintenance and growth.

Seasonal variation in surface flows under the second condition will result in greater amounts of surface water available for vegetation during the spring months over the available quantities in the 6.52 mgd effluent discharge condition (see Figure 2-3). The relatively greater surface flow in the spring could

result in more germination and seedling establishment of cottonwood and willow along the river channel over that expected in the first discharge condition due to the larger area of saturated soil. Saltcedar is not expected to be significantly affected by seasonal variation in stream flow under the second condition.

SOCIOECONOMIC FACTORS

Socioeconomic factors addressed in this assessment concern flooding, institutional arrangements, public health considerations, and nuisance insect problems. The following discussion includes an analysis of flooding within the project area in terms of both historical documentation and current potential. Under "Institutional Arrangements," the floodplain regulations of Maricopa County are described as well as the effluent reuse commitments of the Multicities. Future effluent reuse potential is then addressed. After a discussion on the public health impacts from potential surface and groundwater quality from effluent, the role of effluent in nuisance insect problems is described.

FLOODING: A major issue raised by residents in the project area is flooding. The concern that riparian vegetative growth contributes to floodwater spreading is discussed in this section.

General. Presently, upstream impoundments provide water conservation as a primary objective and as such do not provide storage for downstream flood protection. Flooding in the project area differs in summer and winter; historically, floods have most often occurred in the winter. In 1978 and 1979, above average rainfall resulted in major winter storm flooding. Summer thunderstorms, formed in the Gulf of Mexico, sometimes result in flooding, but they seldom produce enough runoff volume to create serious problems. Flooding from

such summer storms is normally confined to small areas and is of short duration. Major historical floods in the Salt River are shown on Table 2-9.

Flooding is expected to occur when the natural channel flow capacity is exceeded, resulting in overflow and inundation of the low lands, which are characteristic of the river channel in the project area. Damages to residential, commercial and agricultural areas depend on the extent of those land uses within the floodplain. Determination of floodwater spreading under various flood flow conditions requires the application of hydrologic and hydraulic principles to the physical conditions which exist in the river channel and overbank areas. In brief, the ability of the river to pass a given flood flow is a function of channel area, depth, slope, and characteristics of the boundaries of the channel.

The basic information required for a flooding assessment includes estimates of flow in a river under specific hydrologic conditions, determination of the geometry of the river channel at all locations where changes occur, determination of "roughness coefficients" for each river section, determination of backwater effects, and the relating of water levels to topography in the floodplain area. A more detailed discussion is available from the U.S. Army Corps of Engineers (1975).

Although a reliable determination of flood potential can be made from data collected at a particular time, if certain physical changes occur, the potential for flooding will be altered. Physical changes in the floodway which alter flooding potential include:

1. Encroachment of vegetation, which may cause a reduction in flow velocity and the deposition of sediment.

TABLE 2-9
HISTORICAL FLOODS ON THE SALT RIVER

Date	Flood Peak (ft^3/s)
February 1891	300,000
April 1895	115,000
November 27, 1905	200,000
January 19-20, 1916	120,000
January 29-30, 1916	105,000
February 1920	130,000
March 1938	85,000
March 1941	40,000
December 1965-January 1966*	67,000
February 21-May 29, 1973*	22,000
March 2, 1978*	122,000
December 19, 1978*	140,000
January 19, 1979*	88,000
March 29, 1979*	67,400

Data for early floods obtained from the Interim Report on Survey for Flood Control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam Site, Arizona, U.S. Army Corps of Engineers, Los Angeles District, 1957.

*Data for recent floods obtained from the U.S. Geological Survey, measured at 48th Street and the Salt River (figures are preliminary and subject to revision).

2. Scouring of river banks and the channel bottom, and the deposition of suspended materials by an intervening flood, which could result in channel migration and changes in channel hydraulic capacity.

3. Saturation of floodway soils from an intervening flood, preventing groundwater recharge that might otherwise occur and reduce total flood volume.

4. Roadway construction or placement of obstructions in the river channel or floodway which could reduce the hydraulic capacity, causing backwater effects and eventual floodwater spreading.

The project area has experienced a series of floods of varying intensities through the years (see Table 2-9). The flood flows and estimated recurrence intervals, as used by the U.S. Department of Housing and Urban Development, are as follows:

Recurrence Interval	Peak Flow (cfs)
100 yrs.	210,000
50	160,000
10	37,000

Analysis of Past and Recent Flooding. As discussed above, a number of factors may contribute to changes in flooding potential over time. The flooding issue in the project area centers on the effect of the recent (1967) encroachment of saltcedar into the area and its relative impact on the river's capability to pass flood flows. This concern is apparently based on observations of flood flows in the mid-1960's, which resulted in minor damages, compared to the floods of 1978-1979, which caused more extensive damages. To address this concern, an analysis was conducted to determine the relative changes in the river channel and intensities of the flow which could account for the differences in the flood spreading.

The flood of 1965-66 came after a long period of stability in the river channel. According to the flood history (Table 2-9), the most recent flood prior to this time was in 1941 and was less intense, at 40,000 cubic feet per second (cfs). As stated in the groundwater discussion, the 25 year span was characterized by a loss in a constant surface flow marked by an extensive decline in the groundwater level. Channel stability may have affected the peak flood flow. According to Aldridge (1970, pp. 160-168), the peak flood flow for the 1965-66 flood at Granite Reef Dam was 67,000 cfs and by the time the flow reached Gillespie Dam the peak was reduced to 64,000 cfs. Flow data for a mid-point of 66,000 cfs was determined at the Joint Head Dam on 48th Street. The 66,000 cfs flow was used in the analysis to indicate the peak flow in the project area.

Documentation of flood damages and area of inundation for the 1965-66 flood were not available for the project area; therefore, interpretation of aerial photographs was necessary to determine the amount of land inundated by the 1965-66 flood flow. The photos indicate that the 1965-66 (66,000 cfs) flood would have reached the southernmost border of the present Holly Acres subdivision.

As part of the analysis, the 1965-66 flood was compared to the most recent flood of March 1979 with a flow of 68,000 cfs (including 600-700 cfs from the Gila and Santa Cruz Rivers). The March 1979 flood flow was chosen for comparison with the 1965-66 flood because peak flows were similar and a comparison of 1964 aerial photographs with 1979 aerial photographs shows a relative abundance of riparian vegetation in 1979 as opposed to sparse growth in 1964, prior

to the 1965-66 flood. The March 1979 flood, according to residents, may have caused some spreading of flood water into the southernmost boundary of the Holly Acres subdivision. This was confirmed by aerial photographs, which showed the increased area of inundation was not great. The comparison, however, proved to be inconclusive without the availability of flood hydrographs, channel topography prior to the flood, and quantifiable flood spreading records.

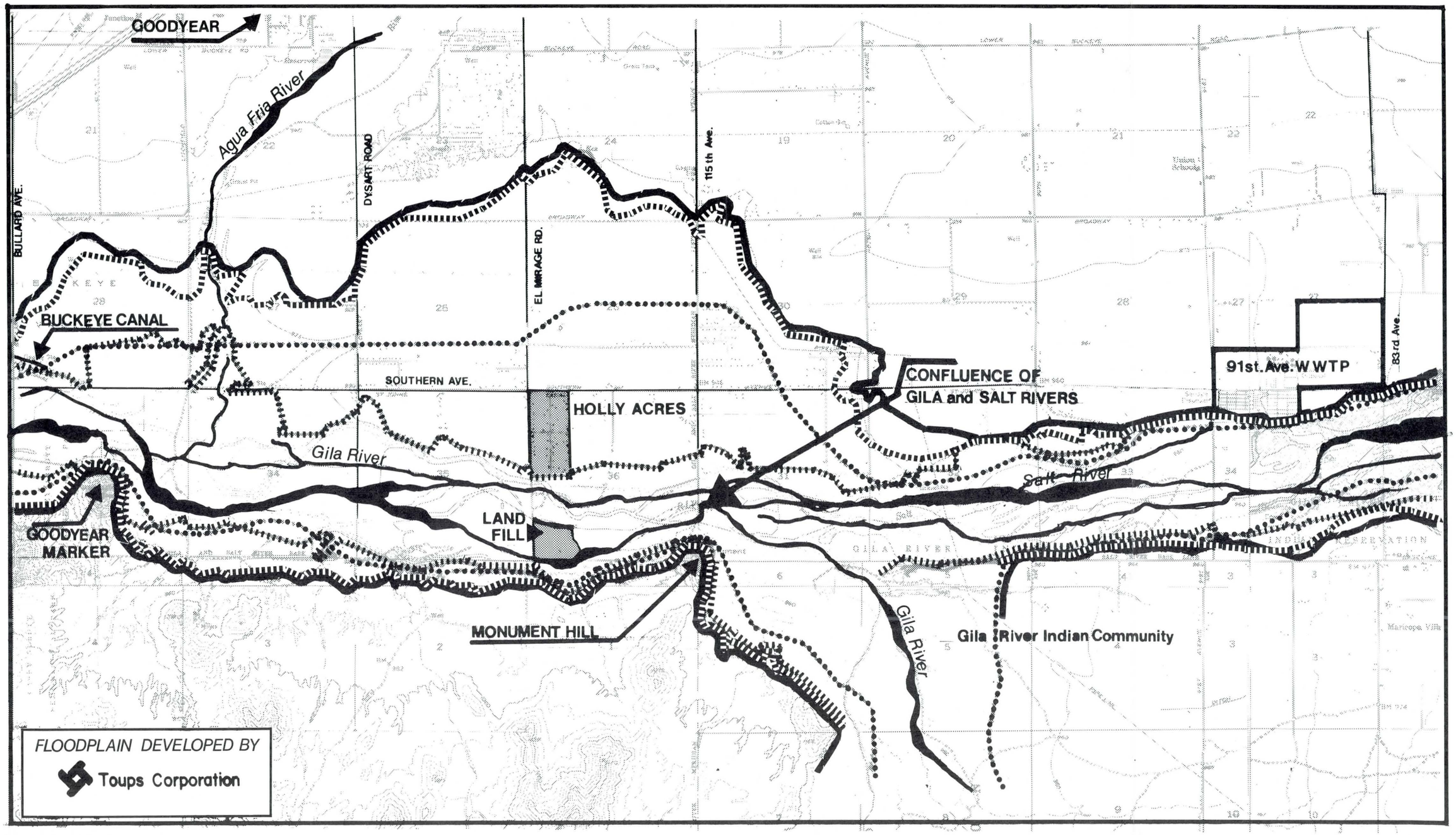
Factors Affecting Flooding. While the comparison of past and recent flooding proved inconclusive due to lack of quantified information, analysis and investigations identified several factors which may influence floodwater spreading that were found to be in effect during the 1978-79 floods (Table 2-9). These factors were not found to be a part of the 1965-66 flood.

o Vegetation - One of the factors centers around the controversy of the impacts caused by the encroachment of saltcedar into the floodplain. According to Robinson (1958), in a stream where saltcedar has become established in the floodplain, there is (1) a depletion of stream flow, (2) an increase in the area inundated by floods, and (3) an increase in deposition of sediment in the areas of saltcedar growth. Riparian vegetative species such as saltcedar are known to produce a resistance to flow and a stability of the floodplain boundary (Graf, 1978). Due to saltcedar's morphology, it produces dense stands of vegetation which would characteristically decrease flow velocities through the areas of dense growth. This could cause an increase in deposition of sediment carried by previous flood flows. This phenomenon was observed by Burkham (1971) along the Upper Gila River in Safford Valley, where sediment islands and sandbars were formed in areas of low velocity. In terms

of changes in the stream channel, however, Burkham concluded that large flood flows were the main cause of the widening of the stream channel and that flood-plain vegetation may have been a minor contributing factor.

o Obstructions - To determine further possible changes in the area that may cause increased flooding, a field investigation of the floodway was conducted to determine any natural and/or man-made obstructions which could result in increased backwaters which were not in effect during the 1965-66 flood. The most notable influence appears to be the placement of a landfill in the center of the floodway. In 1973, Maricopa County Highway Department leased a segment of the river channel from the State Land Department to dispose of solid waste. The landfill was located along the eastern edge of El Mirage Road about 2,000 feet south of the Holly Acres subdivision. The landfill covered about 20 acres of surface area and was later closed in 1977 due to flooding. However, the surface elevation of the abandoned landfill remains approximately 4 to 5 feet (elevation 934±, USGS) above the surrounding channel. Aerial photos taken during the flood indicate that the flood outlined the landfill periphery with negligible cresting, and the landfill apparently continued to divert flows while the flood receded. Initially, this removal of floodway capacity would be expected to cause flow diversion and increased backwater, which could result in increased flooding. A reliable determination of this effect would require a detailed hydraulic analysis of this segment of the channel.

Another structural occurrence in the river is roadways; however, these culverted road crossings may not contribute significantly to a backwater effect, since they are washed out at very low flows (personal communication, ADOT, 1980).



(Based on 1976 topography)

- FLOODWAY
- 100 YEAR FLOOD 210,000 cfs
- 50 YEAR FLOOD 160,000 cfs
- 10 YEAR FLOOD 37,000 cfs

PLATE 2-3
PROJECT AREA
FLOOD AREAS

arthur beard engineers, Inc. / CAMP DRESSER & McKEE INC.

Conclusions. Several conclusions could be made about the recent flooding events, their corresponding changes in the river channel and the overall impact on floodwater spreading. As previously stated, topography and basic channel hydraulic capacity are of primary importance in the conveyance of flood flows. Plate 2-3 shows the location of the Holly Acres subdivision in relation to flood-prone areas; the expected frequency of flooding to the subdivision would be between 10 and 50 years. It should be noted that these relative lines of flood frequency change with time. Such changes occur as a result of alteration in actual river channel capacity, such as increased channel depth from scouring or widening of the floodway by a previous flooding event. It should be further noted that the flood frequency map (Plate 2-3) is based on the most up-to-date (1976) topography, which may have changed due to the more recent floods. Therefore, location with respect to these floodplains should be used primarily as an indication of flood frequency.

The information indicates that numerous factors could affect floodwater spreading and the degree of damage that results. The most significant of these is the intensity of the flood flow and the location of development in relation to the corresponding floodplain. This relationship most adequately explains the reason for the higher levels of flood-related damages in 1978-79 than in 1965-66.

Plate 2-3 provides the relative frequency of flooding and the location of area development relative to flood-prone areas. To determine the correlation between the most recent floods and the expected areas of inundation, the following information should be used: Table 2-~~10~~ 9 provides the peak flows for the

TABLE 2-10
UNUSED EFFLUENT IN 1986
(MONTHLY AVERAGE FLOW)

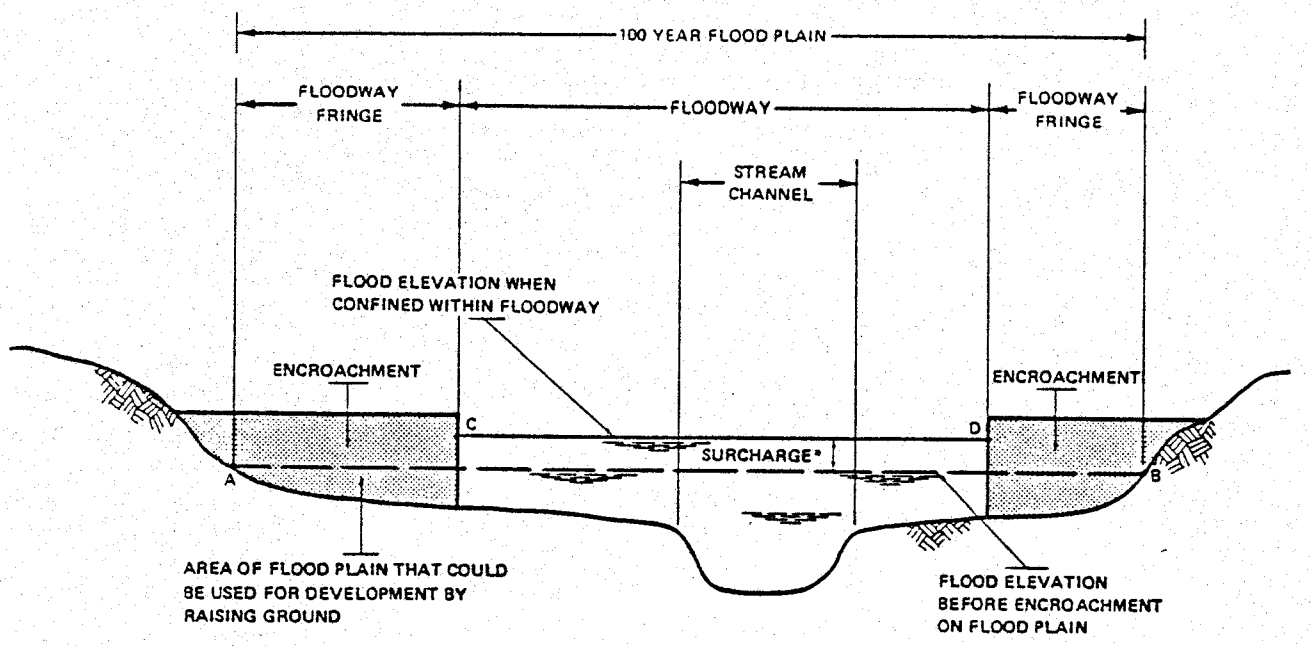
1986 MONTH	91st AVENUE PLANT EFFLUENT FLOWS[1] (mgd)	COMMITTED EFFLUENT[1,2] (mgd)	REMAINING UNUSED EFFLUENT[3] (mgd)
January	96.6	59.5	37.1
February	99.8	58.9	40.9
March	101.9	72.3	29.6
April	101.9	73.5	28.4
May	102.9	99.6	3.3
June	102.9	103.5	-0.6
July	106.1	102.6	3.5
August	108.2	102.6	5.6
September	115.5	98.4	17.1
October	112.4	96.3	16.1
November	107.1	74.1	33.0
December	105.0	87.0	18.0

[1]See Appendix C.

[2]Includes allocations to AGFD, BIC, and ANPP.

[3]Flows derived from data presented in Appendix C.

SOURCE: ABE/CDM 1980.



LINE A - B IS THE FLOOD ELEVATION BEFORE ENCROACHMENT
LINE C - D IS THE FLOOD ELEVATION AFTER ENCROACHMENT

*SURCHARGE NOT TO EXCEED 1.0 FOOT (FIA REQUIREMENT) OR LESSER AMOUNT IF SPECIFIED BY STATE.

Source: HUD, 1979

FLOODWAY SCHEMATIC

Figure 2-5

recent floods. The largest of these floods (140,000 cfs) occurred on December 19, 1978, and, according to Holly Acres residents, was the most damaging. This flow corresponds roughly with the HUD flood frequency curve for a 50 year event at 160,000 cfs. Plate 2-3 shows the areas of land that would be inundated by a 50 year flood; a comparison can be made to locate the expected areas of inundation for the 140,000 cfs flood of December 1978.

The particular area within the boundary of the 50 year flood designation is characteristically a lowland area, located at the confluence of three major rivers. The indication would therefore be that these topographical characteristics and the location of the development appear to be influential in the extent and significance of area flooding.

In order to minimize flooding potential, a floodplain management plan was developed for the purposes of the Flood Insurance Program (HUD, 1979). One aspect of floodplain management involves balancing the economic gain from floodplain development against the resulting increase in flood hazard. Included in the plan was the concept of a floodway which is used as a tool to assist local communities in determining future land uses. Under this concept, the area of the 100-year flood is divided into a floodway and a floodway fringe. The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 100 year flood can be carried without substantial increases in flood heights. Figure 2-5 represents the concept of the floodway and Plate 2-3 indicates its relative location in the project area.

Based on this assessment, neither effluent discharge condition would create a significant change in present flooding potentials in the project area.

INSTITUTIONAL ARRANGEMENTS:

Floodplain Regulations. The "1975 Floodplain Regulations for the Unincorporated Area of Maricopa County," adopted by the Floodplain Board on July 14, 1975, and amended on October 17, 1977, is a two-district floodplain regulation intended to prevent the dangerous and expensive misuse of floodplains in the county. This regulation divides the Regulatory Floodplain (100 year floodplain) into two areas. The first area, the Floodway District, restricts development to uses which are not susceptible to severe or expensive flood damage and which do not obstruct the flow of flood water. In the Floodway Fringe District, the second area, development must be protected from the 100 year flood either by floodproofing or by elevating items susceptible to flood damage so that they are above the flood elevations. The majority of the residential areas within the project area along Southern Avenue, including Holly Acres, are within the Floodway District.

EFFLUENT REUSE:

Existing Reuse Commitments. The Multi-cities, either singly or jointly, have agreed to supply treatment plant effluent from the 91st Avenue Plant to the Arizona Game and Fish Department, the U.S. Department of Agriculture's Water Conservation Laboratory, the Buckeye Irrigation Company, and the Arizona Nuclear Power Project.

The City of Phoenix has agreed to provide the Arizona Game and Fish Department (AGFD) with 20 acre-feet per day (6.52 mgd) of effluent. The AGFD uses the plant effluent as a water supply for vegetative growth that serves as wildlife habitat. The effluent has been supplied to the AGFD through normal

discharge into the Salt River with the rest of the plant effluent. This allocation of effluent to the AGFD is a non-contractual commitment.

A commitment of 1,200 acre-feet per year (1.07 mgd) was made to the United States Department of Agriculture's Water Conservation Laboratory for the Flushing Meadows Project. This advanced wastewater treatment research facility was located in the Salt River about one and one-half miles downstream of the 91st Avenue Plant until it was destroyed in the 1978-79 floods. Since there are no plans to reactivate this project, this 1.07 mgd flow is assumed to be available for reuse in this assessment.

The Salt and Gila River flows are drawn off by the Buckeye Canal at an area between Litchfield Road and Bullard Avenue for irrigation. In 1971, the City of Phoenix entered into a 40-year contract with the Buckeye Irrigation Company (BIC) to supply 30,000 acre-feet of effluent per year in monthly increments of 2,500 acre-feet (26.81 mgd). The effluent must be of sufficient quality to permit its use for irrigation of crops not intended for human consumption. Presently, the delivery of effluent to BIC has been by natural channel in the Salt River; however, they have made arrangements to obtain effluent from the plant through the same pipeline that will convey effluent to the Palo Verde Nuclear Generating Station.

A commitment for portions or all of the remaining effluent has been made by the cities of Glendale, Mesa, Phoenix, Scottsdale, Tempe, and Youngtown to the Arizona Public Service Company (APS) and the Salt River Project (SRP). The effluent is presently intended for use as cooling water at the Palo Verde Nuclear Generating Station (PVNGS) as part of the Arizona Nuclear Power Project (ANPP). The PVNGS flow requirements are expected to be approximately 107,000

acre-feet per year (95.6 mgd), which is about 21,400 acre-feet per year (19.1 mgd) for each of five power generating units. Although generating units four and five have been indefinitely delayed, the total commitment presently contracted under the Multi-cities/ANPP Agreement is 140,000 af/yr (125 mgd). This may be used at the Palo Verde Nuclear Generating Station or any other generating facility APS and/or SRP may choose. The contract expires 40 years after the date the last power generating unit is placed into operation or the year 2040, whichever comes first.

The previously described commitments to Arizona Game and Fish Department, the U.S. Water Conservation Laboratory, and the Buckeye Irrigation Company are higher in priority than the ANPP commitment. Any effluent up to 125 mgd from the 91st Avenue Plant which is not previously committed to other users is to be committed to the ANPP. The 23rd Avenue Plant effluent may be used to fulfill remaining portions of commitment after all of the available supply of 91st Avenue Plant effluent has been allocated.

The effluent will be delivered to ANPP on or adjacent to the plant site. A pipeline is presently being constructed by ANPP which will be used to convey effluent from the 91st Avenue Plant to PVNGS. This pipeline will also convey effluent to the Buckeye Irrigation Company. The contract establishes effluent quality requirements on an annual average basis for three effluent constituents:

1. Phosphate - 60 mg/l
2. Suspended Solids - 30 mg/l
3. BOD_5 - 30 mg/l

The reuse of effluent is a major issue of public concern. Both short- and long-term plans are being developed by the Multi-cities in order to ensure its most beneficial use.

Effluent Reuse Potential. In terms of annual average flows, effluent discharge from the 91st Avenue Plant should be sufficient to meet the expected requirements of existing commitments until such time as the fourth PVNGS unit would become operational in 1988 (see Table 2-4). However, based on monthly average flows, after the third PVNGS unit becomes operational in 1986 all effluent from the 91st Avenue Plant is expected to be utilized by existing commitments, at least for short periods of time. Table 2-10 depicts total unused effluent from the 91st Avenue Plant projected for the year 1986. In June of 1986, effluent from the 91st Avenue Plant will be insufficient to meet existing effluent commitments based on monthly average flow projections. In 1986, a monthly average of only approximately 3.0 mgd should be available for reuse from May through August.

The above discussion is based on expected effluent requirements assuming the operation of three PVNGS units which would require a total annual average of 58.0 mgd of effluent. However, as stated previously, the contractual agreement between the Multi-cities and the ANPP entitles the latter to a maximum of 140,000 acre-feet per year (125 mgd) of effluent. If the ANPP required the maximum quantity of effluent stipulated in the contract, all effluent from the 91st Avenue Plant through the year 2000 which is not previously committed to other users could be fully utilized by ANPP. Based on this assessment, effluent reuse potential beyond existing commitments appears uncertain and greatly dependent upon the requirements of ANPP.

PUBLIC HEALTH: Public health concerns have been expressed by residents of the Gila River Indian Community and others over potential effluent-impacted groundwater as a source of contamination to their potable water supply wells.

However, those constituents of concern that have been tested and relate to effluent recharge, such as nitrates, were not found to be at levels that would create a public health impact (Schmidt, 1980). A monitoring program is necessary to further assess the concentrations of other constituents which may present in the groundwater as a result of natural occurrences.

INSECTS: An additional public concern is that of insect problems in the vicinity of the 91st Avenue Plant. Insects which have been identified as being associated with the effluent discharge are the Culex pipiens mosquitoes and Chironomid (bloodworm) midges.

In the Insect and Odor Report for the 91st Avenue Plant Expansion Facility Plan (ABE/CDM, 1980), large numbers of Culex pipiens were reported in stagnant pools of effluent and irrigation runoff water near the 91st Avenue Plant. However, these mosquitoes can breed wherever standing water exists for an extended time in the project area and generally do not disperse far from their breeding area. They are suspected vectors of viral encephalitis.

Midges of the genus Chironomus, known as bloodworm midges, were found to be especially numerous in the effluent channel with its high organic matter content. The effluent appears to significantly increase midge numbers by creating an optimum breeding habitat. It is likely that some of the midges breeding in effluent dominated areas are dispersing to areas away from the effluent. While they do not bite, midges can create a nuisance by swarming and clinging to sides of houses and eaves.

Mitigation of many insect problems is provided for in the Effluent Disinfection Facility Plan and the Minor Modifications Facility Plan. These

facilities are scheduled for completion of construction by November 1, 1980, and October 1, 1981, respectively. Culex pipiens mosquitoes which breed in the effluent pools near the 91st Avenue Plant should be affected by the construction of disinfection and minor modifications facilities at the plant. The addition of scum removal to the clarifiers will diminish the larval food source by reducing the amount of organic matter deposited in the effluent and Salt River channels. Disinfection at the 91st Avenue Plant should also reduce Culex breeding in the effluent channel by diminishing the food source for the larvae. However, the impacts noted above will be very localized and as such, Culex mosquitoes may still be expected to breed in significant numbers throughout the riparian habitat, agricultural area, and wherever standing water exists.

The addition of scum removal to the plant will reduce the number of breeding sites for midges by reducing the high organic substrate now being deposited in the effluent and Salt River channels. As described for the Culex mosquitoes, disinfection facilities at the 91st Avenue Plant will reduce the food source for these pollution-tolerant insects. The introduction of chlorine through disinfection should result in the reduction of midges by diminishing the quantity of microscopic organisms which are used as food by midge larvae.

In addition, the improved water quality resulting from these plant alterations would enable a greater diversity of insects to inhabit the effluent channel. The cleaner effluent would allow for the survival of more species and probably result in a more balanced community of organisms, including a decline of pollution-tolerant midges. Balance of community refers to the diversity of insect species found in natural communities. In a balanced community, one

species would not normally reproduce in excessive numbers because of competition and predation.

Impacts Under First Condition. The reduction of effluent discharge to 6.52 mgd could diminish breeding sites for Culex mosquitoes. However, Culex mosquitoes may still be expected to breed in significant numbers throughout the riparian habitat, agricultural area, and where there is standing water. With the expansion of the 91st Avenue Plant, there would be a net improvement in water quality over that resulting from the disinfection and minor modifications to the plant as noted above.

The primary advantage of the plant expansion in terms of impact on insects is the reduction in pollution, or high organic and nutrient content, in the water, factors which increase some species of pollution-tolerant insect populations. The cleaner effluent should result in a balanced community of organisms with no dominant nuisance species. As a result, the reduction of potential breeding sites and increased diversity of competing insect species should result in a decreased number of midges.

In addition, after the completion of minor modifications, effluent disinfection and plant expansion, the seasonal variations in effluent discharge and Salt River base flow should not impact nuisance insect populations, assuming ponding is avoided. Both Culex and midges exhibit peak breeding activity in the summer and fall; in summer, they require about ten or eleven days to complete their life cycle, depending on temperature, moisture and food. Under the 6.52 mgd effluent discharge condition a constant flow of water will be maintained in the Salt River during the insect breeding periods.

Impacts Under Second Condition. As noted above, minor modifications, effluent disinfection, and the plant expansion will significantly improve the quality of the effluent discharged from the 91st Avenue Plant. The improved water quality will decrease the number of *C. pipiens* and midges related to the effluent by diminishing their breeding habitat. The second effluent discharge condition should not result in significant breeding habitat. Since the quality of the effluent appears to be a greater factor than effluent quantity in determining the potential for excessive breeding of nuisance insects, the impacts of discharging the remaining unused effluent are expected to be similar to those of discharging 6.52 mgd because both conditions will have cleaner effluent than that presently discharged from the plant. As described in the first effluent discharge condition, with the minor modifications, effluent disinfection and plant expansion, seasonal variations in effluent discharge and Salt River base flow should not impact nuisance insect populations.

CULTURAL FACTORS

Special concerns of area residents regarding insects, flooding attributable to vegetation, and public health are discussed under "Public Concerns Associated with Effluent Discharge" in the introduction to this assessment. In general, community life in the area should be enhanced by the improvement in the quality of effluent under both effluent discharge conditions. Impacts from improved effluent quality would primarily affect current insect problems associated with the effluent in that nuisance insect populations should decrease.

Concern has been expressed over degradation of riparian habitat due to reduction of surface flows. The MAG 208 Final EIS (USEPA, 1979) states that as a

mitigation measure to this potential impact, adequate water supply must be assured for valuable wildlife habitat. Either of the two effluent discharge conditions would be expected to result in adequate surface water for vegetation in the portion of the project area west of 115th Avenue, since this vegetation is primarily dependent on the shallow groundwater. The minimum flow required to maintain the riparian vegetation east of 115th Avenue is not now known, however.

Recreational opportunities provided by hunting, and bird-watching should not be significantly altered under either effluent condition in the area west of 115th Avenue. Those opportunities may, however, be affected by changes which could occur in riparian vegetation east of 115th Avenue.

SECTION 3

CONCLUSIONS

This section presents the results and conclusions of this assessment in terms of the specific concerns presented in the introduction to this report. The conclusions have been based on information examined to date, including documents and correspondence presented in the list of references. Specific issues which require additional study are discussed in Section 4, "Issues to be Resolved."

WATER RESOURCES

Neither the first nor the second effluent condition is expected to appreciably impact project area surface water quality, groundwater quality or groundwater quantity. The most noticeable impact of the effluent discharge conditions would be on surface water quantity; a general reduction in the existing relatively consistent flow of effluent discharge into the Salt River may be expected. As a result, channel flow characteristics would shift under either effluent discharge condition to a more seasonally variable flow, primarily because the river flow would have a higher proportion of irrigation tailwaters. In terms of the general concentration of constituents, surface water quality should not be significantly altered. Groundwater quality and quantity, likewise, are not expected to be significantly altered.

The western portion of the project area exhibits a high groundwater elevation. This is due to a geological fault which results in a subsurface geologic characteristic which favors shallow groundwater levels. The depth to water

beneath the channel is important because it partially controls the amount of recharge that can occur from water in the channel. Typically, the shallower the water level, the less storage space there is for recharge. Therefore, no significant impact on the groundwater quantity in the western part would be expected by variation in effluent flow from the 91st Avenue Plant.

The eastern part of the project area has a somewhat greater depth to groundwater than the western part. Groundwater level in the eastern segment is dependent on recharge from flood flows, effluent, and other flows. In the first condition, 6.52 mgd annual average discharge, an estimated 1,500 acre-feet per year of recharge from 91st Avenue Plant effluent would be expected to occur, the majority which would be in the eastern part of the project area. During dry periods, water levels could decline at a rate of several feet per year in excess of that normally encountered during such periods (Appendix B; Schmidt, 1980). Under the second condition, an estimated 4,000 to 8,000 acre-feet per year (approximately 3.6 to 7.1 mgd annual average) of recharge from 91st Avenue Plant effluent would be expected to occur, primarily in the eastern part of the project area. Water levels may be expected to decline slightly in the long term under this alternative. The precise magnitude of this decline is unknown, but a rate less than one foot per year is likely (Appendix B; Schmidt, 1980).

In terms of groundwater quality, no significant change is likely to result within the western part from either effluent discharge condition. In the eastern part, under the 6.52 mgd effluent discharge condition, salinity of the groundwater could increase slightly due to the reduction in effluent recharge.

Under the second effluent reuse condition, however, the reduction in effluent discharge into the Salt River is not expected to significantly impact groundwater quality because of the small decrease in total groundwater recharge.

Seasonal fluctuations of effluent discharge caused by ANPP withdrawals are not expected to affect overall surface water or groundwater quality. Throughout the year, the combined flows of effluent discharge and the receiving streams ultimately dilute the various pollutants in each. Under the second condition, by 1986 seasonal fluctuations in effluent withdrawals are expected to result in the greater percentage of river flow being comprised of effluent during the winter months. During the summer, the river flow should be predominantly irrigation tailwater.

Therefore, although the overall surface water quality should remain relatively consistent, flows in the river during the winter may be expected to have relatively greater percentages of BOD, ammonia, and chloramine toxicity from the effluent. Summer flows should be comprised of higher percentages of total dissolved solids, total suspended solids, and elevated pH.

RIPARIAN VEGETATION AND WILDLIFE HABITAT

The 208 Final Environmental Impact Statement (USEPA, 1979) states that the riparian vegetation downstream of the 91st Avenue Plant must be assured an adequate water supply. Under either effluent condition, surface flows should be sufficient to maintain both exotic and native riparian vegetation west of 115th Avenue. This vegetation is primarily supported by shallow groundwater levels which are expected to remain stable as long as large-scale pumpage is not developed, and continuous flows provide recharge. In general, east of 115th

Avenue, the riparian vegetation is more dependent on surface water flows and gross groundwater fluctuations than the vegetation located to the west. However, further investigation is necessary to determine the minimum surface flow required to maintain this eastern riparian vegetation. The decrease in annual average stream flow is expected to reduce the amount of saturated soil surface in either condition. This is expected to result in a thinning of native riparian vegetation associated with the river channel (cottonwood and willow) east of 115th Avenue.

Seasonal fluctuations caused by ANPP withdrawals should not have any significant effect on the vegetation, either native or exotic, or on aquatic organisms downstream of the 91st Avenue Plant. The combined baseline river flow and effluent discharge should result in lowest monthly flows occurring in the winter, when evaporation and evapotranspiration are lowest. Therefore, impacts resulting from low flow conditions should be minimal. Flows during these months are still expected to reach the Buckeye Heading.

FLOOD HAZARDS

Flooding in the project area is one of the major concerns of the local residents. Development in a flood-prone area is one of the most significant reasons for extensive flood damages. These flood-prone areas are most readily determined by the topography of the river channel and adjacent land and intensity of the flood flows. Flooding events are classified by using a specific rainfall quantification, the accumulated runoff to the river, and the capacity of the channel to convey the flow. These frequencies of occurrence are customarily ranked as 10, 50 and 100 year events. As discussed in the text, the

exact location of these floodplains may change as does the channel topography. However, they do provide relative frequencies and areas prone to inundation. Plate 2-3 was derived from the most recent topographical data (1976) and should provide a relatively accurate indication of those areas which would have been inundated by the recent floods.

Changes in the configuration of these floodplains could occur as a result of various factors. The most logical would be obstructions in the floodplain which would inadvertently reduce the channel capacity and increase the potential for overflow. One of the recent changes in the channel would be the addition of a sanitary landfill adjacent to Holly Acres. The contribution of the obstacle during high flood flows would not be expected to be great. A detailed hydraulic analysis would be required to determine the flows and corresponding effects.

The encroachment of saltcedar into the project area has been cited by area residents as the cause for increases in floodway damages they have experienced in recent years. This assertion appears to be based on observation of floods before and after the recent (1967) encroachment of saltcedar into the project area. A quantified determination of the effects of saltcedar on the increases in flooding was not possible based on the existing information analyzed as part of this assessment. However, during the course of this assessment, it was found through analysis of the 1965-66 flood of 66,000 cubic feet per second (cfs) flows would have reached the southern boundary of the portion of land which is now the Holly Acres subdivision. The floods which followed in March 1978 at 122,000 cfs and December 1978 at 140,000 cfs occurred after the encroachment of saltcedar. Based on the low elevation of the area, the location

at the confluence of three major rivers, and the relative location of development to the corresponding floodplain (as indicated on Plate 2-3), it appears that the greater intensity of the flood flow was the significant factor in the increase in flooded areas.

INSECTS

Neither of the two effluent discharge conditions should have any significant impact on nuisance insects. The current problems with the two nuisance insects associated with the effluent (*Culex* mosquitoes and midges) are expected to be mitigated through the construction of facilities identified in the Minor Modifications, Effluent Disinfection, and the Plant Expansion Facility Plans prior to the reduction in effluent discharge resulting from existing reuse commitments. In addition, seasonal fluctuations of the effluent discharge caused by ANPP withdrawals are not expected to have any effect on nuisance insect populations.

SECTION 4

ISSUES TO BE RESOLVED

WATER RESOURCES

Historically, there has been a lack of both water-level measurements and groundwater quality monitoring in the southern portion of the project area. Therefore, the necessity exists for implementing a regular monitoring program for groundwater in the project area between Southern Avenue and Baseline Road. As a part of this monitoring program, water levels should be measured in wells less than 250 feet deep on a quarterly basis. Approximately one dozen existing wells, as close to the river as possible, should be selected for water-level measurements. In addition, about six monitor wells should be installed to fill gaps in the network. These wells should be about fifty feet deep and perforated from about ten feet below the stated water level in the fall (in the absence of flood releases) to the bottom. Six-inch diameter PVC casing should be installed to allow water sample collection by submersible pumps. Water samples should be collected from this network on a quarterly basis and analyzed for the major inorganic chemical constituents: boron, fluoride, iron, manganese, chromium, arsenic, cadmium and dissolved organic carbon. Temperature, electrical conductivitiy and pH should be measured in the field. An extensive study of organic chemicals in groundwater of the south part of the project area could also be undertaken.

The data that would be collected could also be used in a more definitive assessment of the riparian vegetation that is supported by the groundwater regime.

This data would also help assess any possible future impacts that could occur as a result of changes in groundwater depth.

The baseline river flow was determined using various parameters that were necessary in this assessment and are important to the downstream ecosystem. A more quantified determination of the baseline river flow would enable a more accurate assessment of the precise times and quantities of seasonal fluctuations that would occur in the project area. This could be accomplished by the gauging of flows through road culverts such as at 115th Avenue. These projections could then be correlated with times of germination and seedling establishment to further monitor changes in the riparian habitat.

RIPARIAN VEGETATION AND WILDLIFE HABITAT

As stipulated in the MAG 208 Final EIS (USEPA, 1979), sufficient effluent should be discharged to ensure an adequate water supply for the riparian habitat. For the determination of the minimum flows necessary to support the vegetation, several factual aspects would have to be known. Of primary importance would be an updated areal and density quantification of the riparian habitat by species. As stated, quantified flow data on the irrigation tailwaters discharged to the project area would have to be known, particularly because these flows are so seasonally variable. Also needed would be determination of evapotranspiration rates for individual species, percolation rate of a surface water flow, depth to water table and surface water evapotranspiration rates, all on a site specific basis. In addition, a continuation of monitoring the groundwater level in the western portions of the project area is necessary. This would be used to monitor any possible decline caused by pumping which could impact the habitat.

With this data input the flows required to meet the consumptive use rate and the area evapotranspiration rate could be determined.

FLOOD HAZARDS

A number of studies are presently underway which can aid in the determination of flooding potential within the project area. The Central Arizona Water Control Study being conducted by the U. S. Water and Power Resources Service (WPRS) is addressing flood control in the Salt and Gila Rivers. As a part of this study, the Corps of Engineers is sponsoring investigations of phreatophytes (saltcedar) and channel stability in the Salt-Gila River project area. Specific parts of that study include:

- A literature search of phreatophyte control
- An investigation of phreatophyte invasion in the Salt-Gila project area
- Mapping of phreatophyte distribution in the project area
- A study of channel stability and changes in the river channel

Studies such as those noted above can contribute information to the eventual quantification of flooding potential and the influence of vegetation on flooding in the project area.

INSECTS

There are no additional issues to be resolved concerning the effects of the effluent discharge conditions on insects.

APPENDIX A

REFERENCES

LIBRARY

APPENDIX A

REFERENCES

Aldridge, B. N. 1970. "Floods of November 1965 to January 1966 in the Gila River Basin, Arizona and New Mexico, and Adjacent Basins in Arizona." U.S. Geological Survey Water-Supply Paper 1850-C. 176 p.

American Society of Agricultural Engineers. 1966. "Evapotranspiration and Its Role in Water Resources Management." American Society of Agricultural Engineers Conference Proceedings. Chicago, Illinois, Dec. 1966. 66p.

Arizona Department of Transportation. Personal Communication. December 1979.

Arizona Public Service. 1975. Palo Verde Nuclear Generating Station Units 1, 2, 3. September 1975.

Arizona Water Commission. 1968. Water Quality Standards for Surface Waters in Arizona. HEA5.2:571.

Arizona Water Commission. July 1975. "Inventory of Resources and Uses." Phase I - Arizona State Water Plan.

Arizona Water Commission. 1978. Current and Expected Water Supplies and Demands and Groundwater Conditions in Maricopa County. Prepared for MAG. 100 p. plus maps.

Arthur Beard Engineers, Inc./Camp Dresser & McKee Inc./ECOS Management Criteria. "Appendix G: Insects and Odors." 91st Avenue Draft Plant Expansion Facility Plan. Vol. 3.

Attebery, James E. 1971. Flood Damage Report - Storm and Flood of September 4-6, 1970. City of Phoenix Engineering Department. 20 p.

Babcock, H. M. 1968. "The Phreatophyte Problem in Arizona." 12th Annual Arizona Watershed Symposium Proceedings. Phoenix, Arizona State Land Department.

Baldwin, Tanna. Arizona State Parks Board. Personal Communication. January 1980.

Baucom, Frank. U.S. Fish and Wildlife Service. Personal Communication. January 4, 1980.

Blaney, Harry F., Paul A. Ewing, Karl V. Morin et al. 1942. "Consumptive Water Use and Requirements." The Pecos River Joint Investigation. Reports of the Participating Agencies. National Resource Planning Board. p. 170-230.

LIBRARY

Blaney, Harry F., and Karl V. Morin. 1942. "Evaporation and Consumptive Use of Water Empirical Formulae." American Geophys. Union Trans.

Blaney, Harry F. 1952. "Determining Evaportranspiration by Phreatophytes from Climatological Data." American Geophys. Union Trans.

Blaney, Harry F. and Wayne D. Criddle. 1962. "Determining Consumptive Use and Irrigation Water Requirements." U. S. Dept. of Agriculture Technical Bulletin.

Bouwer, H., J. C. Lance, and E. D. Escavega. 1974. "High-Rate Land Treatment, I: Infiltration and Hydraulic Aspects of the Flushing Meadows Project." Water Pollution Control Federation. Vol 46, No. 5. pp. 834-843.

Bowie, James E., and William Kam. 1968. "Use of Water by Riparian Vegetation, Cottonwood Wash, Arizona." U. S. Geological Survey Water-Supply Paper.

Bowser, Curtis W. 1952. "Water Conservation through Elimination of Undesirable Phreatophyte Growth." American Geophys. Union Trans.

Brooks, Kenneth N., and David B. Thorud. 1971. "Antitranspirant Effects on the Transpiration and Physiology of Tamarisk." Water Resources Research.

Brown, G. W., Ed. 1974. Desert Biology. Vol. II. Academic Press, New York.

Burkham, D. E. 1970. "Precipitation, Streamflow, and Major Floods at Selected Sites in the Gila River Drainage Basin Above Coolidge Dam, Arizona." U. S. Geological Survey Prof. Paper 665-B.

_____. 1971. "Channel Changes of the Gila River in Safford Valley, Arizona, 1846-1970." U. S. Geological Survey Prof. Paper 665-G.

_____. 1970. "Hydraulic Effects of Changes in Bottom-Land Vegetation on Three Major Floods, Gila River in Southeastern Arizona." U. S. Geological Survey Prof. Paper 665-J.

_____. 1976. "Effects of Changes in an Alluvial Channel on the Timing, Magnitude, and Transformation of Flood Waves, Southeastern Arizona." U. S. Geological Survey Prof. Paper 655-K.

Campbell, C. J., and W. A. Dick-Peddie. 1964. "Comparison of Phreatophyte Communities on the Rio Grande in New Mexico." Ecology. 45:492-502.

Culler, Richard C. 1970. "Water Conservation by Removal of Phreatophytes." American Geophys. Union Trans. 51:684-689.

Culler, Richard C. et al. 1970. "Objectives, Methods, and Environment--Gila River Phreatophyte Project, Graham County, Arizona." U. S. Geological Survey Prof. Paper 655-A.

Daum, C. R. 1967. "A Method for Determining Water Transport in Trees." Ecology. No. 48. p. 425-431.

Decker, John P., William G. Gaylor, and Frank D. Cole. 1962. "Measuring Transpiration of Undisturbed Tamarisk Shrubs." Plant Physiology. 37:393-397.

Ferguson, Morris and Simpson, Inc.; Stevens, Thompson, and Runyan, Inc. 1978. "Surface Water Quality Standards and Goals for Effluent-Dominated Streams." Corps of Engineers, Phoenix Urban Study. February 1978.

Gary, Howard L. 1962. "Removal of Tamarisk Reduces Water-Table Fluctuations in Central Arizona." U.S. Department of Agriculture Forest Service, Rocky Mountain Forest and Range Experiment Station Note 81. 6 p.

Gary, Howard L., and C. J. Campbell. 1965. "Water-Table Characteristics Under Tamarisk in Arizona." U. S. Forest Service Research Note RM-58. 7 p.

Gatewood, J. S., T. W. Robinson, B. R. Colby, J. D. Hem, and L. C. Halpenny. 1950. "Use of Water by Botton-Land Vegetation in Lower Safford Valley, Arizona." U. S. Geological Survey Water-Supply Paper 1103. 210 p.

Graf, William L. 1978. Fluvial Adjustments to the Spread of Tamarisk in the Channels of the Salt and Gila Rivers. Arizona State University, Tempe, Arizona. September 1979.

_____. 1979. "Potential Control Measures for Phreatophytes in the Channels of the Salt and Gila Rivers." ASU, Tempe, Arizona. September 1979.

_____. January 1980. General Discussion of Geology and Morphology. Prepared for Camp Dresser & McKee Inc.

Greeley and Hansen, Inc. October 1979. 23rd Avenue Plant Upgrade Interim Report No. 1.

_____. December 1979. Effluent Disinfection Facility Plan for the 23rd Avenue Wastewater Treatment Plant.

_____. January 16, 1980. Letter from Greeley and Hansen/John Carollo Engineers to Camp Dresser & McKee Inc. with enclosures on flow projections.

_____. February 1980. 91st Avenue Draft Plant Expansion Facility Plan.

Hallock, Robert, Biologist, U. S. Fish and Wildlife Service. Albuquerque, N. M. Personal Communication. December 28, 1979.

Halpenny, L. C. and D. K. Greene. 1975. Water Balance Investigation of River Bed, Salt and Gila Rivers, 23rd Avenue to Gillespie Dam, Arizona. Report prepared for NUS Corporation, Water Development Corporation. Tucson, Az.

Halpenny, L. C. and S. D. Clark. 1977. Supplement to Water Balance Investigation of River Bed, Salt and Gila Rivers, 23rd Avenue to Gillespie Dam, Arizona. November 1977.

Hanson, Ronald L. and David R. Dawdy. 1976. "Accuracy of Evapotranspiration Rates Determined by the Water-Budge Method, Gila River Flood Plain, Southeastern Arizona." U. S. Geological Survey Prof. Paper 655-L.

Horton, J. S., F. C. Mounts, and J. M. Kraft. 1960. "Seed Germination and Seedling Establishment of Phreatophyte Species." Rocky Mountain Forest and Range Experiment Station Paper 48. 26 p.

Horton, J. S. and C. J. Campbell. 1974. "Management of Phreatophyte and Riparian Vegetation for Maximum Multiple Use Values." U. S. Forest Service Research Paper RM-117. Ft. Collins, CO. 23 p.

Laney, R. L. 1977. "Effects of Phreatophyte Removal on Water Quality in the Gila River Phreatophyte Project Area, Graham County, Arizona." U. S. Geological Survey Prof. Paper 655-M.

Lewer, Governor Alexander, Sr., Gila River Indian Community, to the Honorable Charles Salem, Chairman, Maricopa Association of Governments. January 11, 1979.

Maricopa County Flood Control District. 1941 Photograph #C-7290. Fairchild Aerial Surveys, Los Angeles, CA. July 26, 1941.

_____. 1959 Photographs. Aerial Photographic Coverage of Phoenix and Vicinity. Aerial Mapping Company, Boise and Phoenix. #11, 15, 19 of 25.

_____. Map of District Showing Salt-Gila River Clearing.

Meinzer, O. E. 1927. "Plants as Indicators of Ground Water." U. S. Geological Survey Water-Supply Paper 577. 95 p.

Merkel, D. L. and H. H. Hopkins. 1957. "Life History of Salt Cedar (Tamarix gallica L.)." Kansas Acad. Sci. Trans. Vol. 60, No. 4. p. 360-369.

Merrill, Reginald E., R. M. Van De Pol, and W. E. Ryley. June 1979. "Sources of Pollution from Agricultural Drainage." Journal of the Irrigation and Drainage Division.

Newton, C. T. December 4, 1957. Interim Report on Survey for Flood Control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam Site, Arizona. Prepared U. S. Army Corps of Engineers Los Angeles District.

Ohmart, R. D., W. O. Deason and C. Burke. 1977. "A Riparian Case History: The Colorado River." USDA Forest Service General Technical Report RM-43. July 9, 1977.

Ohmart, Robert. Associate Professor Zoology, Arizona State University. Personal Communication. January 8, 1980.

Peterson, Peggy. Holly Acres Flood Control Warning Organization, Personal Communication. January 1980.

Pewe, T. L. 1978. "Terraces of the Lower Salt River Valley in Relation to the Late Cenozoic History of the Phoenix Basin, Arizona: Guidebook to the Geology of Central Arizona." Arizona Bureau of Geology and Mineral Technology Special Paper No. 2. p. 1-46..

Phillips, W. S. 1963. "Depth of Roots in Soil." Ecology. Vol. 44, No. 2. p. 424.

Rantz, S. E. 1969. "A Suggested Method for Estimating Evapotranspiration by Native Phreatophytes." U. S. Geological Survey Prof. Paper 600-D. p. 10-12.

Robinson, T. W. 1952. "Phreatophytes and Their Relation to Water in Western United States." American Geophys. Union Trans. 33(1):57-61.

_____. 1958. "Phreatophytes." U. S. Geological Survey Water-Supply Paper 1423.

_____. 1965. "Introduction, Spread and Areal Extent of Salt Cedar (Tamarix) in the Western States." U. S. Geological Survey Prof. Paper 491-A.

_____. 1970. "Evapotranspiration by Woody Phreatophytes in the Humboldt River Valley, near Winnemucca, Nevada." U. S. Geological Survey Prof. Paper 491-D. 41 p.

Roeske, R. H. 1971. "Floods of September 1970 in Arizona, Utah, and Colorado." Arizona State Land Department Water Resources Report 44. 20 p.

Salt River Project. 1970-1978. Mean Daily Discharge in Second Feet for Grand Canal Below Power House and the Tempe Cross-cut Canal at Heading.

Salt River Project. Written Communication and Flow Data. December 1979 and January 1980.

Schmidt, Kenneth D. 1978. "Groundwater Quality in the Major Basins of Maricopa County." Final Report, Chapter II - Salt River Valley, West Basin. Prepared for U. S. Army Corps of Engineers, Phoenix Urban Study and Maricopa Association of Governments 208 Program. pp. II-16 - II-32.

_____. 1980. Evaluation of Effect of 91st Avenue Effluent Alternatives on Groundwater. Prepared for Camp Dresser & McKee. January 7, 1980.

Sebenik, P. G., C. B. Cliff, and K. J. DeCook. 1972. "Nitrogen Species Transformations of Sewage Effluent Releases in a Desert Stream Channel." Hydrology and Water Resources in Arizona and the Southwest. Vol. II, Arizona Section. Arizona Water Resources Association.

Smith, E. Linwood and Gordon L. Bender. Proposed Natural Areas - Salt River Between 91st and 115th Avenues, Report No. 7. Arizona Academy of Science. Prepared for the Planninging Division, Department of Economic Planning and Development, Office of the Governor, State of Arizona. June 1973.

Tomanek, G. W. and R. L. Ziegler. 1962. Ecological Studies of Salt Cedar. Hays, Fort Hays Kansas State College. 128 p.

Turner, R. M. 1974. "Quantitative and Historical Evidence of Vegetation Changes Along the Upper Gila River, Arizona." U. S. Geological Survey Prof. Paper.

Turner, S. F. and L. C. Halpenny. 1941. "Ground-Water Inventory in the Upper Gila River Valley, New Mexico and Arizona: Scope of Investigation and Methods Used." American Geophys. Union Trans. 22:738-744.

Turner, S. F. and H. E. Skibitzke. 1952. "Use of Water by Phreatophytes in 2,000-foot Channel Between Granite Reef and Gillespie Dams, Maricopa County, Arizona." American Geophys. Union Trans. 33:66-72.

U. S. Army Corps of Engineers. 1949 Photographs. "Photo Album." Granite Reef Dam to Gillespie Dam Phoenix Urban Study.

U. S. Army Corps of Engineers, Los Angeles District. 1957. Interim Report on Survey for Flood Control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam Site, Arizona.

U. S. Army Corps of Engineers. July 1975. Water Surface Profiles. Vol. 6. Hydrologic Engineering Center, Davis, CA.

U. S. Army Corps of Engineers. Flood-Damage Report on Flood of December 1965-January 1966, Salt and Gila Rivers, Granite Reef Dam to Gillespie Dam, Arizona. April 1966.

_____. October 1972. Report on Flood of 22 June 1972 in Phoenix Metropolitan Area, Arizona.

U. S. Army Corps of Engineers, Los Angeles District. December 1978. Fish and Wildlife Enhancement Report for Maricopa Association of Governments 208 Water Quality Management Plan Point Source Metro Phoenix Alternatives. Prepared by Dames & Moore.

U. S. Environmental Protection Agency. July 1979. Final Environmental Impact Statement, Point Source Metro Phoenix 208 Wastewater Management Plan. Maricopa Association of Governments.

U. S. Geological Survey. 1970. Floods of November 1965 to January 1966 in the Gila River Basin, Arizona and New Mexico and Adjacent Basins in Arizona.

_____. 1977. Map: Natural Areas in Arizona Established and Proposed. Scale: 1:1,000,000.

_____. January 8, 1980. Written Communication: Flow data from water years 1972-1979 including flows generated from data provided by Salt River Project.

U. S. Government Printing Office. June 1965. "Interim Report of the District Engineer on Survey for Flood Control, Phoenix, Arizona and Vicinity Including New River, Gila River Basin, Arizona." House Document No. 216. 89th Congress First Session. Washington, D. C.

_____. Floods of November 1965 to January 1966 in Gila River Basin Arizona and New Mexico.

U. S. Soil Conservation Service. 1954 Photograph Numbers DHP-4N-1, DHP-2N-174, DHP-3N-51, DHP-2N-153; 1964 Photograph Numbers DHP-4EE-214, DHP-5EE-29, DHP-7EE-60, DHP-4EE-257.

U. S. Water Resource Conference. March 1976. "Guidelines for Determining Flood Flow Frequency." Bulletin 17.

van Bavel, C. H. M. 1966. "Potential Evaporation: The Combination Concept and Its Experimental Verification." Water Resources Research. 2:455-467.

van Hylckama, T. E. A. 1970. "Water Use by Saltcedar." Water Resources Research. 6:728-735.

Warren, Douglas K. and Raymond M. Turner. "Saltcedar (Tamrix chinensis) Seed Production, Seedling Establishment, and Response to Inundation." Journal Arizona Acad. Sci. 10(3). p. 135-144.

Water Resources Associates, Inc. August 1975. Report on Water Balance Salt and Gila Rivers, 23rd Avenue to Gillespie Dam. Prepared for NUS Corporation.

_____. January 1976. Explanatory Notes on Mapping of Vegetation Types Salt and Gila Rivers 23rd Avenue, Phoenix to Gillespie Dam.

Weist, William G., Jr. 1971. "Geology and Ground-Water Systems in the Gila River Phreatophyte Project Area, Graham County, Arizona." U. S. Geological Survey Prof. Paper 655-D.

Zimmerman, A. L. 1971. "Arizona Floods of September 5, and 6, 1970." Natural Disaster Survey Report 70-2. USDC National Oceanic and Atmospheric Administration. 39 p.

Zimmerman, R. C. 1969. "Plant Ecology of An Arid Basin: Tres Alamas - Redington Area, Southeastern Arizona." U. S. Geological Survey Prof. Paper 485-D.

APPENDIX B

EVALUATION OF EFFECT OF 91ST AVENUE EFFLUENT ALTERNATIVES ON GROUNDWATER

Kenneth D. Schmidt, January 1980

EVALUATION OF EFFECT OF 91ST AVENUE EFFLUENT ALTERNATIVES ON GROUNDWATER

prepared for

Camp Dresser & McKee, Inc.
Phoenix, Arizona

by

Kenneth D. Schmidt

January 23, 1980

EVALUATION OF EFFECT OF 91ST AVENUE EFFLUENT ALTERNATIVES ON GROUNDWATER

by Kenneth D. Schmidt

INTRODUCTION

Presently, about 100,000 acre-feet per year of sewage effluent from the 91st Avenue sewage treatment plant are discharged to the Salt River channel about three miles upstream from the Gila River confluence. The effluent flows westward in the channel, past the confluence, to a point west of the Agua Fria River. At this point, most of the effluent is diverted into the Buckeye Canal. The flow by the year 2000 is projected to be about 134,000 acre-feet per year (Greeley and Hanson, 1979). Present plans call for delivery of from 65,000 to 108,000 acre-feet per year of the effluent through a pipeline to the Palo Verde Nuclear Generating Station. An additional 30,000 acre-feet per year of effluent would be delivered to the Buckeye Irrigation District through this pipeline. The City of Phoenix has agreed to provide the Arizona Game and Fish Department with 7,300 acre-feet per year of effluent for wildlife habitat downstream of 91st Avenue.

The following two alternatives are discussed in this report:

1) discharge of only 7,300 acre-feet of effluent from the 91st Avenue plant to the Salt River.

2) discharge of from 22,600 to 39,400 acre-feet per year of effluent from the 91st Avenue treatment plant to the Salt River.

The study area considered in this report extends from 75th Avenue on the east to Bullard Avenue on the west; and, from Broadway Road on the north to Baseline Road on the south. The objective of this report is to evaluate the impacts of the two alternatives on groundwater quantity and quality in the area between 91st Avenue and the Buckeye Canal heading.

EXISTING CONDITIONS

Surface Water

Halpenny and Greene (1975) reported on a water balance investigation of the Salt and Gila Rivers between 23rd Avenue and Gillespie Dam. By the end of the 1950's, flow in the Gila River at the Buckeye Canal heading had decreased to the point where water was present only after storms. This was due to the effects of surface water impoundments and large-scale pumpage, which resulted in lowered groundwater levels. Since 1941, substantial flood flows were present in the Salt River during the following periods:

December 22, 1965 - January 10, 1966
March 13, 1973 - May 18, 1973
March 1, 1978 - March 7, 1978
December 18, 1978 - January 7, 1979
January 17, 1979 - February 5, 1979
March 15, 1979 - April 16, 1979

Halpenny and Greene (1975) reported on streamflow in the Gila River at the confluence with the Salt River. There was

more than 80,000 acre-feet of flow in water year 1966, about 56,000 acre-feet in 1968, and more than 19,000 acre-feet in 1971. Sewage effluent from the 91st Avenue plant was first discharged to the Salt River in 1958 and by 1964, this totaled 5,900 acre-feet per year. The effluent discharge increased to 25,700 acre-feet per year in 1965, and by 1970 was almost 56,000 acre-feet per year.

Prior to the 1965-66 flood flows, channel seepage in the six and one-half mile reach between 91st Avenue and Buckeye Canal heading were about 35 percent of the discharge on an annual basis. After that flood and rechannelization, the seepage declined to about 26 percent for 1966-67 (Halpenny and Greene, 1975). It has been observed that an organic mat gradually builds up in the channel and limits percolation losses, a situation similar to that observed in the Santa Cruz River channel where effluent from the City of Tucson is disposed (Sebenik, Cluff, and DeCook, 1972). Significant amounts of irrigation tailwater are also discharged to the Salt River in or above the study area.

Subsurface Geology

At least four distinct geologic units have been penetrated by wells in the study area. The uppermost materials beneath most of the area are Recent alluvium. This unit is comprised of coarse-grained deposits, primarily boulders, gravel, and sand, up to 200 feet thick. This unit is a

prolific aquifer in the study area. It is thickest near the Salt and Gila Rivers and is about 100 feet thick in the northern part of the study area. The unit is locally missing in the south part of the study area south of the Gila River, between Monument Hill and the Sierra Estrella Park.

A second distinctive unit has been penetrated beneath most of the study area at depths ranging from about 180 to 270 feet below land surface. This unit is comprised primarily of clay and silt and may be comparable to the "Middle Fine-Grained Unit" of the U.S. Bureau of Reclamation (1977). Because of its low permeability, this unit is a poor water producer. The top of this unit ranges from 210 to 250 feet in depth beneath much of the study area. The south edge of this unit is near the Salt and Gila Rivers, and locally the unit is absent south of Southern Avenue. The unit is underlain by conglomerate or hardrock. The unit appears to thicken considerably to the north beneath the study area. Several wells over 700 feet in depth in the north part of the study area have bottomed in this material. For example, Well (B-1-1) 25add penetrated clay to a depth of almost 900 feet.

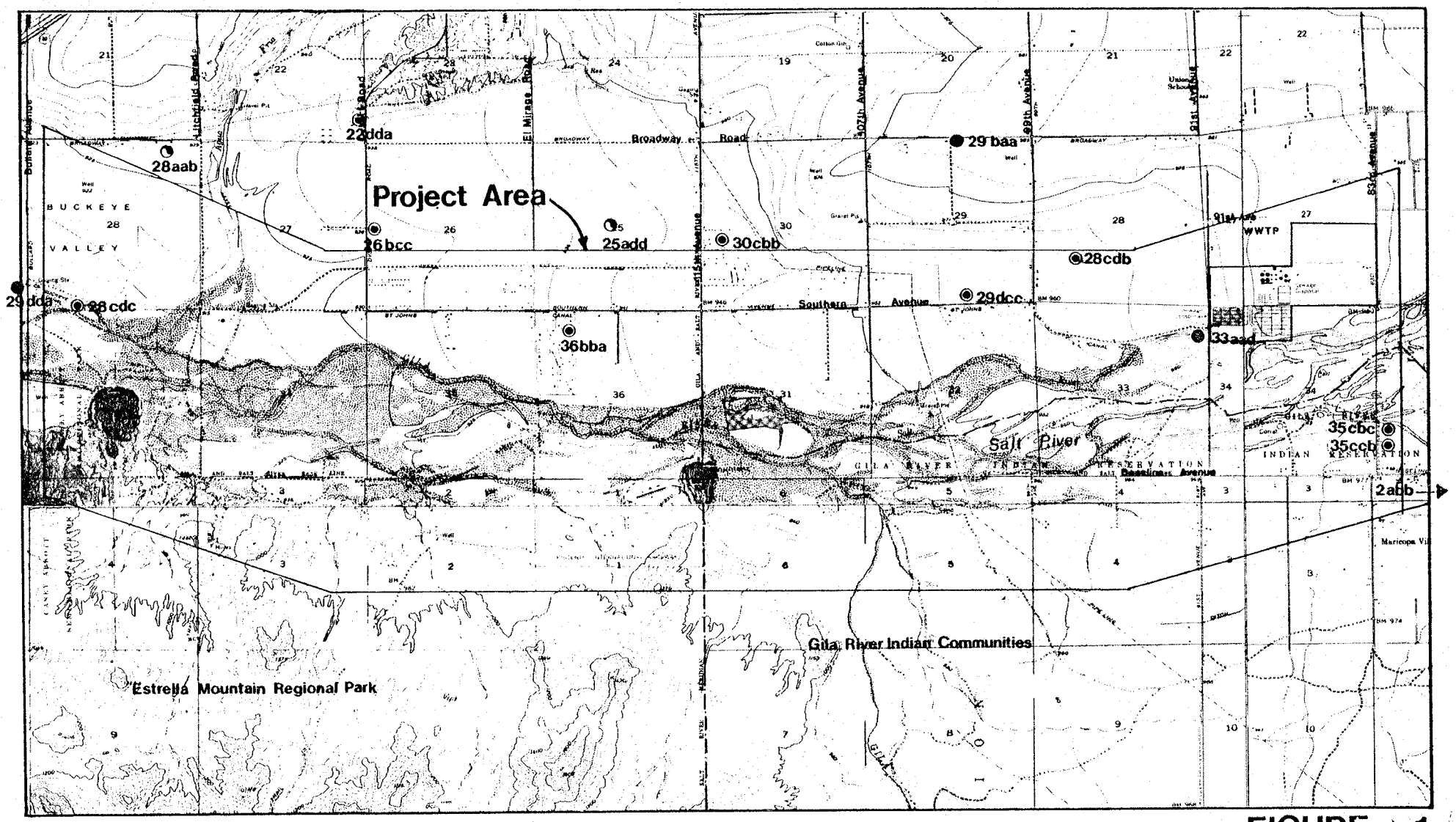
A third distinctive unit penetrated by wells in the area is conglomerate, or the equivalent of the "Lower Conglomerate Unit" of the U.S. Bureau of Reclamation (1977). This unit is present at relatively shallow depths beneath the south part of the study area, but may be very deep or missing beneath the north part. Several wells south of the Salt and Gila Rivers

have penetrated this unit above a depth of 200 feet, whereas beneath the north part of the study area the unit has been penetrated at a depth exceeding 400 feet. The unit is locally a prolific aquifer in the Salt River Valley and is tapped by both deep wells in the western part of the study area and shallow wells in the southern part.

The fourth unit is the hardrock, which is essentially non-water bearing. This unit has only rarely been penetrated by wells in the northern part of the study area, because it underlies a substantial thickness of clay. The hardrock was encountered at a depth of 875 feet below land surface at well (B-1-1)25add and at a depth of 774 feet at well (B-1-1)28aab. On the other hand, some wells south of the Gila River have penetrated hardrock at depths of less than 150 feet. Although the unit can provide small well yields adequate for individual domestic use, it is not of adequate permeability for large-scale groundwater development. Figure 1 shows the use and Figure 2 shows the hydrogeologic information available for selected wells in the study area.

Water Levels

The study area has historically been underlain by relatively shallow groundwater levels, compared to other parts of the Salt River Valley. Largely, this is due to the subsurface geologic structure, chemical quality of the groundwater, and disposal of wastewaters. West of Monument Hill,



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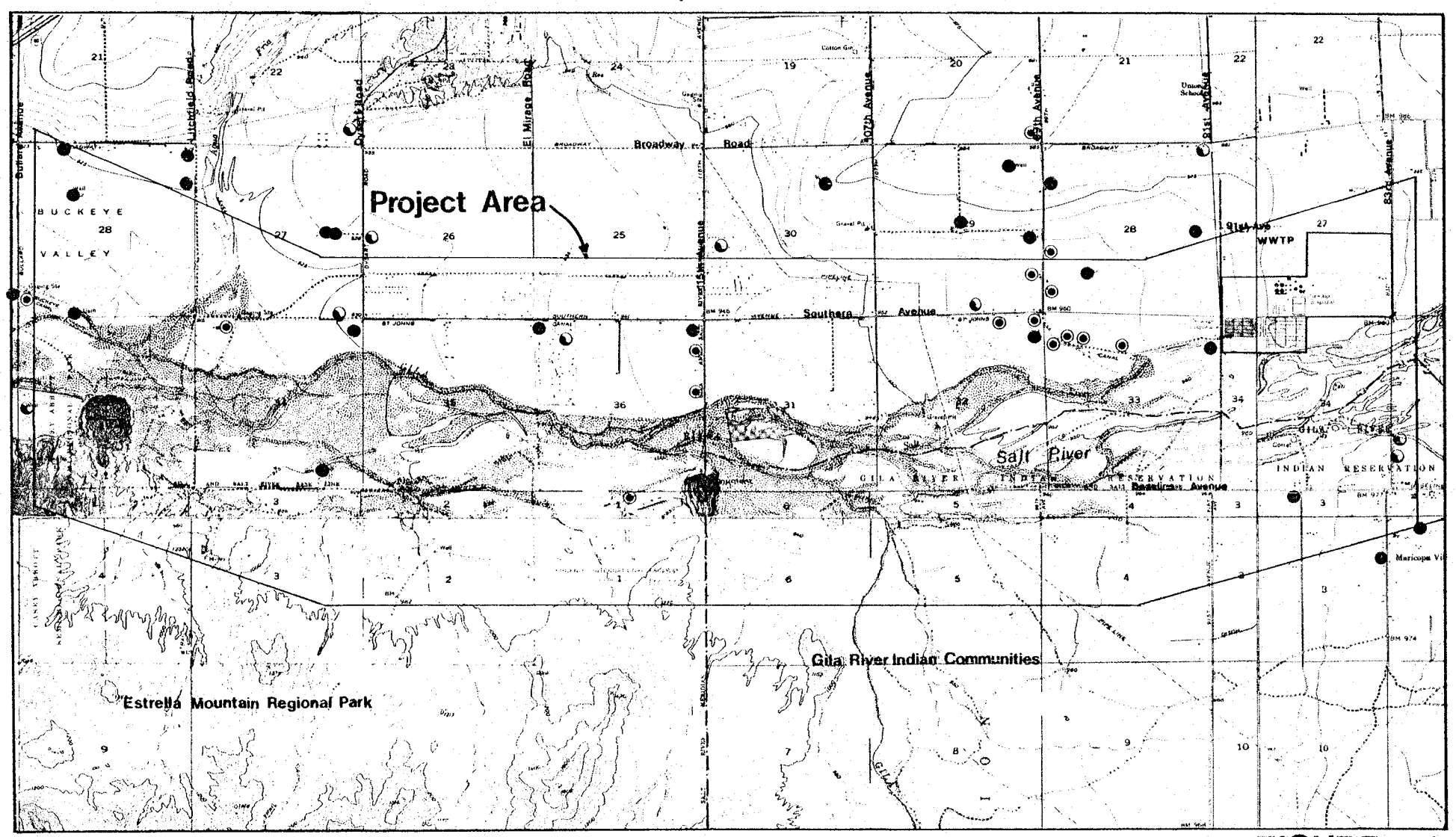
Scale: 1"=2700'

◐ Subsurface Geology
● Water Levels
◉ Chemical Quality

FIGURE 1
Location Of Selected Wells With Hydrogeologic Records



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Scale: 1"=2700'

◉ Domestic or
● Irrigation
◐ Public Supply Stock

FIGURE 2
Location Of Selected Wells In The Project Area

relatively impermeable geologic materials are present at relatively shallow depths near the Gila River. The poor chemical quality of the shallow groundwater results in only limited pumpage. Disposal of wastewaters acts as a source of recharge to the area. As noted by Halpenny and Greene (1975), groundwater levels were near the Salt River channel in 1920, even as far eastward as downtown Phoenix. Groundwater levels declined up through 1965 due to expanded pumpage and a decrease in streamflow. However, west of the Agua Fria River confluence, water levels did not fall significantly below the Gila River channel. After 1965, two sources of recharge became predominant in the study area. These include relatively continuous discharges of sewage effluent and other water and periodic flood releases to the channel of the Salt River. The combined effect of these sources has been to substantially raise water levels in the area from 1965 to the present. Depth to water is discussed in two parts: 1) measurements from wells that are usually some distance from the river, and 2) estimated depths beneath the river channel.

Well Measurements

The depth to water in well (A-1-1)33aad, near 91st Avenue and the Salt River, exceeded 40 feet in the early 1950's. Despite flood flows and some recharge of sewage effluent, the depth to water in this area was still greater than 40 feet in January 1978. A depth to water of about 20 feet was maintained following the flood flows until May 1978, when pumping

for irrigation commenced. After the Summer 1978 pumping season, water levels recovered to a depth of almost 20 feet. Following the flood flows in December 1978, the water level rose to a depth of 16 feet. By February 1979, the water level was again about 20 feet deep.

Water-level measurements for well (B-1-1)28cdc, near the Buckeye Canal heading, indicate that depth to water exceeded 50 feet in 1965-66. In large part the relatively great depth was due to pumping of a series of wells along the upper reach of the Buckeye Canal. The water level rose to a depth of about 35 feet following the flood flows of 1964-65. Water levels in this well rose another 13 feet between 1966 and 1971, and this is attributed largely to recharge from sewage effluent. The flood flows in 1973 only raised water levels slightly in this area, probably because of the shallow depth to water at that time beneath the Gila River channel. Water levels in this area were at a depth of about 35 feet before the 1978 flood releases, and had risen to a depth of 15 feet by 1979.

Water levels in well (A-1-1)29baa, about one and one-half miles north of the Salt River, have been measured on a frequent basis since 1963. Water levels in this well respond markedly to flood flows in the Salt River. In 1964, depth to water was about 73 feet at this location. The water level in this well rose about 19 feet following the flood flows of 1965-66, and this level was generally maintained until 1973. The maintenance of this level was likely due to recharge of

sewage effluent. The water level rose an additional 10 feet following the flood release in 1973. Water levels receded about 12 feet between 1975 and early 1978, but the water level rose about 10 feet following the flood flows in 1978.

On the short-term, water levels in wells in the study area thus fall during drought periods and rise during wet periods. During wet periods, two predominant factors control the depth to water. First, there is direct recharge during flood flows. Second, pumpage is usually substantially decreased at the time of flood flows, because of the abundance of available canal water. These factors combine to produce rather marked responses in water levels following flood flows. In dry periods, this source of recharge is not present and pumping tends to be greater because of the decreased availability of canal water. On the long-term, there has been a gradual rise in water levels since the mid-1960's in the study area, and this is attributed to sewage effluent and the prevalence of more runoff in the Salt and Gila Rivers than occurred in previous decades.

Conditions Beneath River Channel

Depth to water beneath the channel is important because it partially controls the amount of recharge that can occur from water in the channel. In general, the deeper the water level, the more storage space there is for recharge. Depth to water beneath the channel of the Salt and Gila Rivers in the study area is poorly known because of a lack of measurements for wells near the channel. Ideally, measurements

would be available in this area for wells which tap only the Recent alluvium. For purposes of this report, information has been extrapolated from deeper wells, at some distance from the channel. Near 91st Avenue, the depth to water in January 1978 was believed to be about 25 feet beneath the river channel. At this same location, depth to water was believed to coincide with the surface of the channel in December 1978 and to be less than five feet deep in February 1979. At the site of the former Flushing Meadows Project in the east half of section 32, T1N/R1E, depth to water between 1967 and 1978 was usually about five feet below the channel. However, during drought periods the depth to water fell to almost 10 feet below the channel. During flood flows, the water level apparently coincided with the level of the stream channel. The relatively shallow depth to water at this location is apparently due to the lack of nearby active large-capacity wells and recharge from 91st Avenue sewage effluent and flood flows.

Extrapolation of measurements from wells to the north and south of the Gila River near the Agua Fria River confluence suggests that groundwater levels beneath the western part of the study area have been at or near the elevation of the river channel (less than five feet deep) since the mid-1960's. However, east of Monument Hill, depth to water has generally ranged from 10 to 20 feet deep beneath the Salt River channel.

The direction of groundwater movement in the study area is not well known, due to a lack of intensive water-level measurements. However, intensive measurements in 1972 indicated that the regional direction of movement was to the west. The slope of the water table was about 7 feet per mile near 91st Avenue and about 13 feet per mile near the Agua Fria River. It is likely that following flood releases, there is a more northerly component to the regional direction of groundwater movement.

Recharge and Discharge

The primary sources of recharge to groundwater in the study area are:

1) seepage of flood releases from the floodplains of the Salt and Gila and Agua Fria Rivers.

2) seepage of sewage effluent and irrigation tailwater from the channels of the Salt and Gila Rivers.

3) deep percolation of irrigation return flow.

Halpenny and Greene (1975) determined that there was about 10,400 acre-feet of recharge in 1966-67 due to seepage of sewage effluent from the 91st Avenue plant. At that time, about 41,000 acre-feet per year of effluent were discharged from the plant. This recharge amounted to about 26 percent of the discharge. However, this rate is likely high compared to normal conditions because of the extensive scouring of the channel prior to when the budget study period began. At the present discharge rate of about 100,000 acre-feet per

year, recharge of 91st Avenue plant effluent in the study area is probably about 8,000-10,000 acre-feet per year.

Recharge from flood releases can be estimated from water level responses and from streamflow measurements. For the 1965-66 flood flows, an estimated 15,000-20,000 acre-feet were recharged in the study area, primarily east of Monument Hill. These calculations and a review of water-level measurements for wells in the study area indicate that flood flows are extremely important in three ways:

1) They supply direct recharge.

2) They clear the channel of the organic mat which temporarily greatly enhances the seepage of sewage effluent and other water from the stream channel.

3) They conincide with periods of abundant canal water, which results in minimal pumpage.

The water level responses during and after flood flows thus reflect direct recharge of flood water, enhanced percolation of effluent and other water due to channel scouring, and a reduction in pumpage.

Aquifer Characteristics

Well yields and specific capacities in the study area depend highly on the geologic units tapped. Yields of 4,000 to 5,000 gpm are possible from shallow wells (less than 200 feet deep) tapping the Recent alluvium. Specific capacities for such wells commonly range from 100 to 150 gpm per foot of drawdown. The transmissivity is estimated to range from

170,000 to 250,000 gpd per foot of aquifer width. Well (A-1-1)28cdb, which is perforated from 50 to 140 feet in depth, was pump-tested in Summer 1979 as part of the AWC Salt River Valley groundwater model study. The specific capacity was 182 gpm per foot. The calculated transmissivity was 1,140,000 gpd per foot, but this value is likely high due to recharge in the area.

Because of poor chemical quality, many wells are not perforated opposite the shallowest strata. Specific capacities for wells ranging from 330 to 450 feet deep in the study area range from 50 to 70 gpm per foot. Although these wells tap some additional water-bearing strata below the Recent alluvium, the specific capacity is lower because the wells are not perforated opposite a significant part of the Recent alluvium.

Chemical Quality

Schmidt (1978) discussed the regional distribution of a number of inorganic chemical constituents in groundwater of the Salt River Valley. Most of the chemical analyses used in that investigation were for water from large-capacity municipal or district irrigation wells, and not private domestic or irrigation wells. Except for several SRP wells in the east part and several Buckeye Irrigation District wells near the west boundary of the study area, most wells are owned or operated by individuals, small water companies, or small irrigation districts. In general, salinity of groundwater decreases to the north in the study area. Electrical conductivity of well water is usually less than 3,000 micromhos per centimeter at 25°C north of Lower Buckeye Road. Near Southern Avenue, electrical conductivity may exceed 5,000 micromhos. Chloride content increases to the south and west, from about 600 mg/l near Lower Buckeye Road, to over 1,000 mg/l near the west boundary of the study area. Total hardness contents are very high and generally increase to the south. Hardness contents usually range from 400 to 800 mg/l in the study area. Nitrate contents increase to the north. They are usually less than 25 mg/l south of Broadway Road, but often exceed 45 mg/l north of Lower Buckeye Road. Fluoride contents are usually less than 1.0 mg/l in water from wells in the study area.

Chemical analyses were collected from the files of the Arizona Department of Health Services, Maricopa County Health

Department, and Bureau of Indian Affairs to supplement existing data compiled in the MAG 208 program. Table 1 contains chemical analyses of water from eight wells in the study area (Figure 1). Chemical quality of groundwater varies both areally and vertically in the area. All well water sampled in the area is of the sodium chloride type, and total dissolved solids contents range from less than 800 mg/l to more than 4,200 mg/l.

Wells north of the Salt and Gila Rivers and downgradient from recharge of flood water and sewage effluent appear to have relatively low salinity water. An example is well (B-1-1)36bba, which is at Holly Acres and about one-half mile from the river channel. Water from this well had a low nitrate content and a total dissolved solids content of about 800 mg/l in 1979. Well (A-1-1)35ccb is located south of the Salt River and east of the 91st Avenue sewage treatment plant. This well was constructed so as to tap only water between about 390 and 410 feet in depth. Water from this well had a low nitrate content and a total dissolved solids content of about 850 mg/l in 1977. Water from this well may also be influenced by recharge of flood water and sewage effluent from the 23rd Avenue plant. Numerous chemical analyses for trace elements have been performed on samples of water from public supply wells in the study area. The only constituent found in amounts exceeding the U.S. EPA drinking water limits is iron. The limit for iron is based on aesthetic, not health concerns, and is

TABLE 1 - CHEMICAL ANALYSES FOR WATER FROM WELLS IN THE STUDY AREA

Constituent (mg/l)	(A-1-1) 28cdb	29dcc	30cbb	35ccb	(B-1-1) 22dda	26bcc	28cdc	36bba
Calcium	216	465	120	30	126	69	108	42
Magnesium	72	185	63	14	39	39	70	19
Sodium	639	640	342	259	312	264	272	200
Carbonate	0	0	0	0	0	0	0	0
Bicarbonate	422	239	156	127	134	151	400	118
Sulfate	348	620	212	118	195	93	261	78
Chloride	1070	1830	760	344	636	624	656	356
Nitrate	26	11	11	3	4	2	23	<1
Fluoride	-	<0.2	0.3	0.9	0.2	0.3	0.3	0.6
Total Hardness ($CaCO_3$)	770	1920	559	133	580	336	546	183
Iron	-	0.1	<0.1	<0.05	0.2	0.44	-	<0.1
Manganese	-	<0.05	<0.05	<0.05	<0.05	<0.05	-	<0.05
Chromium	-	<0.01	0.01	-	<0.01	<0.01	-	<0.01
Arsenic	-	<0.01	<0.01	-	<0.01	<0.01	-	<0.01
pH	7.6	7.4	7.6	7.8	-	7.8	7.6	8.0
Electrical Conductivity (micromhos @ 25°C)	4320	-	-	-	2130	1850	3730	-
Total Dissolved Solids	2580	4250	1730	840	1512	1078	1772	790
Date	11/8/68	4/5/79	4/2/79	6/77	8/22/76	8/11/76	7/77	4/5/79
Perforated Interval (ft)	50-140	-	410 TD	389-407	500 TD	-	55-421	176 TD
Lab	SRP	ADHS	ADHS	ATL	ADHS	ADHS	U of A	ADHS

Data from MAG 208 program and files of Arizona Department of Health Services, Maricopa County Health Department, and Bureau of Indian Affairs.

recommended only. Iron contents slightly exceeded the limit of 0.3 mg/l in water from several wells. This may be an indication of reducing conditions in the aquifer.

Information on the variation in chemical quality with well depth is available for two test holes drilled in 1975 and 1979 in the southeast part of the study area. Below a depth of about 320 feet, clay was the predominant material penetrated by these wells. At well (D-1-1)2abb water in the Recent alluvium at a depth of 80 feet had a total dissolved solids (TDS) content of about 3,400 mg/l. Between a depth of 320 and 360 feet, the TDS of the groundwater was 2,600 mg/l. Below a depth of 420 feet, the TDS ranged from 1,400 to 1,500 mg/l. A similar pattern was found at well (A-1-1) 35cbc.

The chemical quality of water in the Recent alluvium is marginal to unusable for domestic use and irrigation, due to high salinity, chloride, and hardness contents. Water below a depth of about 300 feet is of lower salinity, but is still usually of marginal quality for irrigation or domestic use. Much of the drinking water in the study area is reportedly supplied by bottled water. No analyses have been reported on the organic or radiologic composition of groundwater in the study area.

IMPACTS OF ALTERNATIVES

For purposes of this discussion, the study area is divided into two parts, divided by a north-south line along 115th Avenue. The release of from 22,600 to 39,400 acre-feet per year is termed "Alternative A" and the release of 7,300 acre-feet per year of effluent is termed "Alternative B".

Groundwater Quantity

Potential impacts on groundwater quantity in the study area include changes in recharge and water levels.

Western Part

There is little pumpage of large-capacity wells south of Broadway Road and east of the Agua Fria River in the west part of the study area. This is believed to be primarily due to the poor chemical quality of the groundwater in this area. The subsurface geologic structure between Monument Hill and the Sierra Estrella Park is such that shallow groundwater levels are favored. Hardrock either crops out at the land surface in this area or is present at relatively shallow depth, forming a boundary to the groundwater system south of the Gila River. In addition to sewage effluent, irrigation tailwater, and flood flows from the Salt River, this part of the study area receives additional streamflow from the Gila River and from the Agua Fria River. Groundwater level elevations in recent decades have been near the Gila River channel

following flood events, and up to ten feet below the channel at other times. Dense growths of phreatophytes are believed to have been present west of Monument Hill for many years, due to the shallow groundwater levels.

Impacts on groundwater levels and recharge should be minimal in this part of the study area under either of the alternatives. Water levels beneath the Gila River channel have not declined substantially in this area even in the absence of flood flows. Pumpage has also had a limited effect in this area due to its relatively small magnitude. Recharge to groundwater in this area will still be possible from flows in the Gila River due to:

1) Sewage effluent from the 23rd Avenue plant.
2) Irrigation tailwater.
3) Flood flows from the Salt, Gila, and Agua Fria Rivers.
4) Deep percolation of irrigation return flow.

Unless some new large-scale pumpage was to be developed in this area, little change in water level is expected to occur under either alternative.

Eastern Part

Groundwater level elevations in recent decades have been near the Salt and Gila River channels following flood events, and up to 25 feet below the channels at other times. Dense growths of phreatophytes have not generally been present in most of this area in the past two decades. Most of this area is upstream from the direct influence of the Gila and Agua

Fria Rivers. Recharge of effluent in this area is limited because of a more predominant buildup of the organic mat closer to the point of effluent discharge. The subsurface geologic structure east of Monument Hill does not form a groundwater barrier south of the Salt River. Lastly, there is substantial pumpage for irrigation in this part of the study area. All of these factors combine to produce a somewhat greater depth to water than occurs in the western part of the study area.

Under Alternative A, an estimated 4,000 to 8,000 acre-feet per year of recharge from 91st Avenue plant effluent would be expected to occur, the majority of which would be in the eastern part of the study area. Recharge from other sources of water would continue to occur. Water levels would probably slightly decline on the long-term under this alternative. Under Alternative B, an estimated 1,500 acre-feet per year of recharge from 91st Avenue plant effluent would be expected to occur, the most of which would be in the eastern part of the study area. During dry periods, water levels could decline at a rate of several feet per year in excess of that normally encountered during such periods. However, a mitigating factor would be that recharge from flood flows would be enhanced due to lower water levels, which provide more storage space. Presently, some recharge is rejected during flood flows because of the shallow water levels. The overall effect would be a greater decline in

water level than now occurs in the absence of flood flows, but more recharge during flood flows. A long-term decline in water level would result. The precise magnitude of this decline is unknown, but a rate less than one foot per year is likely.

There is some question as to the amount of percolation losses that will occur under the alternative where only 7,300 acre-feet of effluent are discharged. The effluent would have to travel more than two miles to the point of use. Percolation losses under this alternative have previously been estimated to average about 1,500 acre-feet per year. It should be noted that this value is applicable when the organic mat is developed and infiltration of effluent is thereby limited, which is the normal situation. However, when the discharge is first commenced, or the channel has been recently scoured by flood flows, percolation losses may reach 50 percent or more of the discharge. This situation occurred following the 1965-66 flood flows. Apparently the organic mat can be developed fairly extensively within about nine months following channel scouring.

Presently, studies are underway involving potential flood control facilities for the Salt River Valley and tributary watersheds. Development of additional flood control facilities would likely enhance recharge of flood flow in the project area. This is because less flood water would have to be released over short periods. Longer periods of

release would allow more recharge. Also, pumpage might be decreased. The net effect would likely be beneficial to water levels in the project area.

Groundwater Quality

Impacts on groundwater quality in the study area may occur due to changes in recharge.

Western Part

No change in groundwater quality will likely result west of El Mirage Road from either alternative. However, east of El Mirage Road, groundwater salinity could theoretically increase due to a reduction in recharge of effluent in the upgradient (southeast) direction. A mitigating factor is that flood flows of even lower salinity than sewage effluent would be recharged in greater amounts. The overall effect would likely result in little change in groundwater quality.

Eastern Part

No significant change in groundwater quality would result from Alternative A, because of the small decrease in recharge. Under Alternative B, salinity of the groundwater could increase due to the reduction in effluent recharge. However, a mitigating factor would be the enhanced recharge of relatively low salinity flood flows. The overall change would likely be a slight increase in salinity. Since some

organic chemicals and trace elements may be present in sewage effluent, a reduction in recharge of effluent could be beneficial to groundwater quality in the area.

MITIGATING MEASURES

Historically, there has been a lack of both water-level measurements and groundwater quality monitoring in the south part of the study area. In the future it would be advisable to implement a monitoring program for groundwater in the study area between Southern Avenue and Baseline Road. Water levels should be measured in wells less than 250 feet deep on a quarterly basis. Approximately one dozen existing wells as close to the river as possible should be selected for water-level measurements. In addition, about six monitor wells should be installed to fill in gaps in the network. They should be about fifty feet deep and perforated from about ten feet below the static water level in the fall (in the absence of flood releases) to the bottom. Four-inch diameter PVC casing should be installed to allow water sample collection by submersible pumps. Water samples should be collected from this network on a quarterly basis and analyzed for the major inorganic chemical constituents, boron, fluoride, iron, manganese, chromium, arsenic, cadmium, and dissolved organic carbon. Temperature, electrical conductivity, and pH should be measured in the field. An extensive

study of organic chemicals in groundwater of the south part of the study area could also be undertaken.

REFERENCES

Bouwer, H., Lance, J.C., and E.D. Escarcega, 1974, "High-Rate Land Treatment, I: Infiltration and Hydraulic Aspects of the Flushing Meadows Project", Water Pollution Control Federation, vol 46, no 5, pp 834-843.

Halpenny, L.C., and S.D. Clark, 1977, "1977 Supplement to Water Balance Investigation of River Bed, Salt and Gila Rivers, 23rd Avenue to Gillespie Dam, Arizona", report prepared for NUS Corporation, Water Development Corporation, Tucson.

Halpenny, L.C., and D.K. Greene, 1975, "Water Balance Investigation of River Bed, Salt and Gila Rivers, 23rd Avenue to Gillespie Dam, Arizona", report prepared for NUS Corporation, Water Development Corporation, Tucson.

Schmidt, K.D., 1978, "Groundwater Quality in the Major Basins of Maricopa County", Final Report, Chapter II-Salt River Valley, West Basin, prepared for U.S. Army Corps of Engineers Phoenix Urban Study and Maricopa Association of Governments 208 Program, pp II-16 - II-32.

Sebenik, P.G., Cluff, C.B., and K.J. DeCook, 1972, "Nitrogen Species Transformations of Sewage Effluent Releases in a Desert Stream Channel", in Hydrology and Water Resources in Arizona and the Southwest, vol II, Arizona Section AWRA.

U.S. Bureau of Reclamation, 1977, "Geology and Groundwater Resources Report, Maricopa and Pinal Counties, Arizona", Central Arizona Project, Buckeye-Phoenix Subarea.

APPENDIX C

EFFLUENT FLOW PROJECTIONS

Greeley and Hansen, January 1980

TABLE C-1

PLANT EFFLUENT FLOW PROJECTIONS

Month	23rd Avenue Plant Effluent Flows, mgd			91st Avenue Plant Effluent Flows, mgd			Combined Effluent Flows, mgd		
	Monthly Average	Weekly Minimum	Daily Minimum	Monthly Average	Weekly Minimum	Daily Minimum	Monthly Average	Weekly Minimum	Daily Minimum
1980									
January	38.3	36.4	18.9	83.4	78.4	36.1	121.7	114.8	55.0
February	37.9	35.6	16.4	86.2	81.0	38.1	124.1	116.6	54.5
March	37.2	36.1	17.7	88.0	81.8	40.9	125.2	117.9	58.6
April	37.2	35.0	17.5	88.0	80.1	38.4	125.2	115.1	55.9
May	36.5	34.2	18.9	88.9	79.1	41.1	125.4	113.4	60.0
June	36.8	34.6	18.7	88.9	78.2	40.7	125.7	112.8	59.4
July	37.2	35.0	21.7	91.6	83.4	49.2	128.8	118.4	70.9
August	36.1	34.3	20.6	93.4	84.1	44.6	129.5	118.4	65.2
September	35.7	33.9	20.7	99.8	92.8	46.4	135.5	126.7	67.1
October	35.0	33.6	21.2	97.0	87.3	44.5	132.0	120.9	65.7
November	33.9	32.2	17.7	92.5	87.0	40.9	126.4	119.2	58.6
December	35.7	33.9	18.0	90.7	85.3	42.7	126.4	119.2	60.7

(Continued)

TABLE C-1 (Continued)

Month	23rd Avenue Plant Effluent Flows, mgd			91st Avenue Plant Effluent Flows, mgd			Combined Effluent Flows, mgd		
	Monthly Average	Weekly Minimum	Daily Minimum	Monthly Average	Weekly Minimum	Daily Minimum	Monthly Average	Weekly Minimum	Daily Minimum
1981									
January	38.3	36.4	18.9	85.6	80.5	37.0	123.9	116.9	55.9
February	37.9	35.6	16.4	88.4	83.1	39.1	126.3	118.7	55.5
March	37.2	36.1	17.7	90.2	83.9	42.0	127.4	120.0	59.7
April	37.2	35.0	17.5	90.2	82.1	39.4	127.4	117.1	56.9
May	36.5	34.2	18.9	91.1	81.1	42.2	127.6	115.3	61.1
June	36.8	34.6	18.7	91.1	80.2	41.7	127.9	114.8	60.4
July	37.2	35.0	21.7	93.9	85.4	50.4	131.1	120.4	72.1
August	36.1	34.3	20.6	95.8	86.2	45.7	131.9	120.5	66.3
September	35.7	33.9	20.7	102.3	95.1	47.6	138.0	129.0	68.3
October	35.0	33.6	21.2	99.5	89.6	45.7	134.5	123.2	66.9
November	33.9	32.2	17.7	94.9	89.2	41.9	128.8	121.4	59.6
December	35.7	33.9	18.0	93.0	87.4	43.7	128.7	121.3	61.7
1982									
January	38.3	36.4	18.9	87.9	82.6	38.0	126.2	119.0	56.9
February	37.9	35.6	16.4	90.7	85.3	40.1	128.6	120.9	56.5
March	37.2	36.1	17.7	92.6	86.1	43.1	129.8	122.2	60.8
April	37.2	35.0	17.5	92.6	84.3	40.5	129.8	119.3	58.0
May	36.5	34.2	18.9	93.6	83.3	43.3	130.1	117.5	62.2
June	36.8	34.6	18.7	93.6	82.4	42.8	130.4	117.0	61.5
July	37.2	35.0	21.7	96.5	87.8	51.8	133.7	122.8	73.5
August	36.1	34.3	20.6	98.4	88.6	47.0	134.5	122.9	67.6
September	35.7	33.9	20.7	105.1	97.7	48.9	140.8	131.6	69.6
October	35.0	33.6	21.2	102.2	92.0	46.9	137.2	125.6	68.1
November	33.9	32.2	17.7	97.4	91.6	43.1	131.3	123.8	60.8
December	35.7	33.9	18.0	95.5	89.8	44.9	131.2	123.7	62.9

(Continued)

TABLE C-1 (Continued)

Month	23rd Avenue Plant Effleunt Flows, mgd			91st Avenue Plant Effluent Flows, mgd			Combined Effluent Flows, mgd		
	Monthly Average	Weekly Minimum	Daily Minimum	Monthly Average	Weekly Minimum	Daily Minimum	Monthly Average	Weekly Minimum	Daily Minimum
1983									
January	38.3	36.4	18.9	90.2	84.8	39.0	128.5	121.2	57.9
February	37.9	35.6	16.4	93.1	87.5	41.1	131.0	123.1	57.5
March	37.2	36.1	17.7	95.1	88.4	44.2	132.3	124.5	61.9
April	37.2	35.0	17.5	95.1	86.5	41.5	132.3	121.5	59.0
May	36.5	34.2	18.9	96.0	85.4	44.4	132.5	119.7	63.3
June	36.8	34.6	18.7	96.0	84.5	43.9	132.8	119.1	62.6
July	37.2	35.0	21.7	99.0	90.1	53.2	136.2	125.1	74.9
August	36.1	34.3	20.6	100.9	90.8	48.1	137.0	125.1	68.7
September	35.7	33.9	20.7	107.8	100.3	50.2	143.5	134.2	70.8
October	35.0	33.6	21.2	104.9	94.4	48.1	139.9	128.0	69.3
Novmeber	33.9	32.2	17.7	100.0	94.0	44.2	133.9	126.2	61.9
December	35.7	33.9	18.0	98.0	92.1	46.1	133.7	126.0	64.1
1984									
January	38.3	36.4	18.9	92.5	87.0	40.0	130.8	123.4	58.9
February	37.9	35.6	16.4	95.5	89.8	42.2	133.4	125.4	58.6
March	37.2	36.1	17.7	97.5	90.7	45.4	134.7	126.8	63.1
April	37.2	35.0	17.5	97.5	88.7	42.6	134.7	123.7	60.1
May	36.5	34.2	18.9	98.5	87.7	45.6	135.0	122.0	64.5
June	36.8	34.6	18.7	98.5	86.7	45.1	135.3	121.3	63.8
July	37.2	35.0	21.7	101.5	92.4	54.5	138.7	127.4	76.2
August	36.1	34.3	20.6	103.5	93.2	49.4	139.6	127.5	70.0
September	35.7	33.9	20.7	110.6	102.9	51.5	146.3	136.8	72.2
October	35.0	33.6	21.2	107.5	96.8	49.4	142.5	130.4	70.6
November	33.9	32.2	17.7	102.5	96.4	45.3	136.4	128.6	63.0
December	35.7	33.9	18.0	100.5	94.5	47.3	136.2	128.4	65.3

(Continued)

TABLE C-1 (Continued)

Month	23rd Avenue Plant Effluent Flows, mgd			91st Avenue Plant Effluent Flows, mgd			Combined Effluent Flows, mgd		
	Monthly Average	Weekly Minimum	Daily Minimum	Monthly Average	Weekly Minimum	Daily Minimum	Monthly Average	Weekly Minimum	Daily Minimum
1985									
January	38.3	36.4	18.9	94.7	89.0	40.9	133.0	125.4	59.8
February	37.9	35.6	16.4	97.8	91.9	43.2	135.7	127.5	59.6
March	37.2	36.1	17.7	99.8	92.8	46.4	137.0	128.9	64.1
April	37.2	35.0	17.5	99.8	90.8	43.6	137.0	125.8	61.1
May	36.4	34.2	18.9	100.8	89.7	46.6	137.2	124.0	65.5
June	36.8	34.6	18.7	100.8	88.7	46.1	137.6	123.3	64.8
July	37.2	35.0	21.7	103.9	94.5	55.8	141.1	129.5	77.5
August	36.1	34.3	20.6	106.0	95.4	50.6	142.1	129.7	71.2
September	35.7	33.9	20.7	113.2	105.3	52.7	148.9	139.2	73.4
October	35.0	33.6	21.2	110.1	99.1	50.5	145.1	132.7	71.7
November	33.9	32.2	17.7	105.0	98.7	46.4	138.9	130.9	64.1
December	35.7	33.9	18.0	102.9	96.7	48.4	138.6	130.6	66.4
1986									
January	38.3	36.4	18.9	96.6	90.8	41.8	134.9	127.2	60.7
February	37.9	35.6	16.4	99.8	93.8	44.1	137.7	129.4	60.5
March	37.2	36.1	17.7	101.9	94.8	47.4	139.1	130.9	65.1
April	37.2	35.0	17.5	101.9	92.7	44.5	139.1	127.7	62.0
May	36.4	34.2	18.9	102.9	91.6	47.6	139.3	125.8	66.5
June	36.8	34.6	18.7	102.9	90.6	47.1	139.7	125.2	65.8
July	37.2	35.0	21.7	106.1	96.6	57.0	143.3	131.6	78.7
August	36.1	34.3	20.6	108.2	97.4	51.6	144.3	131.7	72.2
September	35.7	33.9	20.7	115.5	107.4	53.7	151.2	141.3	74.4
October	35.0	33.6	21.2	112.4	101.2	51.6	147.4	134.8	72.8
November	33.9	32.2	17.7	107.1	100.7	47.3	141.0	132.9	65.0
December	35.7	33.9	18.0	105.0	98.7	49.4	140.7	132.6	67.4

TABLE C-2

EFFLUENT REUSE FLOW PROJECTIONS

Month	Monthly Average Reuse Flow Projections, mgd			
	Arizona Game and Fish Department	Buckeye Irrigation District	Arizona Public Service	Total
1980				
January	6.5	26.8	-	33.3
February	6.5	26.8	-	33.3
March	6.5	26.8	-	33.3
April	6.5	26.8	-	33.3
May	6.5	26.8	-	33.3
June	6.5	26.8	-	33.3
July	6.5	26.8	-	33.3
August	6.5	26.8	-	33.3
September	6.5	26.8	-	33.3
October	6.5	26.8	-	33.3
November	6.5	26.8	-	33.3
December	6.5	26.8	-	33.3
1981				
January	6.5	26.8	-	33.3
February	6.5	26.8	-	33.3
March	6.5	26.8	-	33.3
April	6.5	26.8	-	33.3
May	6.5	26.8	-	33.3
June	6.5	26.8	-	33.3
July	6.5	26.8	-	33.3
August	6.5	26.8	-	33.3
September	6.5	26.8	-	33.3
October	6.5	26.8	-	33.3
November	6.5	26.8	-	33.3
December	6.5	26.8	-	33.3

(Continued)

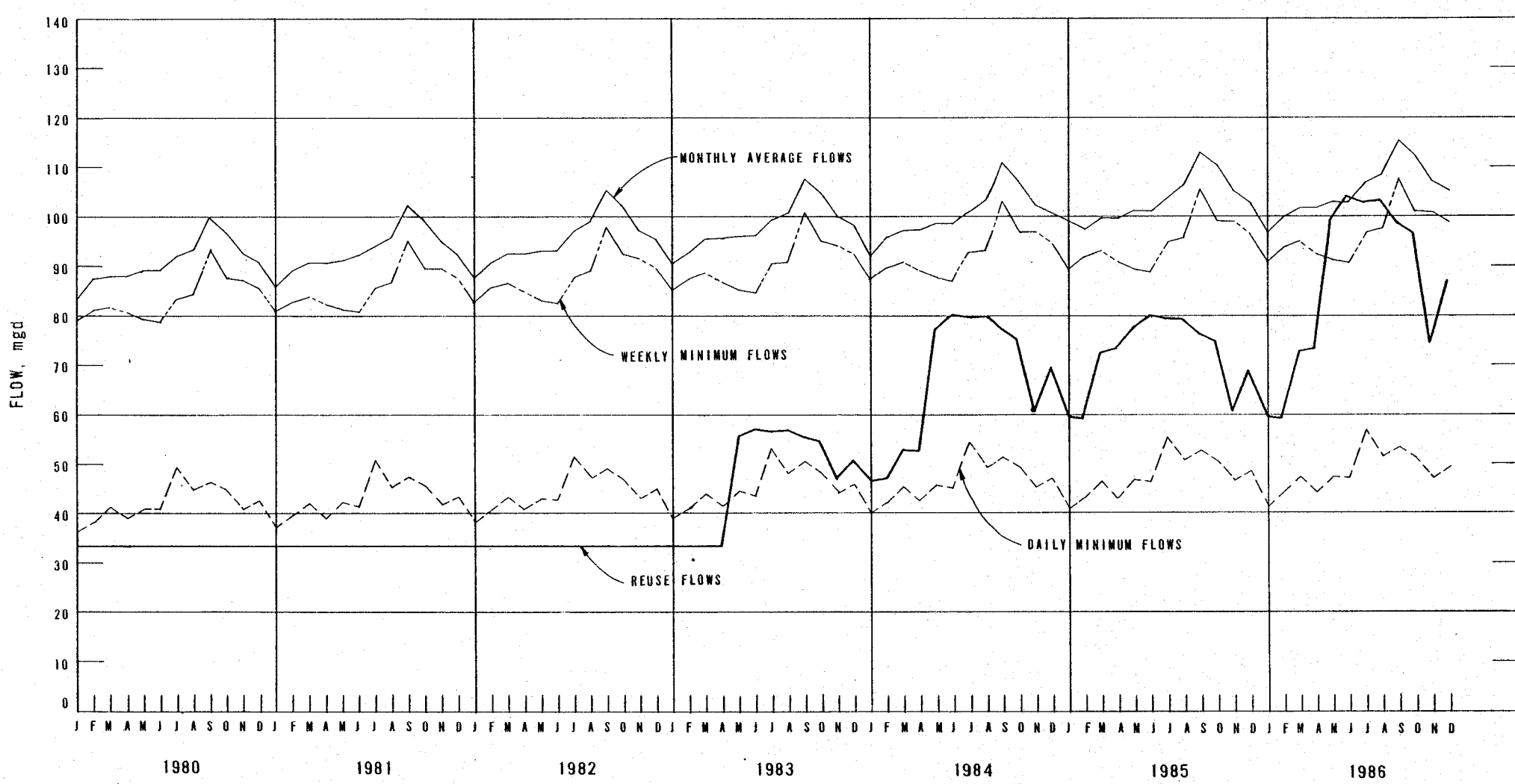
TABLE C-2 (Continued)

Month	Monthly Average Reuse Flow Projections, mgd			
	Arizona Game and Fish Department	Buckeye Irrigation District	Arizona Public Service	Total
1982				
January	6.5	26.8	-	33.3
February	6.5	26.8	-	33.3
March	6.5	26.8	-	33.3
April	6.5	26.8	-	33.3
May	6.5	26.8	-	33.3
June	6.5	26.8	-	33.3
July	6.5	26.8	-	33.3
August	6.5	26.8	-	33.3
September	6.5	26.8	-	33.3
October	6.5	26.8	-	33.3
November	6.5	26.8	-	33.3
December	6.5	26.8	-	33.3
1983				
January	6.5	26.8	-	33.3
February	6.5	26.8	-	33.3
March	6.5	26.8	-	33.3
April	6.5	26.8	-	33.3
May	6.5	26.8	22.1	55.4
June	6.5	26.8	23.4	56.7
July	6.5	26.8	23.1	56.4
August	6.5	26.8	23.1	56.4
September	6.5	26.8	21.7	55.0
October	6.5	26.8	21.0	54.3
November	6.5	26.8	13.6	46.9
December	6.5	26.8	17.9	51.2
1984				
January	6.5	26.8	13.1	46.4
February	6.5	26.8	13.4	46.7
March	6.5	26.8	19.5	52.8
April	6.5	26.8	20.1	53.4
May	6.5	26.8	44.2	77.5
June	6.5	26.8	46.8	80.1
July	6.5	26.8	46.2	79.5
August	6.5	26.8	46.2	79.5
September	6.5	26.8	43.4	76.7
October	6.5	26.8	42.0	75.3
November	6.5	26.8	27.2	60.5
December	6.5	26.8	35.8	69.1

(Continued)

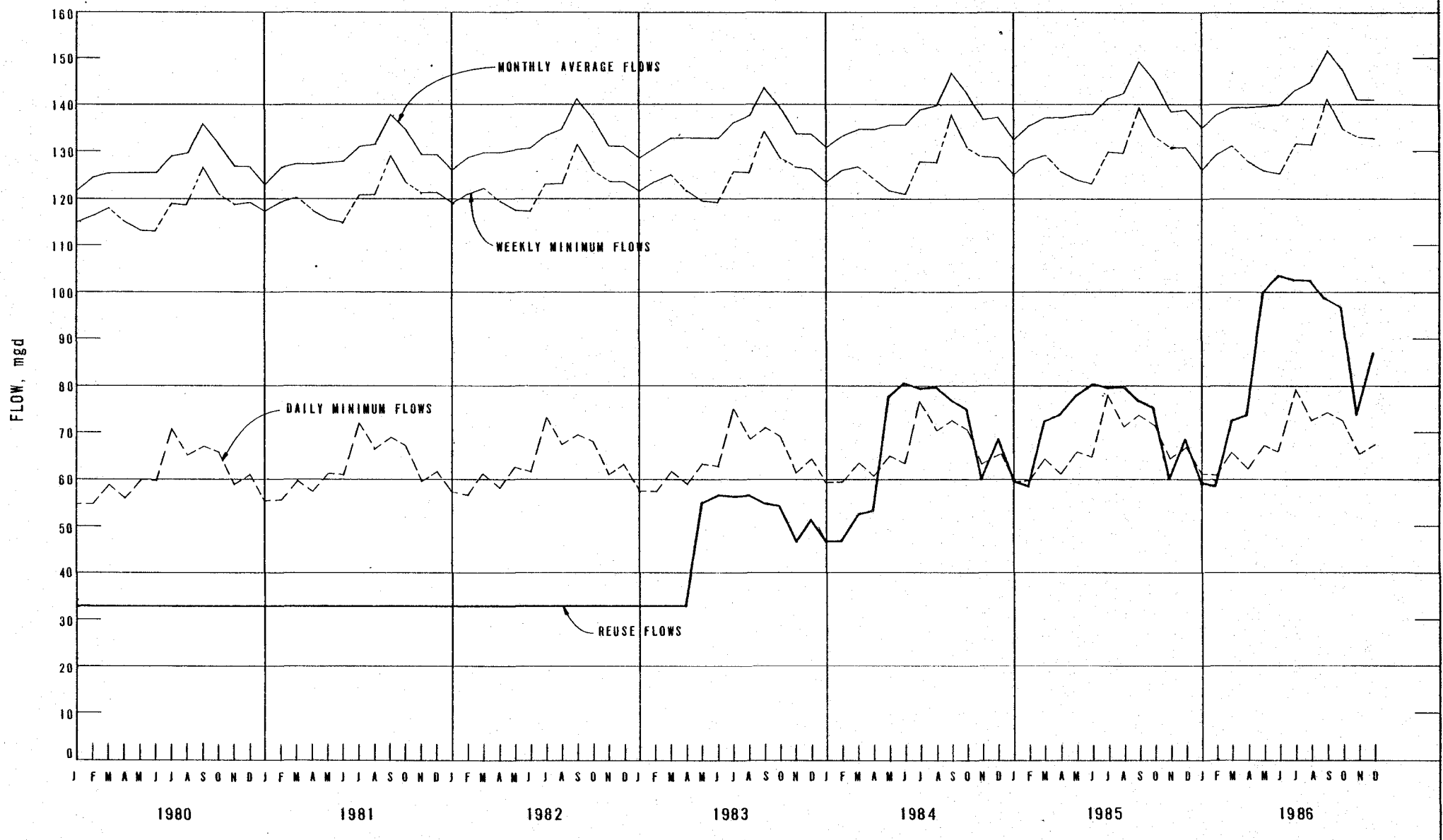
TABLE C-2 (Continued)

Month	Monthly Average Reuse Flow Projections, mgd			
	Arizona Game and Fish Department	Buckeye Irrigation District	Arizona Public Service	Total
1985				
January	6.5	26.8	26.2	59.5
February	6.5	26.8	25.6	58.9
March	6.5	26.8	39.0	72.3
April	6.5	26.8	40.2	73.5
May	6.5	26.8	44.2	77.5
June	6.5	26.8	46.8	80.1
July	6.5	26.8	46.2	79.5
August	6.5	26.8	46.2	79.5
September	6.5	26.8	43.4	76.7
October	6.5	26.8	42.0	75.3
November	6.5	26.8	27.2	60.5
December	6.5	26.8	35.8	69.1
1986				
January	6.5	26.8	26.2	59.5
February	6.5	26.8	25.6	58.9
March	6.5	26.8	39.0	72.3
April	6.5	26.8	40.2	73.5
May	6.5	26.8	66.3	99.6
June	6.5	26.8	70.2	103.5
July	6.5	26.8	69.3	102.6
August	6.5	26.8	69.3	102.6
September	6.5	26.8	65.1	98.4
October	6.5	26.8	63.0	96.3
November	6.5	26.8	40.8	74.1
December	6.5	26.8	53.7	87.0



GREELEY AND HANSEN
JOHN CAROLLO ENGINEERS

FLOW DATA FOR 91ST AVENUE PLANT
PLATE C1



COMBINED FLOW DATA FOR
23RD AVE. AND 91ST AVE. PLANTS

GREELEY AND HANSEN
JOHN CAROLLO ENGINEERS

PLATE C2