COMPOSITION OF SURFACE WATERS OF THE WATERSHEDS OF THE SALT AND GILA RIVERS INFLUENCING THE WEST SALT RIVER VALLEY

BY

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A Report Prepared for the Sun City

Home Owners Association

and

Property Owners and Residents

Association of Sun City West

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COMPOSITION OF SURFACE WATERS OF THE WATERSHEDS OF THE SALT AND GILA RIVERS INFLUENCING THE WEST SALT RIVER VALLEY, MARICOPA COUNTY, ARIZONA

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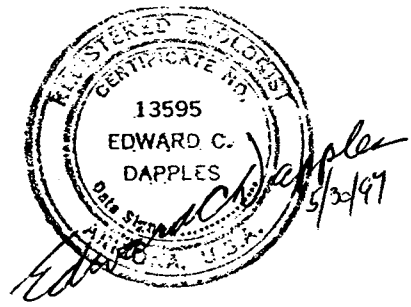
Volume II, No. I



May 1997

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INTRODUCTION

Essentials Of Geologic Conditions

Some fifteen years ago, the directors of the Homeowner's Association of Sun City (HOA) jointly with the Property Owner's And Residents Association of Sun City (PORA), decided that part of their functional activities involved a more aggressive participation in the nature of all water used in the Sun Cities. In so doing each organization was able by means of legal and other forms of active representation to resist certain ill-conceived regulations, and hence to benefit everyone living in these communities. In this connection, because all water used has always been pumped groundwater, as currently provided by Citizen's Utilities, the total amount in the aquifer system is very much dependent upon the regional geologic framework. Although much published information exists for professionals, very little has been prepared for the layman regarding the occurrence of this water, its salinity, and the amount available for the future. Hence, the two organizations authorized continued studies of the geology of surface and groundwaters which enter the basin.

Earlier investigations by the writer have resulted in publication of four separate reports available to all citizens at the offices of the two organizations. Among items described in the last reports are the existence of numerous and very significant geologic faults which delimit, traverse and interrupt the gradual slope beneath the alluvium which currently constitutes the uppermost part of the sedimentary basin. In total these faults establish limits of uplifted and downdropped blocks within the basin, but as seen today the most spectacular are eroded margins of the former mountain block which rise above the sediments of the basin. Also, faulting controls the distribution of alluvium which contains the potable water, by limiting the thickness of the aquifer system below which no water is available. It is this groundwater, withdrawn by existing wells upon which communities and farms depend, which merits additional detailed geologic investigations. For this reason, it has been the purpose of each of the published reports to call attention to certain aspects of the geology of the Sub-Basin, and consequential features which exist to affect the nature and amounts of groundwater supplies.

One of the uncertainties which develops from the geologic conditions concerns the quality of water which currently is being infiltrated into the aquifer from supplies which arrive via the Salt and Gila rivers. It is the composition of this water, some of which becomes part of the aquifer system, that has prompted the study herein reported. Also, the reader should be aware that the chemical character of all water infiltrated into the aquifer system varies considerably depending upon its source. For this reason the locality where such natural infiltration occurs is very important.

Throughout the long history of alluvial filling of the intermontane basins there were localities, more or less of lowest topographic positions, which were restricted in outlet by synchronous outpouring of lava flows, or displacement, i.e., geologic faulting. In these were accumulated shallow lakes of no outlet. In time these became very saline through evaporation, and the accumulated deposits of limey-clay alluvium contain precipitated gypsum and halite (sodium chloride) in discontinuous lens-like layers.

Groundwater Movements And Salinity

Throughout the past hundred thousand or so years, groundwater had its source primarily from rain and snowfall in the mountains surrounding the basin. As runoff from these watersheds still flows by means of seasonally dry stream channels, it infiltrates alluvial sediments of the "valley". Once in the ground, this water fills pore-spaces between pebbles, grains of sand, and the microscopic openings between flakes of clay. Such filling of pore spaces in the alluvium is a gradual process, and this water tends to move slowly down gradient. Under natural conditions, the water level eventually attains a steady-state of elevation, and this surface is identified as the "groundwater table". In the past, but more so today, elevations of the water table have varied throughout time, falling following episodes of drought and rising after wet years. In the Salt River Basin the pattern of natural, long-established groundwater flow was southward and westward toward the present Gila River channel. Any excess of groundwater escaped by means of local springs to feed the Salt and Gila river systems. Ever since irrigation was developed in the Sub-Basin, water levels in wells have changed the natural flow to its present state, and such levels in wells are measured currently as "static-water elevations" (see Maps U_1, U_2 and U_3).

As groundwater moves slowly down gradient through the alluvium, it differentially dissolves minerals and increases the salinity from its original state as rainfall or melted snow. Also, particularly as it moves through layers of clay there exists a common exchange of certain atoms, e.g., sodium by calcium. The sodium remains attached to clay particles in place of calcium ions which are released to the groundwater. Through similar processes such water becomes richer in certain common ions and poorer in others. Much more is dissolved where "gypsiferous" salts had been deposited previously in the alluvium (bottom sediment) of the ancient saline lakes.

It is the writer's interpretation that the very large Grand Avenue Fault, which traverses the Sub-Basin generally paralleling Grand Avenue constituted the northern boundary of an ancient saline lake which occupied much of the central area of the West Salt River Basin (see Vol.1, No. 3). Hence, as rainfall-source water infiltrated the alluvium north of the Grand Avenue Fault, it dissolved much less mineral matter than groundwater moving through that portion south of the fault containing deposits of the former salt lake.

Items Of Concern

There are, however, three other major geologic features which are known to concern investigators. One, is the existence of an enormous mass of salt (Luke Salt Body) centered several miles east of Luke Air Force Base, the upper part of which intrudes the aquifer system. So far the effects of solution of the salt by moving groundwater have been limited to local areas a few miles north and east of Litchfield Park. Nevertheless, the possibility of saline water skirting the Luke Low moving northward (down a recently established gradient) toward the Sun Cities is to be given serious attention. (See Vol.1, No. 2 and 4)

The second, and related item, is the subject of the present investigation and concerns the possible sources of high-salinity groundwater moving northward from the general locality of the

junction of the Salt and Gila rivers. It is this water which advances toward Sun City to bring increasingly saline groundwater to that part south of Grand Avenue where there has been lowering of static-water levels in wells.

As continued pumping has lowered groundwater levels differentially, it has established a special geologic condition. In some localities, pore spaces in the alluvium now are air filled, and collapse of the air-filled cavities results in compaction of the alluvium. In the general vicinity of Luke Air Force Base, i.e., in the area of the Luke Low, subsidence of the land surface has resulted in considerable damage to surface installations. The area of subsidence has advanced outward from a central zone within Luke Base, but as yet has not been recognized eastward of the Agua Fria River valley. Land subsidence is of concern to all citizens as presumably the area of some differential settling will cross the Agua Fria valley into Sun City.

The reader's attention is directed to Map KK. Values of the amount of land subsidence are recorded in feet at each mile of distance in the area covering T2 and 3N - R1W, and contour values of 5-foot intervals were drawn by Schumann (U.S. Geological Survey) indicating the amount of observed total subsidence (1991).* As shown by the contour lines, subsidence decreases outward from a central area near Olive Avenue and Reams Road in a generally circular pattern. On Schumann's map, the present writer has superimposed approximate boundaries of the Sun Cities, the position of major faults (Grand Avenue Fault, F-6, F-11, F-12 and F-16), and the zone where the Luke Salt invades the aquifer. Of the faults trending north-south, F-6 a major mountain-block fault is shown by the trend of contour lines and amount of subsidence to have a pronounced influence upon the direction which subsidence tends to follow. The influence of other faults is less conspicuous because contour lines tend to parallel fault trends, but F-12 which bounds the intrusion of Luke Salt into the aquifer along its eastern boundary extends into the southwestern corner of Sun City. It is this fault which very likely extends to intercept the Grand Avenue Fault that probably will control local subsidence. Particular attention should be given to the precise position of the fault patterns, and the amounts and indications of subsidence throughout the areas where housing developments are established or are undergoing construction.

Sources Of Data

Data regarding sources and analyses of water entering the Sub-Basin from various watersheds have been furnished the writer through the kindness of certain governmental agencies and private enterprises. In particular the writer acknowledges the following individuals who assembled data from volumes of information in agency or company files. Gregory Elliott (Central Arizona Project); Greg Ullinskey (Arizona Dept of Water Resources); Barbara Wirt (U.S. Geological Survey); Paul V. Hursh (Citizen's Utilities) and Dr. Larry Fellows and Thomas McGarvin (Arizona Geological Survey).

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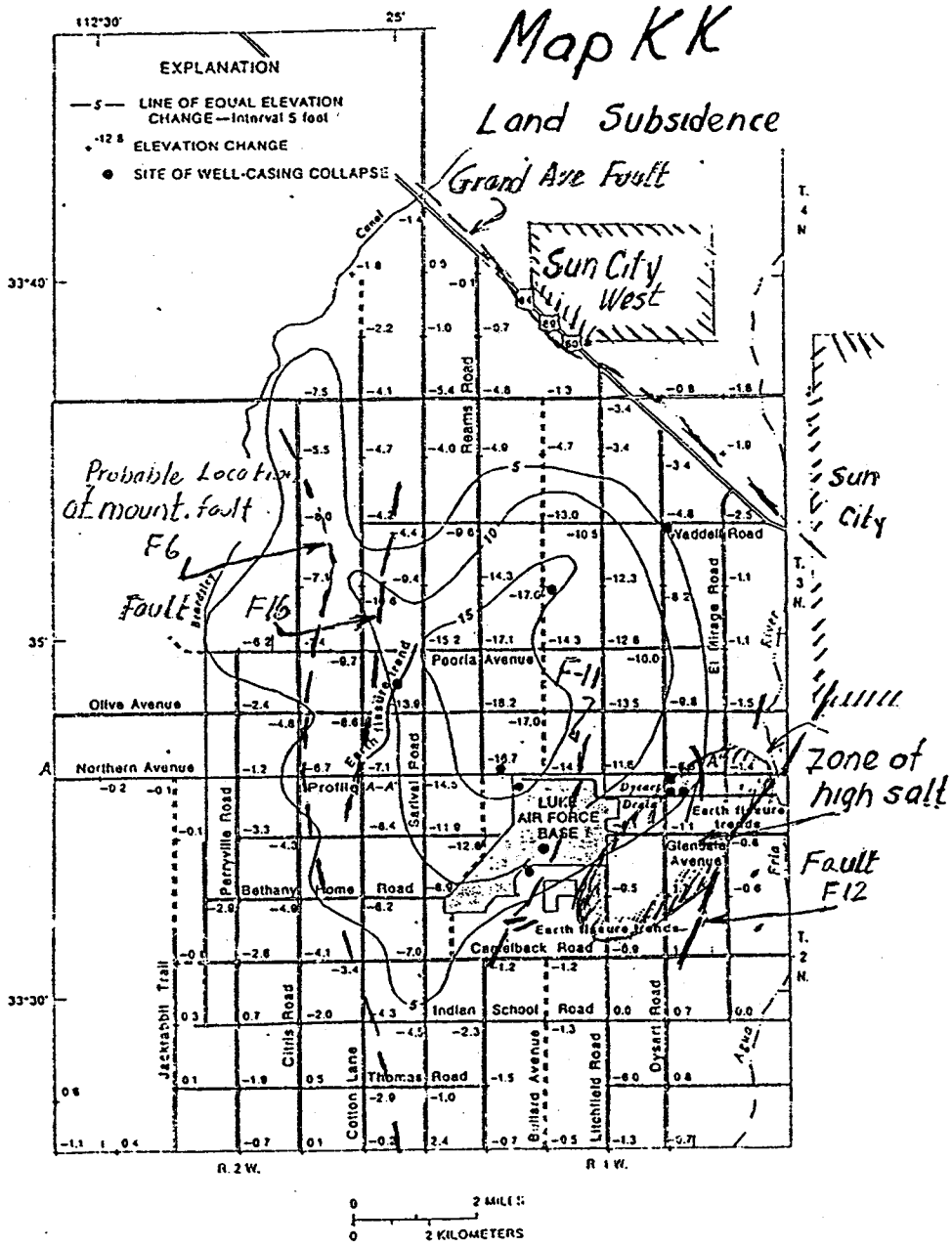
* Schumann, H.A., 1995, U.S. Geological Survey Subsidence Interest Group Conference, Edwards Air Force Base, Antelope Valley, California, November 18-19, 1992, U.S. Geological Survey Open File Report 94-532



Land subsidence in part of the western Salt River Valley, 1957–1991.

Fault positions and salt outline by Dapples

GROUNDWATER FRONT

Relationship To Grand Avenue Fault

Since the early 1930s more and more wells have been drilled in the "valley", and in some part groundwater levels have fallen differentially a total of 200 to 300 feet. Although during the past 15 years some local groundwater levels have tended to stabilize, in general in the northern half of the Sub-Basin more water has been withdrawn from the alluvium than has been received through normal infiltration, or down-gradient flow. Significant natural recharge occurs along the Salt and Gila river channels, and it is this groundwater which can be demonstrated to move northward down gradient to the Glendale Rise (see Vol. 1, No. 2 and 4). As such waters become part of the aquifer system, they increase its salinity as they have moved through "salt-bearing" alluvium deposited south of the Grand Avenue Fault.

The writer has described this fault as constituting a physical boundary between waters of two different compositions (see Vol. 1, No. 4). Invasions of groundwater from the Salt and Gila rivers flow toward groundwater of much lower salinity existing principally north of Grand Avenue. The fault is recognized as an approximate boundary "front" between two bodies of groundwater of considerably different ion composition. Alluvium in the extensive area of the Sub-Basin, generally north of the fault, contains groundwater of low mineral content such that it requires very little treatment. Pumping this water continues to be the most economical method of local water supply both for agricultural and urban needs.

Suburban living with its attendant demands for water has spread northwest of Phoenix to become an integral part of the metropolis. Much of this "housing construction" is occurring in what was formerly largely open desert, and it is here that natural infiltration of rainwater has been reduced by pavement and roofing. Urban development is particularly noticeable north of Grand Avenue where the groundwater of low salinity prevails. This is the area where wells have supplied the needed water, and where significant declines are observed in static-water elevations (Map W). It is also the area in which faulting has raised the rock basement such that the total thickness of alluvium which potentially may contain water is estimated not to exceed 1,500 feet, of which in some areas more than 300 feet has been withdrawn. Moreover, the thickness of alluvium may increase or decrease as individual mountain fault block masses are tilted differentially.

COMPOSITION OF WATER

Constituents Present In Surface And Groundwater

Under natural conditions, surface waters contain particles of rocks and mineral fragments which together with clays provide turbidity to the water. These are particles which move along the stream bottom or settle from suspension. Over thousands of years shifting channels build deposits of stream alluvium and lake beds, which in the West Salt River Basin south of the Grand Avenue Fault may reach total thicknesses of several thousands of feet.

All surface waters contain variable amounts of dissolved inorganic chemical constituents derived through decomposition of minerals during soil-forming processes (see Vol. 1, No. 1). Table 1 illustrates the chemical composition of water in the lower sectors of two major river systems draining extensive areas in the United States. The Mississippi River as sampled near New Orleans contains Total Dissolved Solids (TDS) of 232 parts per million (ppm). This is a stream of enormous watershed, but for the most part drains regions the rainfall of which exceeds 20 inches per year. The Colorado River drains a much smaller watershed, much of which is mountainous receiving winter snows and considerable rainfall throughout the year. But, the watershed of this stream includes dry regions where there is much less than 20 inches of yearly precipitation. Hence, each volume of Colorado River water is much higher in TDS than an equal volume of Mississippi River water at the points of sampling. The ratio of salts to pure water in the Colorado River at Parker Dam, Arizona is 2 1/2 times that of the Mississippi River water. Also, the "hardness" of the Colorado River water as it leaves Parker Dam is about twice that of Mississippi water near New Orleans. Not all salts increase in the same proportion. Note e.g., that sodium and sulphate are over four times greater in Colorado River water. Generally, also rivers draining dry regions tend to be more alkaline (high pH) than those such as the Mississippi which are virtually neutral (pH $7\pm$) in acidity.

As surface water is infiltrated to become groundwater it carries out similar processes of mineral solution in its flow through buried alluvium and rock layers. Eventually, a variable proportion of this groundwater, enhanced in additional chemical ingredients may reappear as "seeps" or springs to become part of the surface water. In semi-desert regions, where the water table is low, the remaining large amount is stored within the aquifer.

The chemical fraction contains also variable amounts of organic compounds, some of which are derived from passage of rain through the atmosphere. Also, under natural conditions some of the organic fraction is supplied by wastes of organisms especially bacteria which multiply in decaying plant and animal debris. Many of these compounds are destroyed as they move through the aquifer system, others remain for long intervals of time.

As Man has developed his civilization, an increasing number of organic chemicals are used throughout industry, transportation, etc. Such organic compounds enter surface as well as groundwater, and literally hundreds must be monitored and reduced in amounts to acceptable levels through elaborate and expensive water-treatment processes (see Table 2).

Table 1
Average Composition Of Waters In The Lower sectors Of The Mississippi And Colorado Rivers*

Location	Date	TDS	Specific Conductance	Hardness As Calcium Carbonate	Sodium	Calcium	Magnesium	Chloride	Sulphate	Bicarbonate	Fluoride	Silica	pH
Mississippi River at Luling Ferry approximately 17 miles west of New Orleans, LA	Average Of Daily Values Oct 1964 thru Sep 1965	232	371	138	20	38	10	24	51	113	0.3	8	7.4
Colorado River at Parker Dam Arizona	Average of Monthly Values Feb 1990 thru Aug 1994	598	996	251	94	75	27	84	252	163	0.4	9	8.2

* Data from U.S. Geological Survey Water Supply Paper 2254, other U.S.G.S. sources, and the Salt River Project
Values shown are in parts per million (ppm)

Table 2

Common Organic Compounds Tested For
Their Presence At the 91st Avenue
Waste-Water Treatment Plan*

1. Acetone
2. Benzine
3. Bromoform
4. Carbon Disulphide
5. Carbon Tetrachloride
6. Chlordane
7. Chloroethane
8. Chloroform
9. Cyanide
10. Diazinon
11. Malathion
12. Methyl Bromide
13. Methyl Chloride
14. Methyl Butyl Ketone
15. Methyl Ethyl Ketone
16. Melthyl Isobutyl Ketone
17. Naphthalene
18. Toluene
19. Vinyl Acetate
20. Vinyl Chloride
21. Total Xylenes

* Presence of compounds listed in Table 2 are tested frequently and have been found to remain below maximum contaminent levels.

Some minerals, formed by various natural processes contain metals and non-metals such as arsenic, copper, lead, magnesium, selenium, sodium and complex ions such as chlorides and sulphates as well as radioactive elements chemically bonded in the mineral crystal. Such elements are released as ions as the crystal is destroyed by soil-forming processes, and are dissolved in surface or groundwater. In arid regions, evaporation of shallow lakes and streams tends to concentrate the amount of these substances before they enter the groundwater system. Once there, they may be precipitated again as a different mineral, and removed from solution as they become intermixed with particles deposited with the alluvium. Eventually, the chemical fraction once again may be dissolved to re-enter groundwater and surface water systems. The point being, oftentimes the locality of origin of a chemical substance remains unknown, and what appears to be potable water is rendered toxic by the presence of small amounts of such elements as arsenic, chromium and selenium the sources of which may be many miles distant.

In order to protect the Public from consuming dangerous amounts of certain toxic ions, limits have been established principally by the U.S. Environmental Protection Agency and the U.S. Public Health Service on the amount of certain ions which should not be exceeded in drinking water. These are called "maximum contaminent levels", and are set at amounts which are known to be harmless to humans. Inasmuch as the so-called "permitted maximum contaminent levels" are changed from time to time as additional information becomes available, costs of re-establishing acceptable levels tend to increase water-treatment processes. Table 3 is a list of maximum contaminent levels of certain common ions present in waters of southwestern states, and which for the most part are present at lower levels in groundwater of the northern part of the West Salt River Sub-Basin. Table 3 is provided so the reader will know the limits set for such ions, and the table can be used as a guide to compare with analyses of water which enters the Sub-Basin (see Tables of compositions of various waters listed in this report).

Analytical Practices

In chemical analyses of water, the practice had developed to report the presence and amounts of common inorganic substances in parts per million by weight (ppm). These are abundant ions which influence the general quality of water namely, calcium, magnesium, potassium, sodium and complex ions such as bicarbonate, chloride and sulphate. As these tend to be extremely variable in amounts dissolved, the practice of enumerating "Total Dissolved Solids" (TDS) in parts per million illustrates the total weight of such substances present in the water. TDS constitute a ready indicator to distinguish waters of high salinity from those of low salinity, i.e., roughly non-potable from potable water (see Table 3). Knowledge of the TDS content of water used for agricultural purposes is particularly important in determining crop yields. Some crops (including grasses for lawns or golf courses) are far more sensitive than others to the total salinity of irrigation water (see Table 3). Particular attention must be paid to the use of effluent from waste-water treatment plants, as this water commonly exceeds maximum contaminent levels in nitrogen and sodium.

Approximate values of TDS can be determined by summation of amounts of various common substances in the water sample, and often checked by weight of residue which remains upon evaporation of a selected sample of water. Recently, the method has been supplanted by measurement of Specific Electrical Conductance of the water sample. Specific conductance yields a very reliable measurement of the total presence of common ions but is controlled by the water temperature and acidity (pH). An approximation of TDS can be obtained by multiplying the Specific Conductance value by 0.6.

Table 3

Partial List of Maximum Contaminant Levels As Established By
U.S. Environmental Protection Agency (1976) And
U.S. Public Health Service (1962)
Acceptable in Arizona (1996)

Arsenic	0.05	(proposed 0.002)	parts per million
Barium	1.0	(proposed 2.0)	parts per million
Boron	0.6	(proposed 1.0)	parts per million
Cadmium	0.005		parts per million
Chromium	0.1		parts per million
Copper	1.0	(proposed <1.3)	parts per million
Fluoride	4.0		parts per million
Lead	0.05	(proposed alert level .015)	parts per million
Manganese	0.2	(proposed 0.05)	parts per million
Mercury	.002		parts per million
Nitrate	10.0	(when determined as nitrogen)	parts per million
Nitrite	1.0	(when determined as nitrogen)	parts per million
Selenium	0.05		parts per million
Sulphate	250	(as much as 500 suggested)	parts per million
Zinc	2 to 5	(proposed 0.2)	parts per million
Total Dissolved Solids (TDS)	500 approx.		parts per million

Sodium		(<69 for Agricultural use in Arizona)	parts per million
Chloride	250	(<1.06 for Agricultural use in Arizona)	parts per million
Bicarbonate		(<90 for sprinklers in Arizona)	parts per million

A second set of analyses involves the quantities of chiefly metal ions present in the water sample, and these tend to be reported in parts per billion. Most common are aluminum, arsenic, boron, copper, iron, selenium and silver. Radioactive elements, of which radon is one, are reported in different values. The amounts of nitrogen present is important as well as its form of occurrence, to indicate certain sources of supply. For example, ammonical radicals are derived from animal and human wastes, whereas the abundance of nitrates tends to indicate sources of chemical fertilizers used to enhance growth of all sorts of vegetation.

A third set of analyses is a growing list of organic compounds used by Man (see Table 2). These are not naturally produced, but made directly or indirectly by industrial processes to be used in many different ways. Such "organics" may be injected into the atmosphere through smoke and automobile exhaust, and enter surface waters as waste products, eventually to become part of the composition of groundwater, sometimes many miles from their source. From year to year this list increases significantly and many of these substances are toxic to all life when present in sufficient quantities. In the Sun Cities the quantity present of any of these "organics" tends to be insignificant, either is not observed below acceptable levels, or reduced by dilution to tolerable limits.

Of late, a fourth set of analyses is the identification of the presence of certain micro-organisms generated through diseases, or capable of causing diseases. Many of these organisms are recognized as having their origin in human or animal fecal matter, and are virtually destroyed by chlorination of the water before delivery for human consumption. Recently, certain of these organisms have become resistant to small amounts of chlorine, and their presence requires elaborate forms of detection as well as expensive destruction.

Distribution Of Common Ions By Surface Waters

The reader should understand that an important purpose of this report (supported by tables of analyses) has been to illustrate observed large ranges in amounts of individual common ions present in streams draining watersheds of the Salt and Gila rivers. Not only do such amounts differ seasonally within an individual stream, but also, during very short intervals of time following episodes of local snow melt or heavy rainfall. For this reason, meaningful indicators of the average salinity of water from a watershed is approximated only by frequent sampling during more than a single year's duration. It is important, as well, to know the amount of water discharged by the stream at the time of sampling, as this becomes a measure of individual ions as well as TDS which are infiltrating alluvium bordering the stream channel.

As stated earlier the ultimate purpose of this report has been to identify localities where surface waters of moderate to low salinities infiltrate the alluvium, to be distinguished from sites where waters of high salinity become part of the aquifer system. Localities where highly saline waters infiltrate alluvium of the West Salt River basin are localities which merit detailed hydrologic studies with an objective to prevent or reduce eventual recharge to the aquifer system. An example is the site, outside the Basin, along the upper Salt River where very saline springs empty into the Salt River channel (see Table 4).

Could the flow of such springs be reduced or eliminated by present-day technology such as injection of cement into the water-escape system?

WATER CONSERVATION

Active Management Areas

For more than 20 years, studies of general declines in groundwater levels, particularly in the northern sector of the Sub-Basin, have indicated that over much of that region normal recharge to the aquifer system was proving inadequate to meet demands. As a consequence, the Arizona State Legislature established separate "Active Management Areas" within which groundwater levels merit specific attention. Included among other provisions is a reduction in groundwater consumption and permissible amounts of groundwater use is reduced following each 10-year interval. Artificial recharge to the aquifer is encouraged. According to the Phoenix Area Active Management plan, withdrawals and recharge are to come into balance by the year 2025, so that water-table levels are brought to a state of general equilibrium at certain depths below the land surface. Such a steady-state of groundwater levels involves very significant reduction in the amounts pumped, and in the absence of a supplementary supply of water, the amounts currently used in the Sun Cities would be reduced drastically. This means that present landscaping, including areas of golf course grass cover, would need considerable reduction and modification.

The Central Arizona Project

To aid the attainment of equilibrium between groundwater recharge and withdrawal in the Phoenix Active Management Area (PAMA) and the Tucson Active Management Area, an additional supply of water is now delivered by the Central Arizona Project (CAP). This elaborate construction brings to the State of Arizona an allotment of Colorado River water via a canal system to Lake Pleasant as a reservoir. By means of various pumping stations from this lake the canal continues to Phoenix and Tucson. Completion of the CAP by the U.S. Bureau Of Reclamation has provided the potential of additional water supplies for agricultural and urban demands in the extensive strip of land paralleling the canal from its source at Parker Dam, Arizona to Tucson.

This project is not without cost to the State of Arizona, to suppliers and eventually to the consumers. Construction of the canal, its operation and maintenance are major aspects of the cost. In addition there will be required construction and operation of treatment plants to lower the salinity of delivered Colorado River water to meet compliance with U.S. Environmental Protection Agency's (EPA) limits (see Table 3). Moreover, a network system is needed to bring this CAP water to points of use for irrigated land and local communities (of which the Sun Cities are to be included). Estimates by professional engineers of total costs of the delivered and treated water are known to range widely. Hence, some organizations consider CAP water will prove excessively expensive for use as agricultural irrigation, and as a supply to many outlying communities. Accordingly, these individuals and organizations advocate for the Sun Cities continued dependence upon existing groundwater supplies, restriction of all water pumped in the Sun Cities to be used in the Sun Cities, and the use of treated waste-water effluent to supplement needs of golf course and agricultural irrigation. Also, they propose significant reduction in urban use of groundwater to be in compliance with restrictions imposed by the PAMA plan.

Table 4

Composition Of Water From Salt Spring Along Salt River Near Chrysotile, Arizona (Approximately Sec. 13, T5N-R 16E)
Also Composition of Salt River Above and Below Salt Spring

Location	TDS	Sodium	Potassium	Calcium	Magnesium	Chloride	Sulphate	Bicarbonate	Non-Carboante	Hardness as Calc. Carbonate	Specific Conductance	pH	Discharge Estimate
Near Chrysatile see (Above for location)	29,000	10,100	170	505	291	16,200	899	1,520	1,210	2,460	41,500	7.1	180 cu. ft/sec. (3-30-59 at Chrysotile, AZ
Salt River near Roosevelt, AZ**	1,640	500				794	126			126			195 cu.ft/sec.
Salt River (one mile upstream from Salt Spring)	1,660	500				843	84						180 cu.ft/sec.

*See Feth, J.H. and Hein, J.D. ,1963, U.S. Geological Survey, Water Supply Paper 1619 H, Pages H 35-36.

**Note the reduction in TDS by virtue of dilution of water originating at Salt Springs near Chrysotile, AZ when mixed with water from the watershed of the Salt River.

The Salt River Project

Approximately 80 years ago, when cropland was the primary economic use of much of the Sub-Basin, the Salt River Project (SRP), a privately-owned entity, came into existence to provide water to farming areas by means of irrigation canals carrying pumped groundwater. Throughout the years this system has been enlarged by the U.S. Bureau of Reclamation to its present stage of construction of large dams at appropriate localities along the Salt River drainage. Such waters feed an extensive canal system with a steady supply of water from the reservoir lakes, supplemented by pumped groundwater (see Map LL_1 & LL_2).

Some years ago, the SRP reached its limits of sustainable water production. The company was aware that in the absence of a supplemental water supply it was unlikely to provide additional water to its agricultural clients and expanding Phoenix metropolis. As a consequence, the Salt River Project has connected its canal system with additional source of the recently completed CAP.

SRP does not supply drinking water directly to urban customers, but delivers to certain municipal water-treatment plants. Of the total water supplied in 1994, approximately 86% came from watersheds of the Verde and Salt rivers, whereas groundwater furnished only 9% of the demand. the remaining 5% was obtained from the CAP (i.e., Colorado River water), and this water is blended with that of the Verde and Salt rivers near the Granite Reef Diversion Dam. It is the announced future policy of the SRP to use increasing amounts of CAP-water to virtually eliminate reliance upon groundwater supplies. At the present time a certain amount of the blended water is allowed to flow into infiltration ponds near the Granite Reef Diversion Dam to recharge the underlying aquifer (see Map LL_2). Such reduction in groundwater withdrawal is to comply with any future plan of the Phoenix Active Management Area (PAMA) and to build a "reserve" of groundwater to be withdrawn during episodes of drought.

Inasmuch as the SRP derives a very large percentage of its water through surface sources, it is well aware that the bulk composition of this water varies considerably between watersheds and also throughout the year. Surface water from a single watershed flowing into a reservoir lake varies in composition from month to month (see Table 5). Compare, e.g., ranges in composition of the Verde River at points of sampling, and below Bartlett Dam which controls the reservoir of Bartlett Lake. Values indicated in Table 6 illustrate the wide ranges in composition in maximum and minimum values in both the Verde and Salt River reservoirs, the strong influence of rainfall is reflected in the composition of waters of tributaries entering both rivers.

The SRP monitors the composition of water as it moves through its distributary-canal system, and on page 1 of its 1994 Annual Report states "these variations can be attributed to influences from agricultural return flow, urban stormwater runoff, groundwater pumped into canals, and seepage and evaporation".

Uncertainty in the month to month composition of surface waters as they leave reservoir lakes, along the Salt River, has caused the writer to assemble data on the compositional variation of surface waters which enter the "valley", infiltrating the alluvium to become part of the groundwater system. The purpose is to illustrate any existing sources of watershed water of low salinity which change to waters of high salinity as they enter and move through the Sub-Basin. The question being, do

Map LL1
Tributaries, Lakes, Dams, Communities
Salt and Gila Watersheds
LEGEND
GAUGING STATIONS
SAMPLING LOCATIONS
CLARKDALE
OAK CREEK
CAMP VERDE
Wet Bottom Creek
CHILDS
EAST VERDE RIVER
PAYSON
VERDE-TANGLE
Horseshoe Reservoir
VERDE RIVER BELOW BARTLETT DAM
Bartlett Lake
Lake Pleasant
CAP Canal
Sun City West
Sun City
Litchfield Pk.
SYCAMORE CREEK
STEWART MTN. DAM
Apache Lake
Roosevelt Lake
Salt River
Salt Spring
SALT RIVER CANYON
Avondale
GRANITE REEF DAM
Buckeye
LAVEEN
Gillespie Dam
Globe
San Carlos River
Coolidge Dam
San Carlos Lake
Gila River
KELVIN
Gila River Indian Reservation
GILA BEND
Santa Cruz River
CAP Canal
Brady Wash
San Pedro River

Map L L2

Phoenix Area SRP Water Supply

map is Fig 2 in SRP 1994 Rpt.

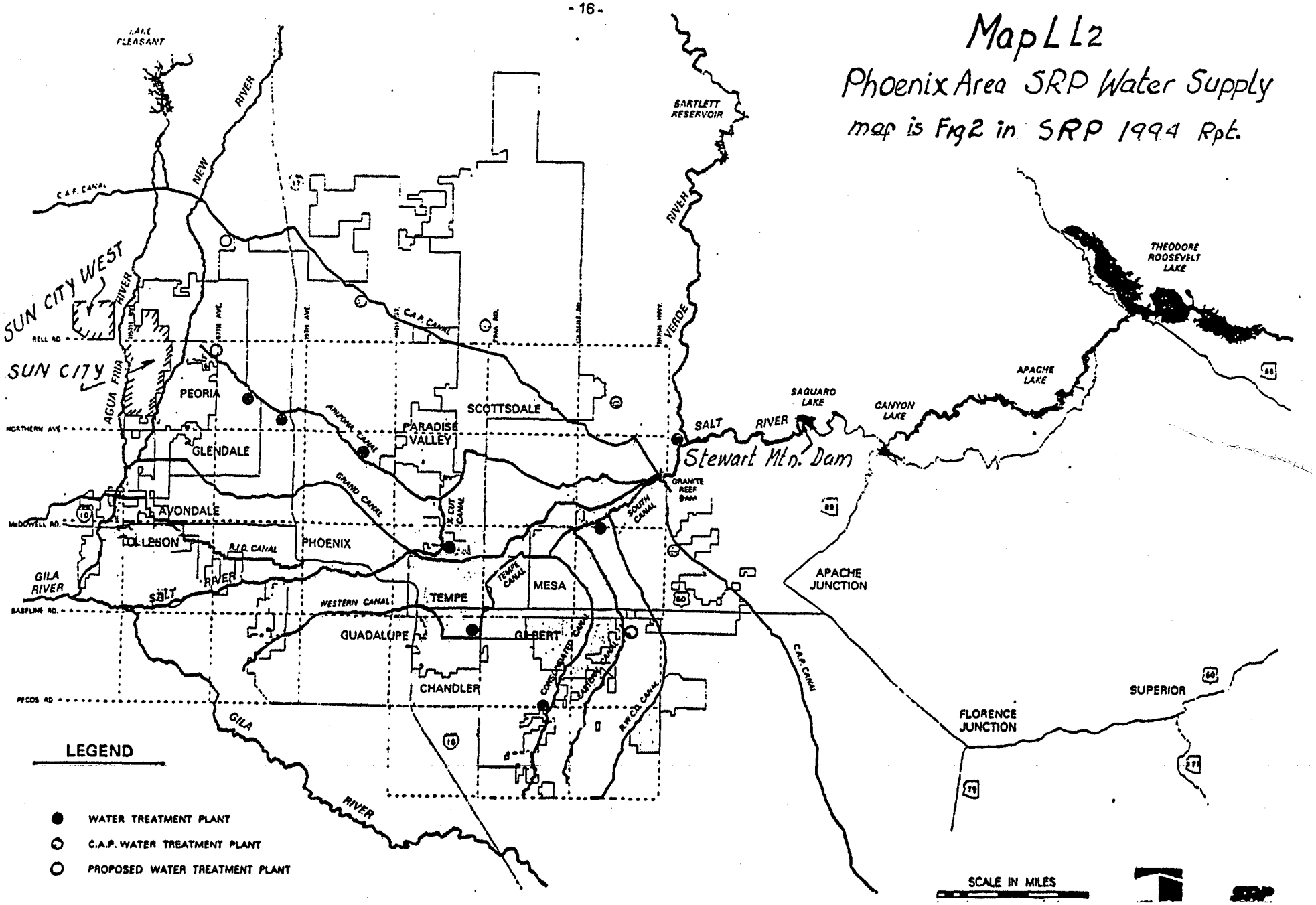


Table 5

Ranges In values of Common Ions In Salt River Watershed During
"Water-Year, December 1994 - November 1995*

Location (See Map LL_1)	TDS**	Sodium	Calcium	Magnesium	Chloride	Sulphate	Bicarborate	Total Nitrogen	Copper	Chromium	Lead	Barium	Arsenic	Silica	Fluoride	Specific Conductance	Laboratory pH
Verde River Near Clarkdale	118-283	7-26	25-54	9-25	4-12	3-9	117-316	0.1-0.12	.001-.002	.001-.002	.003	.050-.160	.005-.018		0.1-0.2	205-579	7.8-8.0
East Verde River Near Childs	171-207	8-14	18-49	6-19	5-8	4-7	174-212	0.02-0.03			.005	.037-.051	.007-.025		.2-.3	321-398	7.6-8.3
Wet Bottom Creek near Childs	48-187	6-28	8-36	7-11	3-14	3-6	41-209					.014-.040	.005-.024	24-39	0.6-2.2	91-383	7.7-8.1
Verde River Below Tangle Creek	138-415	11-51	26-52	12-36	8-28	41-110	128-269	.03-.23		.003	.005-.002	.036-.071	.01-.027		0.2-0.4	280-715	7.8-8.2
Verde River Below Bartlett Dam	108-369	4-44	22-50	8-35	6-26	12-80	101-284	0.5	.051			.038-.068	.008-.020	17-29	0.2-0.4	191-634	8.0-8.4

*Data from SRP Annual Report 1994, and U.S. Geological Survey.

**Common ions and other substances in parts per million (ppm)
TDS values calculated from Specific Conductance by E.C.Dapples
are approximations.

Table 6

Ranges In Values of Common Ions In Salt River
Watershed During "Water-Year", Dec. 1994 - Nov. 1995*

Ion or Complex	Pinal Creek at Inspiration Dam	Verde River below Bartlett Dam	Salt River above Roosevelt Dam (Lake)	Salt River below Stewart Mountain Dam
TDS	2520 (Jun) 2300 (Aug)	339 (Jan) 108 (Apr)	1470 (Jul) 90 (Feb)	507 (Apr) 419 (Nov)
Sodium	76 (Jan) 68 (Jan)	40 (Nov) 9 (Apr)	450 (Jul) 10 (Feb)	123- (Apr) 96 (Feb)
Calcium	510 (Jun) 420 (Aug)	45 (Nov) 27 (May)	75 (Jul) 20 (Feb)	48 (Mar) 43 (Sep)
Chloride	58 (Jan) 50 (Sep)	25 (Jan) 6 (Mar)	710 (Jul) 12 (Feb)	794 (Apr) 140 (Nov)

Ion or Complex	Verde River near Clarkdale	Verde River below Tangle Creek	Salt River above Roosevelt Lake
TDS	283-(Feb) 103 (Apr)	415 (Jun) 138 (Apr)	2290 (Jul) 90 (Feb)
Sodium	26 (Feb) 7 (Feb)	51 (Aug) 11 (Apr)	680 (Jul) 10 (Feb)
Calcium	54 (Feb) 22 (Apr)	52 (Jun) 26 (Apr)	100 (Jan) 20 (Feb)
Chloride	13 (Jun) 4 (Apr)	28 (Jun) 8 (Apr)	1200 (Jul) 12 (Feb)

*Data in ppm from records of Salt River Project.

waters infiltrating the aquifer system slowly add to its salinity, or are existing natural supplies adequate to maintain low salinity water particularly north of the Grand Avenue Fault? Such an analysis is basic to questions of trends in the future salinity of groundwater if pumping is increased outside the Sun Cities, required by the expected growth in suburban population. Also, as ever increasing demands are placed within the PAMA, will suppliers of potable water be obliged to resort to CAP water as the most available and desired source of large amounts of water?

Potential Change In Quality Of Groundwater

On Map W (see also Vol.1, No. 4) certain levels of static water in wells are shown to have declined variably over the 10-year interval (1982-1992) primarily in the north-central part of the Sub-Basin. Over much of the area south of the Grand Avenue Fault, levels have tended to remain more or less in equilibrium during the same 10 years. Locally, in the Luke and Deer Valley Lows, static-water levels have risen, but the Luke Low remains as an important "sink", and is expanding toward the Sun Cities.

Short-term rises and falls in static-water levels are commonplace where wells exist, e.g., an area in northern Sun City shows a rise as much as 20 feet, whereas nearby there are declines. This pronounced variability in groundwater levels is known to be a response to differences in yearly amounts pumped from various wells, how long a well has been "shut down", and when the measurements are made. However, a long-term depression of the water table, such as the Luke Low, does raise questions concerning directions of present-day groundwater movement from positions of infiltration, particularly from major river channels and proposed sites of recharge ponds.

Data currently available indicate that water infiltrated into the aquifer system of the West Salt river Sub-Basin from the Salt and Gila sources is considerably more saline than that which arrives from the northern watersheds. Data presented in Table 7 indicate the weighted average composition of water for 1952 in the Salt River below the Stewart Mountain Dam as 597 for TDS and a sodium-ion value of 150 ppm (see values of other ions). Corresponding values during the water year 1994, 1995 range in TDS between 244 and 507, and sodium from 41 to 123. During March 1996 the TDS in water in the center channel of the Salt River at 91st Avenue contained 1206 ppm TDS (calculated) and 320 ppm of sodium (Table 7). Similarly, the 1995 average of values for the Gila River above the Gila River Indian Community lands indicated TDS amounts of 2602 ppm and sodium of 627, whereas during the same year downstream (but above the junction with the Salt) TDS values ranged between 6960 and 7140 and sodium of 1700.

During the general corresponding year, groundwater in wells north of the Gila River in T1N-R1 and 2W (i.e., downstream of the junction with the Salt) ranged in very approximate values of 4,000 for TDS. Similar downstream increases in TDS and sodium have characterized waters of the Salt and Gila rivers during the past decade, hence, these very important streams have been adding to the total salt content infiltrated into groundwater of the southern margin of the sub-Basin. As this water finds its way north it replenishes zones where water of low salinity has been removed by pumping and is replaced by water of higher salinity.

Table 7

Range Of Ion Composition In Surface Waters
Of Salt and Gila Rivers*

Location	TDS	Sodium	Calcium	Magnesium	Chloride	Sulphate	Bicarbonate	Silica	Fluoride	pH
Salt River below Stewart Mountain Dam. Weighted Average for 1952 "Water Year" (U.S.G.S. Wat. Sup. Pap. 2254 p. 103)	597	150	48	14	233	50	153	18	0.4	
Salt River below Stewart Mountain Dam (Oct 1994-Nov 1995)	507 244	123- 41	50 36	14 8	194 53	75 35	165 129	18 17	0.3	8.3 7.9
Salt River (Center Channel) at 91st Ave. U.S.G.S., Mar 96	1206	320	47	40	410	200	163	4	0.7	8.9
Gila River above diversion for Gila River Indian Community. (Average of 1995 Values U.S.G.S.)	2602	627	167	76	900	537	325			
Gila River above Junction with Salt River (average values 1995-96 (U.S.G.S.)	7140 6960	1700	600	230	3500	960	337			

*Analyses by U.S. Geological Survey. Values are in parts per million (ppm)

AVAILABLE SURFACE WATERS

Sources Of Surface Water

Except for infiltration to groundwater from runoff of the surrounding mountains and rainfall, there are certain major sources from surface waters which enter the Sub-Basin. Each derives its waters from extensive watershed-tributary drainage outside the Sub-Basin, and channels waters into important rivers namely the Agua Fria, the Verde, the Santa Cruz and the Salt, all of which eventually are trunk streams to the master Gila River (see Map LL_1 & LL_2).

In years past under natural conditions, the important watershed of the Agua Fria brought water low in TDS from scattered mountains and semi-desert uplands, southward to the Sub-Basin, eventually to join the Gila River several miles west of its confluence with the Salt. Ignoring times of floods, virtually all water (low in TDS) of the Agua Fria was infiltrated into the aquifer system. Only during times of excess water did the Agua Fria deliver much water to the Gila River channels.

Since construction of the CAP and the new Waddell Dam, natural infiltration in the lower Agua Fria has been almost entirely eliminated, and Lake Pleasant is used as the reservoir for water delivered chiefly by the CAP. Some years in the future, monitor wells within the Agua Fria river channel will provide information concerning the amounts and rates at which water from the Lake Pleasant reservoir has entered the aquifer system at the northern end of the Phoenix Active Management Area. Until this is done, the subsurface recharge to the aquifer from Lake Pleasant is to be considered as a very small quantity, inasmuch as significant "grouting" was done in the region of the dam-site to reduce leakage to a minimum.

By means of its principal tributaries, Santa Cruz, San Pedro, and San Carlos rivers the Gila drains virtually all of southeastern Arizona. Hence, like streams tributary to the Salt it carries water of variable composition depending upon rainfall in the local watershed (see Table 8). Water of varied chemical composition seeps through various channels to become groundwater. About 25 miles southeast of Globe, Arizona, the upper reaches of the Gila are joined by an important tributary (San Carlos), and this part of the Gila drains a watershed which covers a sector receiving some of the highest annual precipitation in Arizona. Most of this drainage is held at Coolidge Dam to constitute the reservoir identified as San Carlos Lake. From this lake, water is channeled into irrigation canals but is not part of the SRP, nor do such canals reach the West Salt River Sub-Basin.

Water in the Santa Cruz River tends to be generally low in salts as shown in Tables 8 and 9. Note e.g., TDS (ppm) values in samples taken periodically from 1976 through 1983 range between 210 and 456 ppm, and sodium between 61 and 200. An analysis of the Gila at Laveen, (Arizona) 1971 shows similar low values, but at the Gila River Indian Community (1995) TDS values had indicated a marked rise to between 2190 and 3120 ppm, and sodium between 540 and 750 (see Table 10 and 11).

Table 8
Comparison Of Ion Composition In Certain River Waters*

Location	Date	TDS Approx Values	Sodium	Calcium	Magnesium	Chloride	Sulphate	Bicarbonate	Silica	Fluoride	Specific Conductance	pH	Hardness
Mississippi River** at Luling Ferry, LA 17 mi W. of New Orleans	Mean of daily Values Oct 1964 thru Sep 1965	232	20	38	10	24	51	113	8	0.3	371	7.4	138
Verde River below Bartlett Dam	Jan 1994 thru 1995	108-369	4-44	22-50	8-35	6-26	12-80	101-284	17-29	0.2-0.4	191-634	8.0-8.4	
	Approx Average for 1995	273 288	29	40	20	28	50	228	20	0.3	480	8.2	171
Salt River above Roosevelt Lake	Jan thru Dec 1995	90-2290	10-680	20-100	4-36	12-1200	11-180	65-246	15±	0.2-0.3	206-4250	7.8 8.2	
	Approx Average Jan-Nov 1995	1123 1309	330	65	22	546	105	161		0.2	2182	8.0	
Salt River below Stewart Mtn Dam (after addition of Verde River)	Weighted Average for 1952	597	150	48	14	233	50	153	18	0.4	1090		
Santa Cruz River near Laveen, AZ above Junction with Gila	Sep 1976 to Oct 1983	162-990	27-200	0.9-120	0.2 29	10-280	38-380	99-160	5-25	0.4-1.7	270-1650	7.7-9.7	3-420
	Approx Average Sep 1976 to Oct 1983	397-383	113	30	6	81	95	140 (76-78 only)	14	1.0	638	8.5	81
Gila River near Laveen, AZ (high water)	Aug 24, 1971	283	37	48	9	10	88	150	22	1.1	472	7.5	150

* Data from U.S.G.S. Water Supply Paper 2254, Other U.S.G.S. Sources, and Salt River Project.
Common ions and other substances in parts per million (ppm)

** The purpose in illustrting a compositional average for waters of the Mississippi River is to indicate values of a very large drainage area over a region of significant rainfall and infitration through a great variety of soil types and rocks. The values indicated can be used as examples of ppm of common ions present in potable river water of moderate hardness, also to compare compositions of waters of the Verde, and the upper Salt and

Table 9
Ranges In Ion Composition Of Water In Santa Cruz River Near Laveen, Arizona*

	Date	Discharge cu/ft sec	Approx Value of TDS (Calc. by ECD)	Solids Residue	Sodium	Sodium Percent	Calcium	Magnesium	Chloride	Sulphate	Bicarbonate	Total Nitrogen	Lead	Barium	Arsenic	Silica	Fluoride	Specific Conductance	pH (field)	Hardness (as Calc. Carbonate)
1976	9/27	.50	210	206	61	79	10	1.4	19	16	160	2.0	.010 .02		.009 .020	9	0.4	350	7.7	30
1977	10/14	976	346	346	67	54	38	5.2	28	97	160	3.6	.030		.01	25	0.9	579	8.2	120
1978	1/26	0.28	162	174	27	41	27	3.2	10	30	140				.09	11	0.3	270	7.9	81
	3/1	16	456	481	150	88	14	1.6	100	100	140	3.4				10	1.5	760	9.2	42
	4/5	.14	990	1080	190	49	120	29	280	380	99	6.0				6	1.1	1650	8.0	420
	8/3	1.6	453	435	150	94	70	.30	72	70		9.6	.003	1.2	.05	18	1.7	755	9.5	19
	10/27	.20		438									.023		.050					
	11/30	9.1	237	276	33	32	51	4.2	16	82		9.9				18	.40	395	7.9	140
1979	1/5	193	238	251	35	41	35	4.6	19	68		7.9				21	.40	397	7.8	110
	1/26	52	330	345	100	86	10	1.0	67	51		3.5	.016		.050	10	.90	550	8.4	29
	3.29	32	451	485	170	94	7.5	0.5	110	74		5.6		1.3		15.	1.4	751	8.9	21
1980	2/20	18	451	442	150	94	5.0	1.2	110	74		5.6	.017	.13	.080	15	1.4	751	8.9	18
1981	2/10	9.6	600	609	200	78	6.0	25	150	160		5.6	.002	.2	.052	12	1.2	1000	8.8	120
	3/6	1.0	352		130	98	0.9	0.2	76	38		4.2				12	1.0	586	9.7	3
1983	10/3	1320	276															460		
Arthmetic Average of Values	1976 to 1983		397 383	347	113		30	6	81	95	140 (1976 thru 1978 only)					14	1.0	638	8.5	81

*Station 0948900 U.S. Geological Survey, also analyses

Table 10
Ion Composition of Water along Gila River Drainage*

Location	Date	Stream Width	Discharge cu/ft sec	Approx Value of TDS	Solid Residue	Sodium	Sodium Percent	Calcium	Magnesium	Chloride	Sulphate	Bicarbonate	Nitrogen	Nitrogen: Organic and Ammonium	Lead	Barium	Arsenic	Silica	Fluoride	Spec. Conductance	pH(Field)	Hardness
Santa Cruz River near Laveen (51st Ave)	Sep '76		.50	210	206	61	79	10	1	19	16	160	2.0	1.4	.010		.020	9	0.4	350	7.7	30
	Oct '77		976	346	346	67	54	38	5	28	47	160	4	1.4	.3		.1	25	1.	577	8.2	120
See Table 9 Aver Value	Jan thru Nov '78		5	460	481	110	51	56	8	96	132	126	7	1.2	.08	1.2	.05	12	1.	766	8.5	140
Aver Value	Jan thru Mar '79		92	340	360	102	74	18	2	65	64		6	1.2	.160	1.3	0.5	15	.9	603	8.4	53
	Feb '80		18	451	442	150	94	5.	1	110.	74		6	0.8	.17	1.3	.08	15	1.	751	8.9	18
Aver Value	Feb Mar '81		5	476	(609)?	165	88	4	13	113	99		5	1.1						793		
	Oct '83		1320	276																460		
Gila River above diversion for Gila Indian Community	Jul 1995	17	82	3120	3070	750	65	200	94	1100	700	283.	7	1.1	.04	.1	.007	23	2			
	Sep	12	154	2190	2040	540	65	140	63	740	420	245.		1.7	.001	.07	.008		2			
	Nov	150	273	2496	2340	590	64	160	72	860	490	311.		1.3	.001	.07	.01		2			
Gila River above confluence with Salt River	Mar 1996	38		7140	7210	1700	60	600	230	3500.	960	337	3	.2				28		11900	7.6	2400
				6960																11600		
Gila River Diversion at head Buckeye Canal (see Tables 11 & 24)	Nov 1995			1314								293	16	13						2190	7.6	
	Jan thru Apr '96		265	1587	1520	340	60	95	50	555	240	299	17	14				20	1.4	2645	7.7	483
Salt River at 51st Ave Bridge	Aver Jan-Feb 1995	165		365	333	63	44	36	16	76	52	164		0.7		.012				608		
Effluent Water from 91st Ave Waste-Water Plant	Jan thru Apr 1996		102	881	837	178	59	57	26	217	170	261	15	14				20	1.7	1468		

*Data from U.S. Geological Survey reports.
Values in ppm. Approximate values of TDS
are calculated by ECD from Specific Conductance

Table 11
Composition Of Major Ions In Salt and Gila River Water.
Also Groundwater And Effluent Of 91st Avenue Plant (1995 - 1996)*

Location	TDS	Sodium	Calcium	Magnesium	Chloride	Bicarbonate	Sulphate	Total Nitrogen
Salt River at 51st Ave Bridge (Average of Values)	365	63	36	16	76	164	52	3
Groundwater north of Salt River from TIN-R3E to Junction with Gila River (Average of Values)	1339	313		35	351		240	
Effluent Water from 91st Ave Waste Water Plant (Average of Values)	881	178	57	26	217	261	170	15
Salt River below 91st Ave. Waste-Water Plant (Average of Values)	1206	320	47	40	410	163	200	3
Gila River above diversion for Gila Indian Community (Average of 1995 Values)	2602	627	167	76	900	325	537	
Gila River above Junction with Salt River (Average of Values)	6960 7140	1700	600	230	3500	337	960	3
Gila River above diversion at Buckeye Canal (Nov 1995 thru Apr 1996)	1532	340	95	50	535	298	240	17
Groundwater north of Gila River in T1N-R1 & 2W below Junction of Salt and Gila (Very approx values).	4000			98	1120		8	
Gila River at Gillespie Dam Weighted Aver 1952 "Water Year"	4940	1220	353	149	1980	355	1000	

*Data from U.S. Geological Survey Analyses in parts per million (ppm)

Verde River Watershed

As indicated on Map LL_1 & LL_2, the watershed of the SRP consists of flowage of two principal river systems namely, the Verde River and the Salt. The Verde River tributary system drains southeastward from margins of the Colorado Plateau in the central western part of Coconino County, and joins the Salt River northeast of Phoenix. Although the Verde is tributary to the Salt, it is considered as separate because its watershed drains a distinctly different area of north-central Arizona. According to the SRP 1994 Annual Report, the two watershed areas are quite similar in areas involved, the Verde covering about 6,600 square miles, whereas the upper Salt drains approximately 6,300 square miles. However, the annual total supply waters of the two river systems average quite differently in compositions. The Verde River tends to flow water considerably lower in Total Dissolved Solids (TDS), sodium and chloride ions despite the fact that its yearly discharge is considerably less than that of the Salt.

In order that the reader becomes aware of the significant range in composition of the Verde River waters they are illustrated in Tables 5 and 12a-e. Table 5 is a summary (November 1994 to November 1995) of the yearly maxima and minima in principal common ions. Tables 12a-e illustrate details in compositions of waters flowing in each tributary. Except for the tributary Wet Bottom Creek, the yearly average salinity (TDS) of the Verde River remains much the same from Clarkdale to below Bartlett Lake Dam, and attains maximum values during monthly occasions when atmospheric precipitation is low throughout the watershed. Minimum values are recorded when rainfall or snow melt is heavy sometimes during a single month. Note however, that samples taken below Bartlett Dam show ion amounts present during the year to remain within limits supplied by each tributary to the Verde. As stated earlier, this illustrates the great advantage of the reservoir lake as a mixing system to provide water of more or less uniform composition throughout the year.

Water drained from watershed of the Verde River, and mixed in Bartlett Lake, tends to be lowest in all salts entering the principal Salt River, and during the interval of sampling was always below limits recognized to be safe for agricultural irrigation water (see Table 3). Only in calcium and bicarbonate values (i.e., "lime content") does such water exceed acceptable standard for human consumption. Also, low values of sulphate-ion indicate that beds of gypsum and related salts (e.g., those in shales exposed near Camp Verde) do not appear to influence the quality of surface water in the lower part of the Verde River system.

Salt River Watershed

Certain tributaries of the Salt River drain southward to the main channel of the river from margins of the Colorado Plateau in east-central Arizona (see Map LL_1 & LL_2). Most of these streams are long such as Tonto Creek, and the maximum area of watershed occurs in that part of Arizona which receives some of the greatest annual precipitation. This drainage pattern of land sloping toward the Salt River channel provides a condition that waters can be interrupted by several dams conveniently place in canyons along the Salt. These dams have developed several reservoir lakes upstream, of which the largest is Roosevelt Lake.

Table 12a

Range In Ion Concentration In Verde River
Water Near Clarkdale, Arizona*

Month	TDS**	Sodium	Calcium	Magnesium	Chloride	Sulphate	Bicarbonate	Total Nitrogen	Copper	Chromium	Lead	Barium	Arsenic	Fluoride	Spec Conductance	pH Laboratory
January																
February	283	26	54	25		9	311	.1		.002			.014	.2	531	7.9
	227	7	25	8.5	4.2	3.2		.12				.052	.005	0.1	225	7.9
March																
April	272	23	51	23		9	307	.0					.015	.2	514	8.0
	216	7.7	22	7.7	3.7	3.3	117	.03		.001		.050	.004	0.1	205	7.8
May																
June	276	24	49	24		8	316	.0	1				.016	.2	519	8.0
	322	24	50	24	13	8.1	290			.001		.160	.015	0.2	494	7.9
July																
August	275	24	52	24		7.	309	.0	2		.003		.018	.2	478	7.8
	284	22	47	21	12	6.9	268	.08		.001		.150	.016	0.2	479	8.
September																
October							287									
November							295	.09								
December							308									

* Data from Salt River Project, "Water year Nov. 1994 - Oct 1995.

** The lowermost values of TDS have been calculated by E.C.D. from the average of the two values of Specific Conductance. All values are in ppm.

Table 12b

Range In Ion Concentration In Verde River
Water Near Childs, Arizona*

Month	TDS	Sodium	Calcium	Magnesium	Chloride	Sulphate	Bicorbonate	Total Nitrogen	Lead	Barium	Arsenic	Fluoride	Specific Conductance	Field ph
January									Max .005	Max .051	Max .070			
February	186	8	42	16	5	7	209		Min .005	Min .037	Min .025	0.2	353	7.6
March	207	8.2	49	17	5.6	6.6	227					.2	398	8.2 8.3
April	188	10	37 18	6		7	209					.2	365	
May	201	11	42	19	6.3	6.5	214	.03				.3	378	8.1 8.1
June	185 218	14 12	34 38	18 18	8 7.2	6 6.3	186 203					.3 .3	358 364	8.2
July														
August	173 198	13 14	30 32	17 17	7. 8.4	4 5.6	192 174					.3 .3	338 321	8.1 8.2
September								.02						
October	188	12	36	18	7.5	4.5	200 212						359	8.3
November														
December							228							

* Data from Salt River Project. All values in ppm.
Lowermost value of TDS calculated by E.C.D. from average of Specific Conductance.

Table 12c

Range In Ion Concentration In Wet Bottom Creek
Near Childs, Arizona*

Month	TDS	Sodium	Calcium	Magnesium	Chloride	Sulphate	Bicarbonate	Copper	Chromium	Barium	Arsenic	Silica	Fluoride	Spec Conductance	Lab pH	Aluminum
January	55	6	8.	3.	3.4	2.8	41			.020		27	0.6	91	7.9	
February									.001		.005					
March		10	13	4	4		73			.014		24	1.1	151	7.3	.530
April									.001		.010					
May		20	30	9	8		154			.030		34	1.7	293	7.7	.010
	175	19	29	8.	8.4	5.8	150			.024		32	1.7	291	8	
June								.001			.006					
July		28	36	11	14		209			.040		39	2.2	383	7.9	
	222	27	31	9.	13	3.9	190			.035		37	2.1	356	8.1	
August											.024					
September																
October																
November	176	21	27	8	8		156			.024		33	2.0	294	7.8	
December																

* Data from Salt River Project, "Water Year" Nov. 1994 - Oct. 1995.
All values in ppm.

** TDS values calculated by E.C.D. from average Specific Conductance.

Table 12d

Range In Ion Concentration In Verde River
Below Tangle Creek

Month	TDS	Sodium	Calcium	Magnesium	Chloride	Sulphate	Bicarbonate	Total Nitrogen	Copper	Chromium	Lead	Barium	Arsenic	Fluoride	Spec Conductance	Lab pH
January																
February	292 286	25 14	46 35	26 15	9	41	269 161	.23	.001	.003	Max .002	Max .071	Max .015 .018	0.3 0.2	539 349	8.1 8.1
March											Min .005	Min .036	Min .010			
April	349 269	37 11	46 26	32 12	8	72	256 128	.03					.018	0.4 0.2	616 280	8.2 7.8
May																
June	415 417	48 45	48 52	36 34	28	110	261 257						.023	0.4 0.4	715 676	8.1 8.1
July																
August	384 398	51	41	35		95	246						.027	0.3	663	8.1
September																
October							254									
November																
December							289									

* Data from Salt River Project, "Water year" Oct. 1994-Aug. 1995.
All values in ppm.
Lowermost TDS values calculated by E.C.D. from average values of Specific Conductance.

Table 12e

Range In Ion Concentration In Verde River
Below Bartlett Dam*

Month	TDS	Sodium	Calcium	Magnesium	Chloride	Sulphate	Bicarbonate	Total Nitrogen	Copper	Barium	Arsenic	Silica	Fluoride	Spec Conductance	Lab pH	Hardness	Aluminum
January	339	42	46	34.4	25	73	233			.050		22	.39	617	8.4	260	
February	316 322 359	31 32	43 44	32.8	19 20	60 53	273 262			.053 .053	.012	20 21	.30 .37	570 626	8.1 8.4	245	.58
March	376 120 252	32 11	46 24	10.1	19 5	61 14	262 110			.038	.012	21 29	.30 .2	500 340	8.2 8.2	100	103
April	323 108 222	36 9	50 22	7.6	19 6	57 11	264 101			.061	.010	20 16	.30 .12	550 191	8.4 8	85	.77
May	324 136 224	35 11	49 27	10.3	23 12	58 13	261 127			.063	.011	21 17	.30 .16	555 234	8.2 8.1	110	100
June	328 175 272	32 16	47 33	13.9	21 8	61 20	283 166			.052	.006	20 17	.30 .23	570 335	8.2 8.2	140	.53
July	312 200 230	33 17	42 36	16.6	19 8	57 26	262 187			.056	.011	20 22	.40 .22	500 266	8.2 8.1	160	
August	312 200 266	33 17	46 35	15.2	19 13	52 25	266 188			.064	.015	19 17	.30 .24	520 365	8.2 8.2	150	.67
September	309 208 288	34 20	43 39	17.6	20 6	49 23	268 200			.060	.008	20 18	.40 .24	578 381	8.1 8.2	170	
October	318 227 288	36 20	44 40	17.8	22 11	57 26	255 216	.48		.068	.018	22 18	.40 .26	572 388	8.1 8		
November	334 361	44 40	42 45	28.7	26 22	80 65	256 260		.051	.056	.020	22 22	.40 .36	634 571	8.4 8.3	230	
December	337 356	43 40	44 45	26 29	22	79 66	284 264			.057	.012	22 21	.40 .35	630 556	8.4 8.2	230	150
Approx Average of Above Values	273 288	29	40	20	28	50	228			.057	.011	20	0.3	480	8.2	171	.87

*Data from Salt River Project "Water Year" Nov. 1994-95. Values in ppm.
Lowermot value of TDS calculated by E.C .D. from average of Specific Conductance.

Surface water samples taken by the SRP during the "water year 1995" are from three strategic locations where the composition of water arriving via large tributaries can be determined to affect that flowing from headwaters of the Salt (see Tables 6, 7, and 8). In this connection there are the previously mentioned springs upstream from Roosevelt Lake (see Table 4 and Map LL_1). These springs flow very saline groundwater into water of lower salinity which arrives from headwater streams, namely the Black and White rivers. Fortunately, the discharges from these very saline springs, although variable, are not large enough to seriously influence the content of the mainstream of the Salt which arrives at Roosevelt Lake (see Table 13).

Analyses listed in Tables 6 and 7 also 8 indicate significant ranges in composition which reflect spring freshets when accumulated snow melts to add water throughout the northern watershed. This is to be compared with drainage entering from a southern source namely, Pinal Creek (see Tables 13 and 14a which remained essentially the same throughout 1994. Presumably, this reflects the normal condition changing only during exceptionally severe floods which must occur at certain intervals. Pinal Creek delivers waters to the Salt which are calcium, magnesium and sulphate-rich. Commonly the combination of high values of these ions suggest that such waters have come into contact with strata containing "gypsiferous deposits", or which receive groundwater which has moved through beds containing gypsum and related salts deposited formerly as deposits of saline lakes.

Samples taken from the Salt River above Roosevelt Lake incorporate water which has been delivered by the normally highly saline Pinal Creek, and the salt springs described above, but which are diluted by mixing in Roosevelt Lake with snow melt and rain waters low in mineral content. Note, that in 1994 TDS in the Salt River above Roosevelt Lake ranged from 90 to 2290 ppm (see Table 13), and correspondingly there was a wide range in values of sodium and chloride ions (constituents of common salt). The extent of dilution and mixing attained in passage through the three reservoir-lake system are illustrated by the TDS reported in the river below Stewart Mountain Dam where the spread in annual values (1994) had been lowered to 244 and 507 ppm. Correspondingly, ranges in amounts of sodium, calcium and magnesium, etc., show reduction from waters above Roosevelt lake to those below the three-lake reservoir system. Water which leaves Stewart Mountain Dam has been reduced in ion content to that of almost potable water, and requires little treatment for human consumption, particularly when blended with Verde River water leaving Bartlett Dam (see Table 5).

Central Arizona Project (Colorado River Water)

Table 15 (See Map LL_1) illustrates analyses of Colorado River water following diversion into the CAP Canal from Parker Dam (near Parker Arizona) to arrive at 7th Street in Phoenix (milepost 162.3). Uniformity in the character of CAP water throughout the years 1990-1994-1995 suggests that except for long episodes of drought in Colorado River watershed, the current average composition of CAP water in values of common ions is likely to persist for years. This condition indicates that CAP water can be regarded to remain of essentially uniform composition from its sources to its delivery at Lake Pleasant. Hence, the average of all common ions can be depended to range within narrow limits, e.g., the TDS to remain approximately between a maximum of 659 to a minimum of 548 ppm. This means that water in the CAP reservoir system can be relied to continue tin quality, i.e., to not greatly exceed currently acceptable standards for potable water (see Table 3).

Table 13
Ranges In Ion Concentration In Surface
Waters Of The Salt River*

Location See Map LL	TDS	Sodium	Calcium	Magnesium	Chloride	Sulphate	Bicarbonate	Total Nitrogen	Copper	Chromium	Lead	Barium	Arsenic	Silica	Fluoride	Specific Conductance	Field pH
Pinal Creek at Inspiration Dam (WSRVPC4)	2300?-2600?	68-79	420-540	110-130	50-63	1600-1800	71-121	0.0-0.1	.003-.085	.001-.012	.005-.016	.027-0.1	.005	34-77	1.3-4.	2590-2890	6.6-7.8
Salt River Above Roosevelt Lake (VSRVSL6)	90-2290	10.-680	20-100	4-36	12-1200	11-180	65-246	0.2	.001-.011	.001-.003	.005-.011	.027-.050	.003-.006	15	0.2-0.3	206-4250	7.9-8.2
Salt River Below Stewart Mountain Dam (WSRVSL2)	244-507	41-123	36-50	8-14	53-194	35-75	129-165	0.3-0.6	.013-.020	.015		.005-.065	.004	17-18	0.3-	430-933	7.9-8.3
Salt River Below Stewart Mtn Dam Weighed Average for "Water Year" 1952 USGS Water Supply Paper 2254, p. 103	597	150	48	14	233	50	153							18	0.4	1090	
Drainage of Irrigation Water from Salt River NE 1/4-35, TIS-R6E Jun 1949 USGS, Water Supply Paper 2254, p. 95	1260	53	277	64	605	113	85							74	0.2	2340	

* Data and symbols from Salt River Project Annual Report 1994, and U.S. Geological Survey. Values reported in ppm. "Water Year" Oct. 1994 - Nov. 1995.

Table 14a
Range In Ion Concentration In Pinal Creek
At Inspiration Dam*

Location Pinal Creek at Inspiration Dam	TDS	Sodium	Calcium	Magnesium	Chloride	Sulphate	Bicorbanate	Total Nitrogen	Copper	Chromium	Lead	Barium	Arsenic	Silica	Fluoride	Specific Conductance	Field pH
January	2370 1632	68	470	110	58	1600	112	.002						54	1.8	2720	7.7
February	2520 1704	75	500	120	62	1700	119	 .001	.008 .003	 .001	Max .016	Max .100	Max .005		1.3	2840	7.6
March	2370 1638	71	470	110	57	1600	108	.006			Min .005	Min .027	Min .005	34	2	2730	7.2
April	2500 1692	72	470	130	63	1700	121	0	.008 .011	 .001					1.3	2820	7.5
May																	
June	2620 2520 1677	79 76	510 510	120 130	63 52	1800 1700	97 86		.005 .009					 77	1.4 4	2860 2730	7.6 7.8
July																	
August	2660 2300 1659	76 71	540 420	120 120	59 53	1800 1600	118 71	0 .002	.005 .085	 .012			2	 63	1.3 3	2890 2640	7.6 7.7
September	2600 2300 1635	77 68	490 430	120 110	59 50	1800 1600	100 73	0 .003	.003 .037	.002			1	 63	1.6 3	2860 2590	6.6 7.6
October																	
November																	
December																	

*Data from Salt River Project, "Water year" Jan - Dec 1944.
Lowermost Value of TDS Calculated by ECD from average of Specific Conductance Values.
All Values in ppm.

Table 14b

Range In Ion Concentration In Salt River Above Roosevelt Lake*

Month	TDS	Residue Solids	Sodium	Calcium	Magnesium	Chloride	Sulphate	Bicarbonate	Total Nitrogen	Copper	Chromium	Lead	Barium	Arsenic	Selica	Fluoride	Spec Conductance	Lab pH	Aluminum
January	1620		470	100	33	730	160	246			.002		.100	.006		.3	3000	8.1	
February	635 89.9? 428		150 10	52 20	15 4.1	250 12	85 11	159 65	.002	.004			.038	.005	15	.2	1200 206	7.8 7.9	.10
March																			
April	521 629 491 645		130 160 120	44 41 46	12 11 13	210 270 200	51 65 57	124 135 118		.002 .001	.001	Max .011	Max .027 .050	Max .103 .004		.2 .2	1030 1230 966	7.9 8. 8.	
May												Min .005	Min .016	Min .003					
June	1010 1700 1560		270 510	63 81	20 31	470 810	100 170	159 161		.001	.001	.002	.045	.004 .005		.3 .2	1960 3240	8.1 8.2	
July	2290 1470 2160		680 450	89 75	36 29	1200 710	180 120	188 156		.008			.100	.007		.3 .3	4250 2770	7.9 7.9	
August																			
September	1550 1470 1668		460 420	64 82	25 27	790 710	110 130	184 178		.011	.003	.004	.100 .100	.007 .007		.2 .3	2860 2700	7.9 8.1	
October																			
November	1758		460	83	29	740	130	220					.100			.2	2930	7.9	.10
December																			
Arithmetic Avg of Above Values Not Including E.C.D. Values	1123 1309		330	65	22	546	105	161								0.2	2182	8.0	

*Data from Salt River Project, "Water Year" 1994-95. All Values in ppm. Lowermost Value of TDS calculated by ECD from Average Values of Specific Conductance.

Table 14c

Range In Ion Concentration In Salt River Below Stewart Mountain Dam*

Month	TDS	Sodium	Calcium	Magnesium	Chloride	Sulphate	Bicarbonate	Total Nitrogen	Copper	Chromium	Barium	Arsenic	Silica	Fluoride	Spec Conductance	Lab pH	Hardness	Aluminum
January	451	101	49	14	154	54	152						16.5	.32	846	8.4	180	
February	244	41	38	9	53	35	132				Max		18	.2	460	8.1		
	450	96	46	13	152	75	129				.061		16.7	.31	848	8.2	170	
	392																	
March	248	43	36	8	54	35	143				Min		18	.3	430	7.9		
	499	119	48	14	177	56.	163				.005		16.4	0.3	869	8.2	175	
	390																	
April	289	52	40	10	72	39	149				.038		17	.3	500	8.4		.063
	507	123	45.	13.	194	55	143	0.6				.004	16.5	0.25	933	8.1	168	
	430																	
May	340	68	44	11	100	46	140				.045		17	.2	620	8.3		
	485	121	45	13	184	46	148					.004	16.9	0.23	911	8.4	160	
	459																	
June	349	67	43	10	101	51	151				.040		18	.3	640	8.1		.087
	495	118	46	13	187	54.	148					.004	16.5	0.26	923	7.9	170	
	484																	
July	430	93	46	12	136	57	165				.060		18	.3	730	7.9		.058
	480	116	44	13.	174	55.	148						16.4	0.25	905	8.0	160	
	491																	
August	432	98	50	14	145	49	148				.061		18	.3	780	8.2		.056
	448	105	43.	13.	162	50.	143	.31					16.1	0.27	859	8.1	160	
	492																	
September	467	106	50	14	159	58	156				.062		18	.3	918	7.9		.051
	439	108	44	12.	156	47.	138		.013	.005			17.7	0.25	808	8.0	160	
	518																	
October	501	112	49	13	142	74	154				.065		18	.3	896	8.1		.090
	435	102	43	12	157	47	144						17.4	0.26	783	7.9	155	
	504																	
November	470	105	50	14	156	67	151		.060		.060		17	.3	912	8.1		
	419	103	44	12	140	44	148						16.3	0.27	802	8.3	160	
	514																	
December	458	104	48	14	154	53	163		.020		.060		17	.3	878	8.2		
	454	108	45	12	168	42.	151						16.5	0.29	798	8.3	160	
	503																	

*Data from Salt River Project "Water Year" Nov. 1994-Oct. 1995. All Values in ppm. Lowermost value of TDS calculated by ECD from Average of Specific Conductance.

Table 15
Composition Of CAP Canal Water From Parker Dam, Arizona To 7th Street, Phoenix*

Location	Date	Avg discharge	TDS	Solids (SUM)	Sodium	Calcium	Magnesium	Chloride	Sulphate	Bicarbonate	Nitrogen	Barium	Arsenic	Silica	Fluoride	Spec Conductance	pH	Hardness (As Calc Carbonate)
At Milepost 7.98 Near Parker Dam	Feb to Aug 1990	1110	570	625	86	71	27	75	253	165	0.4	.100	.003	9	0.3	950	8	290
NE-SE-SE,8,T N-R3E, At Milepost 162.3 NE 1/4, SE 1/4 29, TION-R17W at 7th St. Phoenix	Jan to Sept 1990	1003	580	617	87	69	27	74	243	152	<0.1	.100	.002	7	0.3	967	8.4	283
At Milepost 7.98 Near Parker Dam	Oct 90 thru Jul 91	1585	567	606	88	68	26	76	225	168	0.2	.100	.003	10	0.4	945	8.2	278
At Milepost 162.3 at 7th St Phoenix	Oct 90 to Sep 91	594	602	626	94	67	28	81	262	145	0.1±	.150	.003	8	0.4	1003	8.4	283
At Milepost 7.98 Near Parker Dam	Oct 91 thru Jul 92	1588	626	663	97	75	29	94	270	162	0.2	.100	.003	9	0.3	1043	8.3	103
At Milepost 162.3 at 7th St, Phoenix	Oct 91 thru Sep 92	594	548	612	94	67	28	87	261	139	.08	.125	.003	8	0.4	913	8.4	283
At Milepost 7.98 Near Parker Dam	Oct 92 thru Jul 93	1922	568	600	97	66	25	79	228	158	.06	.100	.003	10	0.4	946	8.1	268
At Milepost 162.3 at 7th St, Phoenix	Oct 92 thru Sep 93	728	580	594	89	64	26	82	242	143	.05+	.100	.003	9	0.4	966	8.5	268
At Milepost 7.98 Near Parker Dam	Nov 93 to Aug 94	1050	659	709	100	79	30	94	285	164	0.2	.150	.003	9	0.4	1098	8.2	318
At Milepost 162.3 7th St Phoenix	Oct 93 to Sep 94	1069	605	658	93	70	28	84	253	155	0 2	.135	.003	8.6	0.4	1009	8.3	284
Average CAP Water at Granite Reef Dam	1995		587		93	71	28	81	229	167		.111	.003					

*Data from U.S. Geological Survey TDS Values Calculated by ECD from Specific Conductance.

Table 16
Composition Of Sun City, Arizona Water (1994)
In Various Plants Of Citizens's Utilities*

Plant		TDS	Residue of Solids	Sodium	Calcium	Magnesium	Chloride	Sulphate	Bicarbonate	Total Nitrogen	Nitrate	Selenium	Lead	Barium	Arsenic	Fluoride	Field pH	Hardness	(calculated)	TDS as Calc. ECD
Plant 1		247		26	37	19	43	25	97? 62		4.1			.03	<.005	<.4	7.5	171		258
Plant 2		339		32	29	18	41	20	199?		4			.03	<.005	<.4	7.8	147		234
Plant 3		341		32	40	20	93	27	129?		5.5			.05	<.005	<.4	7.7	182		329
Plant 4	Revised Value	212		26	32	12	23	27			7.4			.01	.005	<.4	7.6	129		206
Plant 5		307		30	41	18	45	34	139?		2.5			.02	<.005	<.4	7.7	177		279
Plant 6	Revised Value	278		42	36	17	62	30	893?		6.6			<.01	.005	<.4	7.2	160		292
Plant 7		265		26	38	16	19	20	146?		4.1			.02	<.005	.<4	7.7	120		196
Plant 8	Revised Value	234		26	38	19	26	27	644?		4.2			.02	<.005	<.4	7.2	173		246
Maximum Contamint Levels as Prescribed by USEPA		500±									10.0			2.0	.05	4.0				
Approx. Aver. Values CAP Water at Parker Dam (Milepost 7.9)	Nov. 93 Aug. 94	659	709	100	79	30	94	285	164	.02				.15	.003	0.4	8.2	318	194	782
Approx Aver. Values CAP Water at 7th St Phoenix (Milepost 162.3)	Oct. 93 Sep. 94	605	658	93	70	28	84	253	155	.02				.14	.003	.04	8.3	284	172	701
Approx Drinking Water Standards Acceptable In AZ		500±						500±		10.0	10	.05	.05	2.0						

*Data from Citizen's Utilities reports. Samples taken from point of entry into plant. All Values in ppm and are average values for 1994.

Table 17
Composition Of Sun City West, Arizona Water (1994)
In Various Plants Of Citizens's Utilities*

Plant	TDS	TDS Calc by ECD	Sodium	Calcium	Magnesium	Chloride	Sulphate	Bicarbonate	Total Nitrogen	Nitrate	Selenium	Barium	Arsenic	Silica	Fluoride	Spec Conductance	Field pH	Hardness
Plant 1 (Average Value 1994)	Revised Value 300	249	91	21	6	37	45	50		0.8		<.01	.018		1.24		7.6	77
Plant 2 (Average Value 1994)	Revised Value 325	351	81	39	13	52	72	90		0.1		.03	.013		1.31		7.6	151
Approx. Average Values CAP Water at Parker Dam (Milepost 7.9) Nov 93-Aug 94	659	709	100	79	30	94	285	164	.02			.15	.003	9	0.4	1098	8.2	318
Approx. Average Values CAP Water at 7th St Phoenix (Milepost 162.3) Oct 93-Sep 94	605	658	93	70	28	84	253	155	.02			.14	.003	9	0.4	1009	8.3	284
Approx. Drinking Water Standards Acceptable in Arizona	500±						250?		10.		.05	2.0			4.0			

Data from Citizen's Utilities Records for 1994, in ppm.

* Note the amounts of Bicarbonate ion present have been calculated by Dapples from Hardness Values as determined by analysis.

Tables 16 and 17 illustrate for comparison purposes differences between Sun City and Sun City West groundwaters as distributed by Citizen's Utilities from their various plants in 1994, and CAP water at Parker Dam and 7th Street Phoenix during approximately the same interval of time. These comparisons are made to indicate expected compositional differences between CAP water delivered to its reservoir (Lake Pleasant) and groundwater pumped from beneath the Sun Cities. Note, pumped groundwater delivered from Citizen's Utilities Sun Cities plants clearly are lower in all ions than average CAP water. Virtually all common ions, and TDS values approximate about one-half corresponding amounts in CAP water. For example, CAP water delivered to Lake Pleasant tends to be higher in sodium (approximately three times), calcium and chloride (more than two times), and sulphate as much as ten times groundwater pumped from beneath Sun City. High values, particularly in sodium, calcium magnesium and sulphate indicate that waters of the lower Colorado River reflect that somewhere upstream the supply of water is gypsiferous. Groundwater has been in contact with saline deposits, hence dissimilar in composition to groundwater withdrawn from below the Sun Cities where there is an absence of saline-lake sediments in the aquifer.

Current PAMA regulations permit without treatment direct recharge of CAP water to groundwater underlying the Sun Cities. All such recharged water is permitted to serve as a "banked source", and can be pumped from the ground as a domestic supply when the need is great. This means that should large amounts of CAP water be recharged to mingle with groundwater north of the Grand Avenue Fault, over the years such water is destined to increase significantly existing values of sodium, calcium, magnesium and sulphate. Moreover, except for theoretical reasons, there is no factual information that lenticular clay layers present above or in the aquifer system extend to underlie the Sun Cities from a site of presumed recharge (Jomax Road and the Aqua Fria river-channel). Also, there is no evidence that such clay layers are likely to reduce by absorption, or by chemical exchange, the long-term ion content of recharged CAP water. However, the reader should be aware that a system of open-pond infiltration to recharge the aquifer (within the flood-plain of the Agua Fria River) is considered to be one of the most economical, and environmentally satisfying methods of complying with PAMA regulations. This suggested location of construction of infiltration ponds is positioned in areas where sand and gravels are believed to dominate the upper alluvium (see Map F). Hence, movement of shallow-depth groundwater toward the Sun Cities could be rather rapid. Should exploration drilling prove this to be the case, static-water levels beneath the Sun Cities will stabilize, or rise, depending upon total pumping withdrawals. Corresponding benefits are to be expected by reduction of ground-level subsidence hazards due to continued groundwater withdrawals within the area of existing housing.

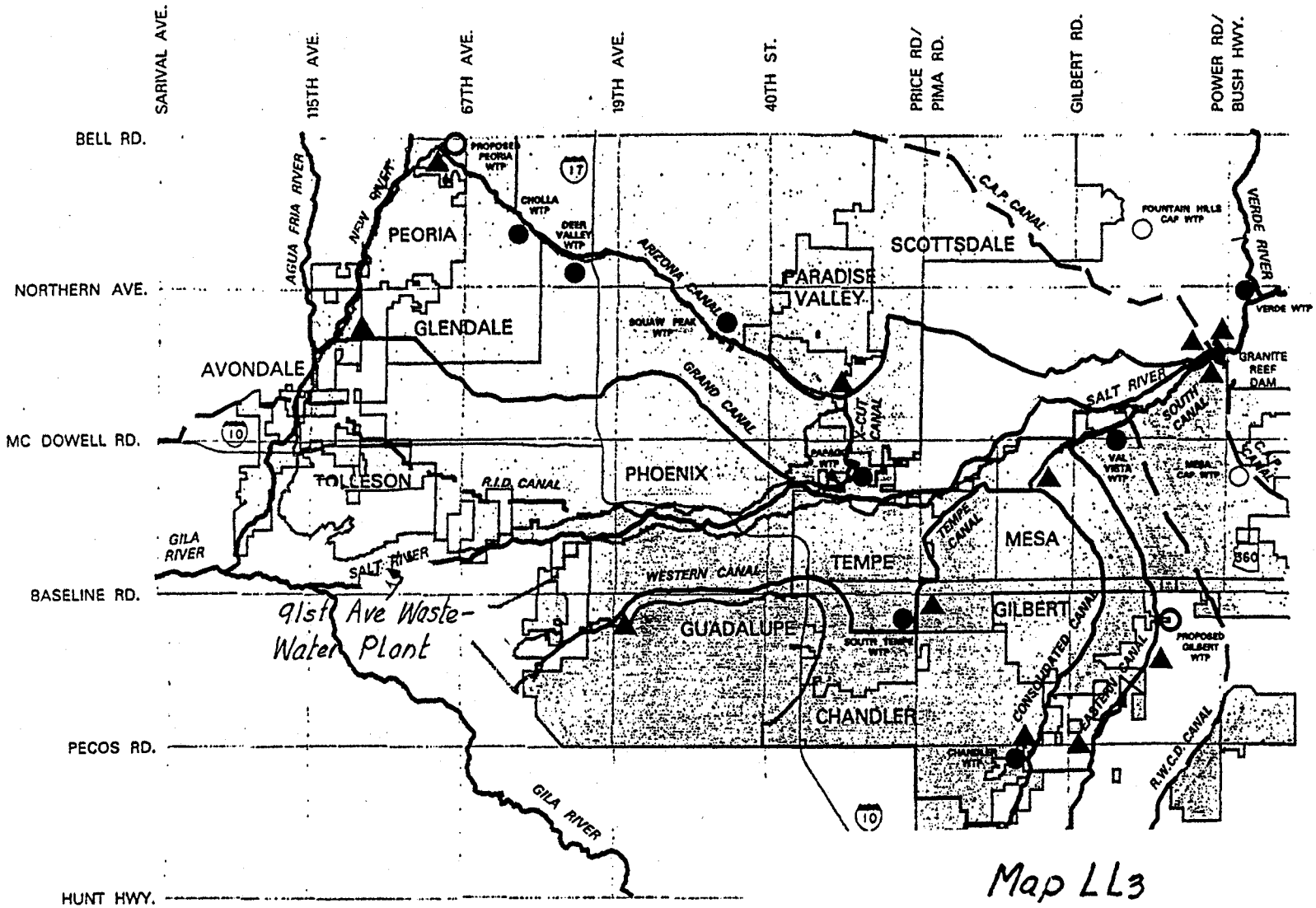
Obviously, if CAP water is to be used directly the primary problem of eventual costs to the consumer center about the total cost to the supplier. What needs to be considered is the total of such items as long-term price of allotments, an efficient distributary system, essential water-treatment plants and the possible use of waste-water effluent as a supplement to irrigation. Should the system of infiltration to the aquifer involve methods of large-scale ponds surrounded by riparian vegetation, careful analysis of this method is warranted. This system may not produce the long-term benefits which are anticipated, nor the effectiveness of direct use of CAP water blended with a fixed amount of groundwater.

Waters In The SRP Canal System

According to the SRP (1994) Annual Report, water throughout its canal system was delivered primarily from surface sources, namely watersheds of the Verde and Salt rivers, but the following statements are made "the volume and mixture of the water supplied to the canals varies seasonally .... . Releases from the Salt River system can be significantly reduced in winter months when water demand is lower. The Verde River water quality will predominate during these low flow conditions. . . . . the amounts of groundwater mixed into canals can heavily influence the water quality in the system's lower portions".

Table 18 has been arranged to indicate the effects of canal transportation upon the amounts of common ions present in each of the various canals. The reader should note that Table 18 lists mean, maximum and minimum (1995) values determined for each common ion in primary water sources, namely the CAP canal at Granite Reef Dam and the corresponding water of the Salt River below Stewart Mountain Dam. From each primary source proportionate amounts are fed into separate canals of the SRP system, namely the Arizona, the Grand, the South Tempe intake to water Treatment Plant, the Western, the Eastern and the Consolidated to supply demands of clients (see Map LL_3). As was expected, water from the CAP source tends to be somewhat higher in minimum values than Salt River water below Stewart Mountain Dam, but except for magnesium and sulphate ions differences are not great so that the blended water is about the same for each canal. Further along in Table 18, analyses of water in each of the aforementioned canals are indicated at the sites of sampling. This permits the reader to observe differences in water compositions between each canal. Also, the effect of seasonal changes, i.e., dilution from groundwater which is pumped from adjacent wells, and evaporation which concentrates the TDS as water moves along each canal. These analyses illustrate that for each canal the compositional differences during a year are much greater between recorded maxima and minima as water arrived from primary sources, than corresponding values as maintained in the various canals. As water compositions change in CAP water and from the reservoir lakes discharging at Stewart Mountain Dan, they are blended with more or less water from either source and well water of lower TDS, in order to maintain an approximate uniformity in composition of delivered water in the canals.

In order to demonstrate maintenance of composition of water in the canals, at locality of blending (Granite Reef Dam), water delivered from the Salt River system tends to be lower in TDS, calcium, magnesium, and sulphate ions, and slightly higher in chloride than equivalent CAP water. As noted previously, such differences suggest that the CAP water (Colorado River) always tends to be higher in "gypsiferous salts" (i.e., calcium and magnesium sulphate) than water of the Salt River watershed at the point of delivery into the SRP canal system. If one follows the route of the Arizona Canal between Granite Reef Dam to its terminus at 72nd Avenue (near Bell Road), there is little change (within the limits of sampling) in composition in the canal water. The sulphate ion value has been reduced by addition of groundwater to that of the Salt River below Stewart Mountain Dam. Water in the Grand Canal, sampled at 99th Avenue (Glendale) is not unlike water entering canals at the Granite Reef Dam. Waters of the Tempe (intake) and Western Canals indicate that the Western Canal at certain times is somewhat higher in TDS, chloride and bicarbonate ions than waters at Granite Reef Dam, whereas the Tempe (intake) at the sample point near 19th Avenue tends to show increases in mean average amounts of TDS, sodium, magnesium and sulphate. Such analyses of canal waters indicate observed ranges in composition depend largely on the composition



Map LL3
SRP Canal System
map is Fig. 6 in SRP 1994 Rpt.

Table 18
Composition of Canal Waters of
Salt River Project (1995)*

Location of Sampling	Total Dissolved Solids			Sodium			Calcium			Magnesium			Chloride			Sulphate			Bicarbonate		
	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
CAP Canal at Granite Reef Dam	587	705	314	93	114	56	71	84	40	28	35	15	81	100	40	229	302	69	161	176	143
Salt River below Stewart Mtn. Dam		507	244		123	41		50	36		14	8		194	53		75	35		165	129
Ariz Canal at Granite Reef Dam	370	469	156	80	115	20	41	46	27	14	24	10	113	169	18	42	65	17	155	211	126
Arizona Canal at Invergarden & Indian School Rd	367	471	152	81	119	19	40	47	26	13	19	10	116	172	17	41	59	15	147	176	123
Arizona Canal near 72nd Avenue	364	487	148	80	117	18	39	49	25	14	24	9	112	174	18	43	67	15	146	201	117
Grand Canal near 99th Avenue	382	495	153	82	117	21	40	49	26	15	22	10	119	183	19	45	65	15	149	194	122
South Canal at Granite Reef Dam	371	484	165	75	119	25	43	49	27	16	28	10	101	185	23	48	65	18	173	246	123
South Canal near Brown Road	396	482	158	81	118	22	45	54	27	17	27	10	105	160	20	63	130	16	166	249	123
Tempe Canal intake to South Treatment Plant	399	496	151	79	121	20	45	51	26	18	27	9	101	176	18	69	132	18	171	246	121
Western Canal near 19th Avenue	517 (?)	848	213	107	169	33	52	85	30	21	40	11	153	264	49	87	160	23	171	251	129
Eastern Canal at Warner Road	420	732	151	88	204	19	45	55	26	16	27	9	116	294	17	67	130	17	164	242	123
Eastern Canal at Pecos Road	417	573	162	88	139	23	46	71	28	16	22	10	127	213	21	63	83	18	146	193	122
Consolidated Canal at Pecos Road	409	499	152	83	118	21	45	52	26	18	27	10	107	182	20	70	139	17	167	240	118

*Data from Salt River Project Reports. Values are in ppm.

Table 19
Range In Metal Ions In Canal Waters
Of Salt River Project (1995)*

	Aluminum			Arsenic			Barium			Chromium			Copper			Selenium		
	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
CAP Canal at Granite Reef Dam	53	181	25	3	5	2	111	144	57	6	13	5	8	36	5	4	28	1
Ariz Canal at Granite Reef Dam	245	1,200	25	5	10	2	48	59	30	5	5	5	8	29	5	1	1	1
South Canal at Granite Reef Dam	79	393	25	6	14	2	46	60	25	5	11	5	9	26	5	1+	2	1
South Canal Near Brown Road	149	418	25	6	13	2	53	67	23	6	11	5	7	25	5	1+	2	1
Ariz Canal at Invergordon & Indian School Rds	86	226	25	5	9	2	46	60	22	6	12	5	6	11	5	1	1	1
Ariz Canal Near 72nd Avenue	202	296	25	6	10	2	42	60	19	6	10	5	7	13	5	1	1	1
Grand Canal Near 99th Avenue	117	245	52	5	9	2	51	59	30	5	5	5	8	28	5	1	1	1
Western Canal Near 19th Avenue	120	224	25	4	8	2	58	88	27	6	16	5	9	38	5	1	1	1
Eastern Canal at Warner Road	123	281	25	5	13	2	51	69	23	6	12	5	8	25	5	1+	3	1
Eastern Canal Near Pecos Road	137	289	25	5	10	2	52	70	26	6	12	5	7	19	5	1+	2	1
Consolidated Canal at Pecos Road	121	251	25	6	12	2	52	64	26	5	5	5	6	14	5	1+	3	1
Intake to Tempe South Treatment Plant	175	368	25	6	13	2	54	66	25	6	14	5	8	35	5	1+	4	1
Effluent 91st Ave. Waste-Water Treatment Plant				Nov 95 4 Dec 95 4 Jan 96 4						<10 <2 <10			7 5 4			<3 <3 <3		

*Note values reported are in Parts Per Billion, rather than Parts Per Million as reported for common ions. Data from Salt River Project Records.

of the primary-source water at the time of sampling, which in turn is controlled by the amount and composition of inflow water into the reservoir lakes. Except for sulphate-ion the Eastern and Consolidated Canals at Pecos Road sampling sites show relatively small differences from waters at Granite Reef Dam, and there is no satisfactory explanation other than similarity in water composition at times of sampling.

Table 19 indicates the distribution of metal-ions in canal waters. Except for aluminum which shows some increase in amount with greater distance from Granite Reef Dam, all other values of metal-ions are very low in amounts. Indeed, such differences which are observed are likely to be consequences of sampling error. In short, water in the SRP canals is so well blended, and so well managed, that essentially the same quality of water is delivered throughout the entire system.

Salinity Increases In The Lower Salt River

The Salt River, which from time to time undergoes very extensive flooding following episodes of abnormal precipitation or snow melt in its watershed, tends to show very significant ranges in composition of common inorganic ions. These ranges in composition are illustrated in Table 20 which shows this variability during 1995, as indicated by samples taken and analyzed chiefly in laboratories of the U.S. Geological Survey. Table 20 is best interpreted by examining analyses and discharges taken along the river at various sampling points, e.g., stream discharge out of Roosevelt Dam was 15,900 cubic feet, per second (cu. ft./sec.) on Feb 16, 1995. This value indicates that large discharges had been occurring for at least several days inasmuch as 53,100 cu. ft./sec. of water movement was recorded at the 27th Avenue sampling site the preceding day. However, the TDS values instead of being lowered showed a total increase from 110 to 356 ppm during approximately the same stage of high-water flow. Such large differences in discharges from Roosevelt Dam are reflected throughout the lower part of the river system, e.g., a flow of 60 cu. ft./sec. was recorded at Priest Drive on January 12, whereas six days earlier it was 1430 cu. ft./sec.. In view of such large variability in amounts of water discharged from Roosevelt Dam, a high degree of uncertainty prevails in the ability to predict the chemical composition of such water downstream. For example, as indicated earlier, the TDS of water when the discharge rate was 15,900 cu. ft./sec. was approximately 110 ppm, whereas the day before at 27th Avenue when the rate of flow was 53,100 cu. ft./sec. the TDS value was 356. Yet in general, values of TDS tend to lower when there exists corresponding increases in discharge rates. Sodium, chloride and bicarbonate values tend to follow patterns similar to TDS values, but predictability in composition of waters is quite uncertain as water of the Salt River continues downstream near its junction with the Gila.

Prediction of composition of water flowing in the lower Salt River is complicated by introduction of variable amounts of effluent discharge from the 91st Avenue Waste-Water Treatment Plant which does increase values of sodium, chloride, sulphate, bicarbonate and nitrogen in the Salt River compared to analyses of water in the river at 51st Avenue bridge, Phoenix (see Tables 20, 21 and 22). the reader should understand, however, that all along the channel of the river below Roosevelt Dam, there are recorded variable amounts of common ions, but the total salinity tends to remain low. Only during stages of low water discharge do the TDS tend to exceed maximum contaminant levels as established by the Environmental Protection Agency.

Table 20
Composition Of Salt River Waters (1995) From Below Roosevelt Dam
To Confluence With Gila River near 107th Avenue*

Location	Date of Sampling	Stream Width (ft)	Discharge Cuft/sec	TDS calc by ECD	Solids Residue	Sodium	Sodium % of Metal	Calcium	Magnesium	Chloride	Sulphate	Bicarbonate	Nitrogen	Nitrogen Organic & Ammonia	Barium	Arsenic	Silica	Fluoride	Specific Conductance	Aluminum	Chromium	Copper
Salt River at	2/16	567	15,900	110	105	10	23	20	4	12	11	65	<.05	1.	.016	.003	15	<0.1	206			
Roosevelt below	4/28	107	1150	576	491	120	63	41	11	200	51	118		<0.2	.026	.003		0.2	966			
Roosevelt Dam	7/07	131	225	1740	1480	450	75	75	29	710	120	156		0.2	<.10	.004		0.3	2770			
Salt River at	1/7	1400		416	359	76	52	41	12	110	46	134		.35		.005			694			
Alma School Rd	1/30	80		247		44	37	36	17	52	42	177		<.20		.008			556			
	2/16	900		240	228	29	30	32	15	30	29	157		.81		.018			400			
Salt River at	1/6	805	1430	203	204	36	44	26	8	54	24	98		1.4		.010			338			
Priest Drive	1/12	285	60	403	405	88	30	44	13	130	52	152		.22		.004			672			
Salt River 27th Avenue	2/15		53,000	356	347	37	27	44	25	26	61	243		1.7		.031			593			
Salt River at	1/7	180		354	318	68	53	32	11	88	49	130		.94		.010			590			
51st Avenue	1/30	130		511	467	93	49	46	22	110	80	223		.47		.010			852			
Bridge	2/17			229	214	28	31	30	14	30	26	140		.81		.017			381			
Salt River at 91st Ave (Center Channel)	3/12 1996	11		1206	1170	320	70	47	40	410	200	163	30	15			4.	0.7	2010			
Effluent Water from 91st Ave	Nov 1995			900	834	170		65	32	190	200	288	22	18			2	1.9	1500		.01	.006
Waste-Water Treatment Plant	Aver for 1995					233		56	24				19		.02	.003		1.5		0.1		
	Jan thru Apr 1996		102	881	837	178	59	57	26	217	170	261	15	14			20	1.7	1468			
Salt River below Stewart Mtn Dam Weighted Average	1952 Water Year		562	597	611	150		48	14	233	50	153					18	0.4	1090			

*Data from records of U.S. Geological Survey (1995) in ppm. TDS values calculated by ECD from Specific conductance.

Table 21
Ranges In Common Ions In Effluent From
91st Avenue Waste-Water Treatment Plant*

Date		Stream Width	Discharge cuft/sec	TDS	Solids Residue	Sodium	Sodium Percent	Calcium	Magnesium	Chloride	Sulphate	Bicarbonate	Total Nitrogen	Nitrogen Organic & Ammonia	Silica	Fluoride	Specific Conductance	Field pH	Hardness as Calcium Carbonate
1995	11/29			900	834	170	54	65	32	190	200	288	22	18	20	1.9	1500	7.3	290
1996	1/18		83	924	858	180	59	57	25	230	160	283	21	21	19	1.7	1540	7.6	250
	2/5		224	840	768	170	60	53	24	200	160	283	20	20	21	1.5	1400	7.4	230
	3/2		41	846	866	180	59	58	27	220	180	222	6.6	3.8(?)	19	1.6	1410	7.4	260
	4/10		61	912	856	180	59	58	27		180	257	12	10	20	1.9	1520	7.6	260
Average for Jan-Apr 1996				881	837	178	59	57	26	217	170	261	15	14	20	1.7	1468	7.5	250
Average from SRP and U.S.G.S. for 11 months of 1995 and 4 months of 1996				956		233		56	24	210	176	267							258
Salt River at 51st Ave Bridge Jan-Feb 1995 (See Table 20)		130- 180-		229- 511	214- 467	28- 93	31- 53	30- 46	11- 22	30- 110	26- 80	130- 223					381- 852		
Salt River at 91st Ave (Center Channel)	1996 (Jan thru Apr)	11		1206	1170	320		47	40	410	200.	163	30	15	4	0.7	2010	8.9	280
Salt River below Roosevelt Dam (range of Values See Table 20)	1995		110	1740		10- 450		20- 75	4- 29	12- 710	11- 120	65- 156					206- 2770		

*Data from U.S. Geological Survey Reports and Salt River Project: Values of TDS have been calculated by ECD from Specific Conductance. All Values in ppm.

Table 22
Composition Of Effluent From 91st Avenue Waste-Water Treatment Plant (1995)*

Date 1995	Sodium	Potassium	Calcium	Magnesium	Sulphate	Aluminum	Nitrate as Nitrogen	Chromium	Copper	Arsenic	Fluoride	Selenium	Barium	pH
January	187	14	55	26		.11		.01	.009				.03	7.6
	190	12	58	27		.08	11.		.011	.004	1.28	.003		
February	140	15	60	26		.13		.01	.007					7.1
	191	13	60	27								<.003		7.3
										.003				7.4
March	173	6	53	20		.18		.004	.005				.01	7.2
	179	7	52	21		.15						<.003		6.8
										.002				7.0
														6.9
April	186	15	54	20		.06	6.	.01	.006	.003		<.003	<.01	
	210		59	23	50?	.11	10.		.005	.004				7.2
May	158	13	54	22			10.	.006		.002				
							14.					<.003		7.2
June	199	14	54	25				<.01	.004				.02	
	189		57	24						.003		<.003		7.2
July	180	17	55	23		.05		<.01	.003	.004		<.003	.02	
	179	15	55	22										
August	347	17	56	23		.07	14.	<.01	.004	.004		<.003	.02	
	366	15	57	24					.005		1.52	<.003	<.01	7.0
September	368	13	54	22		.05			.005				.02	6.9
	376	14	55	23			4.			.003		<.003	.02	6.9
October	349	15	55	23		.06		<.02	.004				<.01	6.8
	367		56	23	50?					.004	1.64			6.9
														7.0
November	157	12	59	29			13.	<.01	.007				.02	
	157		60	29					.006	.004		<.003		6.6
December								<.02	.007	.004				7.0
									.003	.004		<.003		7.2
														7.2
Jan 1996								<.01	.004	.004		<.003		
Arithmetic Average for 1995 (Calc. by ECD)	233	12	53	24										7.1

*Data from Capital Adequacy Project (1995). Values in mg/l

During flood conditions, water from the river less than 500 ppm TDS is infiltrated into the aquifer system virtually all the distance to the 91st Avenue plant (see Table 20). When river-water receives the effluent discharge from the 91st Avenue plant there must be some increase particularly in sodium, chloride, sulphate, bicarbonate and nitrogen. However, analyses of water in the Salt River below the 91st Avenue plant indicate exceptionally high values in sodium, chloride, bicarbonate and nitrogen. Although much of the increase in salinity can be attributed to the addition of the effluent, the high values of sodium and chloride suggest ground-water addition feeding into the river during normal river flow. The writer interprets the source of the extraordinary increase in salinity to be the consequence of such groundwater having dissolved salts by flowing through alluvium deposited in the ancient saline lake.

Groundwater In Wells Bordering The Salt River And SRP Canals

On maps prepared by the writer (see Vol.1, No. 4) groundwaters (1988-1991) in wells some distance north of the Salt River, but generally paralleling the river valley from below Stewart Mountain Dam to the 91st Avenue Treatment Plant, indicate westward increases in TDS, sodium and chloride ions toward its junction with the Gila. Over the years, in the same wells there is noted little change in magnesium but more so in sulphate ions (compare Maps EE, FF, GG, and HH). Magnesium and sulphate are indicated as larger values in groundwater than in the average Salt River water leaving Roosevelt Dam. If the composition of the average Salt River water during 1995 approximates that during the interval 1987-1991, the observed composition of the groundwater suggests that it has been in contact with additional salts (see Table 20). Also, that the origin of such salts is likely to be "gypsiferous salts" deposited in ancient saline lakes and incorporated as lenses or layers in the alluvium which in this region is the lower part of the aquifer system.

In order to have a better understanding of this interpretation, analyses of water drawn from SRP wells, the location of which are more or less adjacent to the Salt River, have been assembled (see Table 23 and Map MM). Note e.g., that only during conditions of low river discharge (see Table 20) do ion values exceed those of groundwater pumped from each well. On the date of sampling, the composition of groundwater was higher than Salt River waters as far downstream as the 51st Avenue bridge (see Table 20). Such is true for sodium, calcium, chloride, bicarbonate and sulphate. As these ions increase in groundwater westward, the source of enrichment of such ions must be salts which were deposited previously in the alluvium constituting the aquifer system.

Should additional study prove the former existence of a saline lake near the present site of the 91st Avenue Plant, it is important to note that CAP water delivered by canal to 7th Street Phoenix tends to be considerably lower in sodium, chloride and bicarbonate, but generally higher in sulphate than groundwater drawn from wells paralleling the lower Salt River (see Tables 20 and 23). Such an observation leads to the significant speculation that over the long-term recharge of CAP water in this area should dilute the total salinity of water in the aquifer (see Map EE).

Composition Of Waters In The Gila River System

Examination of water composition in SRP wells cited above (Table 23) indicate that major increases in its salinity are noted in the general region of the lower Salt, especially approaching the confluence with the Gila River. It is the latter waters which appear to be large contributing agents

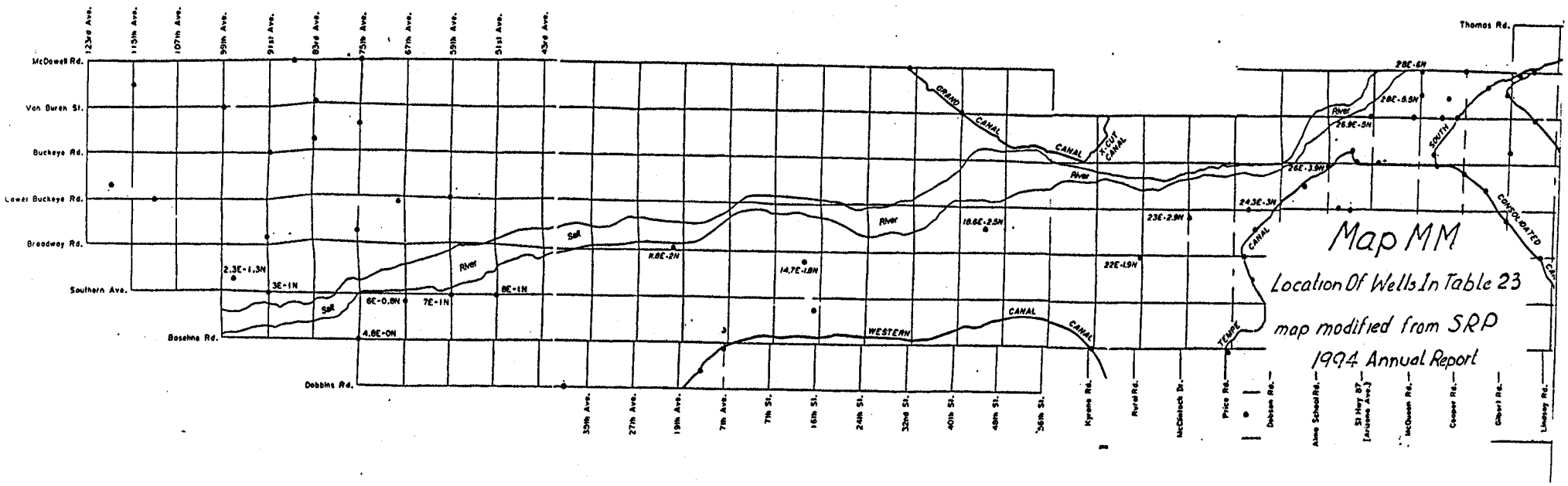

Map MM
Location Of Wells In Table 23
map modified from SRP
1994 Annual Report
McDowell Rd.
Van Buren St.
Buckeye Rd.
Lower Buckeye Rd.
Broadway Rd.
Southern Ave.
Baseline Rd.
Dobbins Rd.
Thomas Rd.
123rd Ave.
115th Ave.
107th Ave.
99th Ave.
91st Ave.
83rd Ave.
75th Ave.
67th Ave.
59th Ave.
51st Ave.
43rd Ave.
35th Ave.
27th Ave.
19th Ave.
7th Ave.
7th St.
16th St.
24th St.
32nd St.
40th St.
48th St.
56th St.
Kyrene Rd.
Rural Rd.
McClintock Dr.
Price Rd.
Dobson Rd.
Alma School Rd.
Hwy 87 (Arizona Ave.)
McQueen Rd.
Cooper Rd.
Gilbert Rd.
Lindsay Rd.
GRAND CANAL
CANAL
X-CUT CANAL
River
Salt
WESTERN
CANAL
TEMPE
CANAL
SOUTH
CONSOLIDATED
2.3E-1.3N
3E-1N
6E-0.8N
7E-1N
8E-1N
4.8E-0N
8.8E-2N
14.7E-1.8N
18.6E-2.5N
22E-1.9N
23E-2.9N
24.3E-3N
26E-3.9N
26.9E-5N
28E-5.5N
28E-6N

Table 23
Composition Of Waters Pumped From Wells Near Salt River By Salt River Project (1994)*

Salt River Project Location (see Map MM)	Date of Sample (1994)	TDS	Sodium	Calcium	Magnesium	Bicarbonate	Nitrate as Nitrogen	Chloride	Fluoride	Sulphate	pH Lab	Specific Corductance	Silica	Aluminum	Arsenic	Barium	Chromium	Copper	Lead	Selenium
2.3E-1.3N	7/11	1390	391	70	29	427	15	39 8	0.6	214	7.5	2170	33.		.006	.036				
3E-1N	6/29	1650	375	153	54	339	11	590	0.3	253	7.1	2750	28	59	.010	.040				
4.8E-0N	6/29	2130	545	171	66	403	19	698	0.3	365	7.1	3470	32	89	.005	.038				
6.E-0.8N	6/30	1360	339	103	40	262	10	494	0.5	206	7.5	2400	24	56	.008	.047	.011			
7E-1N	6/30	1740	476	115	50	468	21	548	0.6	226	7.4	2500	32	64	.006	.043			2	2
8E-1N	9/1	1590	446	90	37	429	13	498	0.8	237	7.4	2340	32		.010	.044			2	3
11.8E-2N	9/15	1130	299	79	28	340	13	367	0.3	129	7.4	2170	26	75		.105	.013	.012		2
14.7E-1.8N	6/27	1380	351	101	41	439	28	385	0.5	154	7.4	2120	34	73	.006	.073				
18.6E-2.5N	9/15	1140	278	89	38	479	13	323	0.5	117	7.5	2150	35	58	.004	.095	.019	.014		2
22E-1.9N	9/19	829	220	60	24	406	7	254	0.3	38	7.6	1550	32			.061	.018	.011		2
24.3-3N	9/21	828	186	69	25	256	11	270	0.2	98	7.6	1600	32			.066				2
26E-3.9N	6/23	637	144	56	18	240	9	194	0.3	63	7.6	1080	23		.005	.053				
26.9E-5N	9/27	508	148	34	11	237	3	127	0.3	52	7.9	967	22		.004	.017				
28E-5.5N	5/19	771	194	65	23	362	6	200	0.2	78	7.6	1270	25							
28E-6N	6/23	633	155	47	16	329	7	156	0.3	63	7.6	1060	24		.005	.040				
Average CAP Water at 7th St Phoenix (93-94)		605	93	70	28	155	2	84	.4	253					.003	.14				
Salt River below Roosevelt Dam See Table 16	7/07 94	1740	450	75	29	156		710		120		2770								

*Data from 1995 Annual Report Salt River Project. Values reported in ppm.

to increased in overall salinity. For this reason, analyses of water constituting the mainstream of the Gila are important in determining localities and sources of occurrences where such increases appear. Inasmuch as this river (surface) water infiltrates the groundwater system, it can be identified as a major source of contamination of the aquifer in the southern part of the Sub-Basin.

The Santa Cruz River, and its watershed, constitute an important source of water from the south delivering water to the Gila River system. Analyses of this water are illustrated in Tables 9 and 10 during the course of periodic sampling from late 1976 to late 1983. At the sampling site near Laveen, Arizona, these waters show extreme variability in discharges and composition. However, the values in composition of common ions range about one-tenth the amounts observed in the principal channel of the Gila near the junction with the Santa Cruz. Differences exist in amounts of all common ions, and these appear roughly related in inverse order to volumes of water flowing past the localities of sampling (note e.g., composition of flood-water (1971) in the Gila, Table 8). Inasmuch as throughout the watershed there has been no significant increase in human population, the general increases in sodium and chloride are interpreted as "natural" and believed to be derived from sporadic return flow of groundwater (more saline) into the stream channel. Inasmuch as TDS values are low in water in the main channel of the Santa Cruz, generally low values of magnesium and sulphate indicate such waters are adequate for crop irrigation, and with little treatment, suitable for human consumption.

Such "potable" waters contrast with water flowing in the channel of the Gila river sampled before it is diverted for use largely for crop irrigation by the Gila River Indian Community (see Table 7). Although flow rates of the Gila are somewhat greater than those of the Santa Cruz (and the years of sampling are not the same) the TDS are about seven times that of water flowing in the Santa Cruz, and similar increases are indicated in common ions dominated by sodium, chloride, magnesium and sulphate. These large differences in composition between waters of the two rivers suggest that Gila waters are fed in part by groundwater which flows through strata containing "gypsiferous salts". The increase in TDS of Gila River-water continues downstream as indicated by samples above its confluence with the Salt (see Table 10). At this point the TDS are recorded to approximate 7,000 ppm, and sodium chloride is extremely high. All ions have increases dramatically (see e.g., the substantial differences in hardness values between waters of the Santa Cruz and those of the Gila proper).

Observed significant increases in TDS and common ions, as the Gila River nears its junction with the Salt deserve thorough investigation concerning the source of this salinity. As indicated earlier the interpretation preferred by the writer, considers the increases in TDS to represent flows of substantial amounts of groundwater through strata deposited in scattered former saline lakes, rather than the product of reflux of irrigation water used on the Gila River Reservation.

If the return flows of groundwater feeding into the Gila upstream of its junction with the Salt are the principal contributing sources of the saline water in the main channel, this should be determined to be distinct from the composition of groundwater several miles distant from the primary river channel. Moreover, if the significant increase in salinity occurs in the channels of the present course of the Gila River in the vicinity of the Indian Reservation, perhaps some cement-lined artificial channel of the river could drastically reduce the salinity of the Gila River downstream.

Sources of salinity in the Gila and Salt rivers are of considerable importance to the southern part of the Sub-Basin. Groundwater that is pumped from this area is replaced by groundwater high in TDS flowing northward along a gentle gradient from the general area of the source near the junction of the Salt and Gila. Maps N, O, AA, EE, FF, and HH illustrate this northward invasion of saline water feeding into the aquifer to advance northward toward the Glendale Rise. From the Glendale Rise in T2N-R1E the gradient of static-water levels is steep into southeastern sectors of Sun City. As water is pumped from southern Sun City it is slowly being replaced by water of higher TDS. In this connection, it becomes important to determine the extent to which the Grand Avenue Fault serves as a partial barrier to prevent contamination of groundwater north of the fault. Based upon present-day information, the writer considers this partial barrier to protect this northern sector of the aquifer. However, as additional groundwater is pumped from the aquifer north of the fault the net effect will be to accentuate the "problem area", and warrants some form of recharge in that area.

The reader's attention is directed to Tables 10 and 24 which list the composition of water in the Gila River where a fraction is diverted into the Buckeye Canal. In November 1995, and the first four-months of 1996, samples of this water indicate TDS values ranged from 1314 to 1674 ppm. When these values, along with those of common ions, are compared with corresponding values in the Gila River channel above the confluence with the Salt, they show a reduction at least approximating four-times. The writer is not aware of how this reduction is brought about, but presumably the river water is blended with groundwater pumped in the local area where the water table is very near to the land surface creating soil saturation. An old analyses of river water (see Table 11) indicates that at Gillespie Dam (near Gila Bend) the river is once again highly saline.

Table 24
Composition Of Gila River Water Above
Diversion At Head Of Buckeye Canal*

	Date	Discharge cuft/sec	TDS	Residue Solids	Sodium	Sodium Percent	Calcium	Magnesium	Chloride	Sulphate	Bicarbonate	Total Nitrogen	Nitrogen Organic & Ammonia	Silica	Fluoride	Specific Conductance	Field pH	Hardness
1995	11/30		1314								293	16	13			2190	7.6	
1996	1/17		1650	1570	360	61	110	49	580	240	301	17	16	20	1.4	2750	7.8	480
	2/7		1590	1500	330	59	110	49	550	240	309	20	17	21	1.8	2650	7.7	480
	3/13	265	1674	1650	370	60	60	55	600	260	317	20	16	20	1.2	2790	7.4	530
	4/11		1434	1360	300	59	100	46	490	220	270	11	8.0	19	1.3	2390	7.7	440
Average Nov. 1995-Apr. 1996			1532	1520	340	60	95	50	555	240	298	17	14	20	1.4	2554	7.6	483

*Data from U.S. Geological Survey report. (U.S.G.S. Stream Station #09513990)
Values in ppm. Approximate values of TDS are calculated by ECD from Specific Conductance.

CONCLUDING REMARKS

General Background

The previously published reports (Vol. 1, No's. 1-4) have been prepared primarily for citizens of the Sun Cities in order that they may better understand the elevation, general gradients and chemical composition of waters which underlie the Sub-Basin. Inasmuch as the current supply for the Sun Cities is entirely groundwater, it has been necessary to report on those geological conditions which influence this supply, and which affect its composition. Although infiltration to the groundwater from its northern sources has continued its southerly flow. Man's agricultural and urban growth has modified this natural pattern by exhaustive pumping. Hence, over the past 60 years regional depressions (Luke and Deer Valley Lows) have formed in the water-table surface, and the original equilibrium and specific directions of flow no longer prevail. Rather, there have developed reduction in the volume of water infiltrated, as roofs and pavement reduce the area of infiltration surface, and pumping has produced differential levels and local gradients. As patterns of urban growth have developed, water-table levels have fallen in those localities such that the environs of the Sun Cities are considered by the writer to be part of a "problem area".

Various organizations and individuals have presented rather opposing viewpoints regarding the future available quantity and quality of this groundwater, based upon very simplistic geologic conditions. Hence the writer has directed the reader's attention to those geologic features which control the water supply, and its chemical composition. It is the geologic control which must be examined in more detail to understand the entire water balance.

In this report, data extracted from scattered reports and files deal with the chemical composition of surface waters which supply some of the needs of the economy of the Sub-Basin. Such data have been interpreted so that the reader has factual information to clarify the issue of whether the chemical composition of the surface water gradually is adding to the salinity of the groundwaters. In future years, will much of the water pumped in the Sub-Basin require treatment, or had we better rely upon the Central Arizona Project to supply adequately the needed water? The reader is now in the position to understand the following:

1. Numerous and extensive geologic faults are known to exist within the Salt River Basin. Some to these outline the mountain blocks the erosion of which have been a primary source of the alluvium containing the groundwater. Hence, the aquifer becomes increasingly thinner toward the mountain blocks to reach theoretical values of zero.

Certain other faults traverse the Basin. It is not known whether some of these displace and tilt parts of the alluvium of the aquifer system, but they do appear to have control over the direction and amount of land-surface subsidence.

2. An important fault traversing the Sub-Basin is the Grand Avenue Fault. As long as groundwater supplies have been plentiful, the presence of this fault has been ignored completely. Among other features this fault is interpreted by the writer to act as a barrier to separate groundwaters of relatively low ion concentration to its north, from groundwater of progressively higher ion concentration prevailing to the south.

3. Extensive lava flows are interbedded with alluvium in the northeast and central sectors of the Sub-Basin. Also, they may reduce the amount of groundwater over their area of distribution. Although these occur at depths below current static-water levels, and hence have been ignored, no one has determined the extent to which these lavas influence the amount and direction of lateral flow of groundwater, or whether they act as basement below which no water occurs.

4. The Luke Salt Body has been studied and known to be very large (several cubic miles in volume), but its influence upon the direction of flow of groundwater is known only generally. As gradients are steepened and modified by pumping, the salinity of groundwater is certain to be increased in the vicinities of Luke Air Force Base and Litchfield Park.

5. Lenses of halite (salt) and gypsum exist in the lower part of the alluvium over a poorly defined area in southeastern parts of the Sub-Basin. These occurrences are the products of precipitation in a saline lake which existed during accumulation of the older parts of the alluvium. The area underlain by this body of water has not attracted any attention by professionals. Groundwater moving through alluvium dissolves some of these salts to become increasingly saline. Whether the Grand Avenue Fault constitutes a barrier to the northeast movement of increasingly saline groundwater is of considerable importance. As static-water levels continue to lower differentially, this more saline water will flow increasingly toward the Sun Cities.

6. As pumping has modified the directions of groundwater flow, gradients of groundwater infiltrated from the Salt and Gila rivers permit a slow invasion of very saline water toward the Glendale Rise. In future years, providing no recharge occurs to the aquifer system, the increase in population throughout the northern part of the Sub-Basin will increase groundwater demands, and continued heavy pumping will accelerate the northward flow of saline groundwater toward the Sun Cities.

Concerning The Present Report

Parts 3 and 4 of the preceding reports outlining the geologic features in the Sub-Basin also revealed the existence of very high values of TDS in groundwater near the junction of the Salt and Gila rivers and farther downstream. These groundwater-composition maps covering a span of more than ten years indicated this saline water to be advancing toward the Glendale Rise, and slowly adding to the salinity of water in the southeastern sector of the Sub-Basin. The new gradient of groundwater flow had been established by continued pumping from wells south of the Grand Avenue Fault, and had been accelerating the replacement of water lower in TDS by the more saline groundwater. This condition led to the writer's inquiry regarding the source of the saline water in the lower Salt, and particularly part of the Gila River.

This search of the composition of water entering the Sub-Basin has in effect produced the present report to provide the reader with an understanding of the composition of all water which influences groundwaters in the Sub-Basin. Fortunately, the SRP has been aware of the great variability in composition of waters which feed its lake-reservoir system, and has published analyses of waters in the tributaries which feed the Salt River. Also for years the U.S. Geological Survey has

monitored the composition of waters in the watershed of the Gila. From such scattered data, the writer has compiled, and interpreted the common ion compositions of these waters, including CAP Water, which has been delivered to the Sub-Basin recently.

It is the summation of these data which has led to the interpretation presented herein, namely that the Gila River surface water is the fundamental source of contamination to groundwater in the Sub-Basin. The consequence of this inquiry is to recommend a very thorough hydrologic study of the Salt and Gila rivers as they deliver surface waters to be infiltrated to the aquifer system. Such a study needs to include the localities where each river derives its significant increases in TDS values (i.e., localities of former saline lakes). Also, whether these saline sources can be reduced or eliminated. In this connection, the relative uniform composition of CAP water must be considered both as a blending source to reduce the high salinity in waters being infiltrated, or as a direct supply of water to the growing metropolis north of Bell Road.

APPENDIX

Maps Used In Volume 1, No's 1 - 4

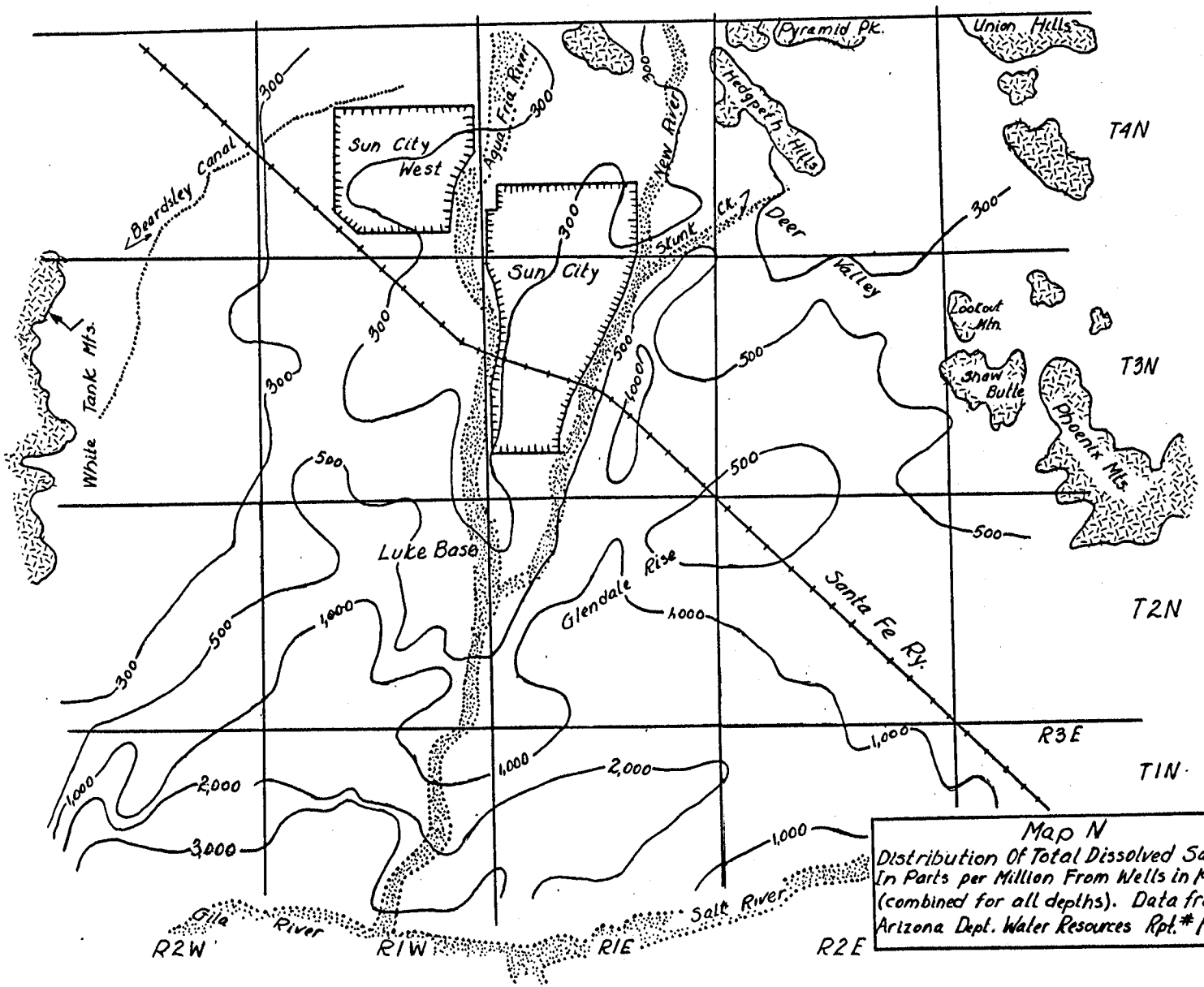
Placed As Appendix

For Ready Reference

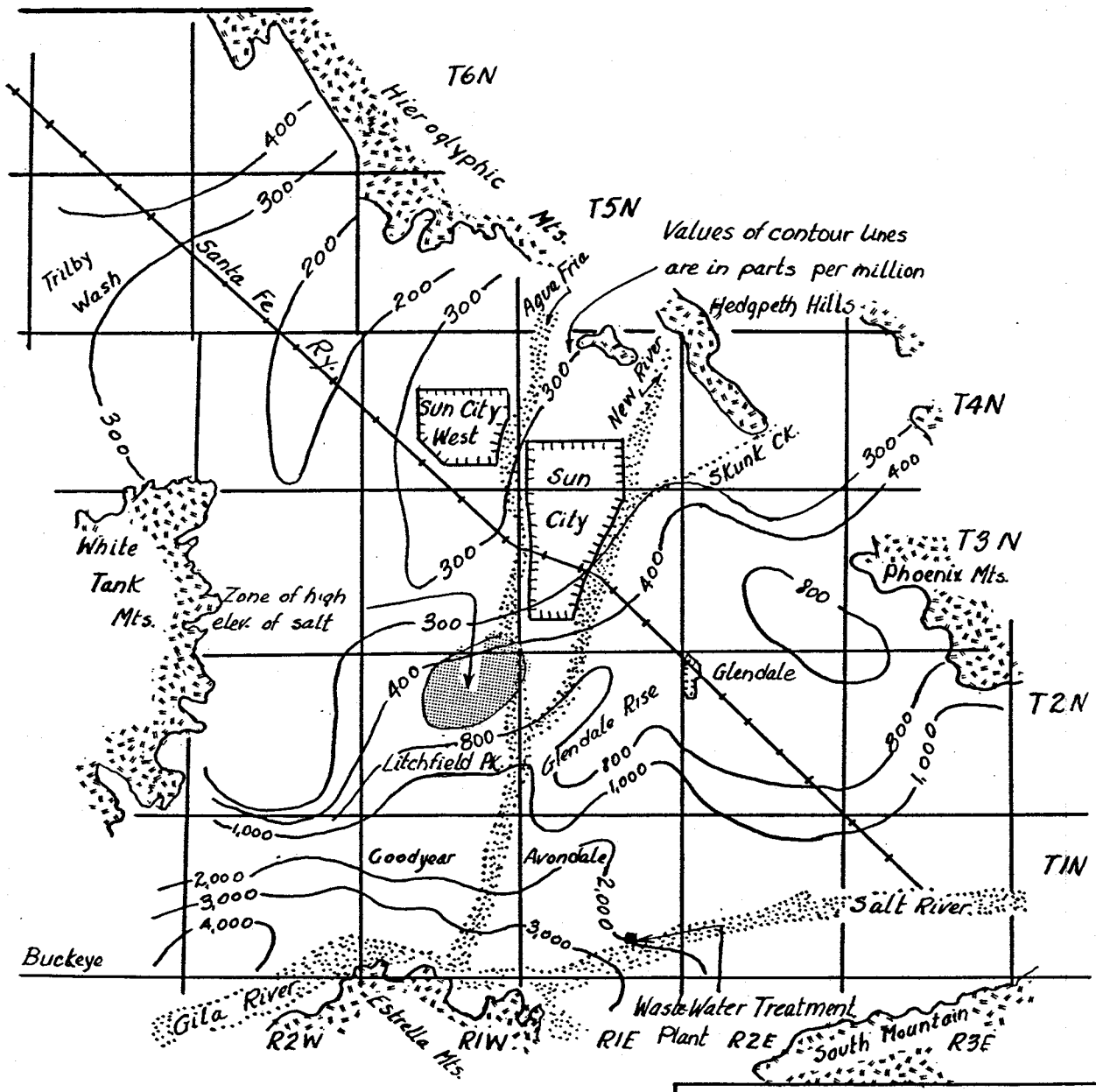
REGISTERED GEOLOGIST
CERTIFICATE NO.
13595
EDWARD C.
DAPPLES
Date Signed
ARIZONA

Edward C. Dapples
5/30/97

A

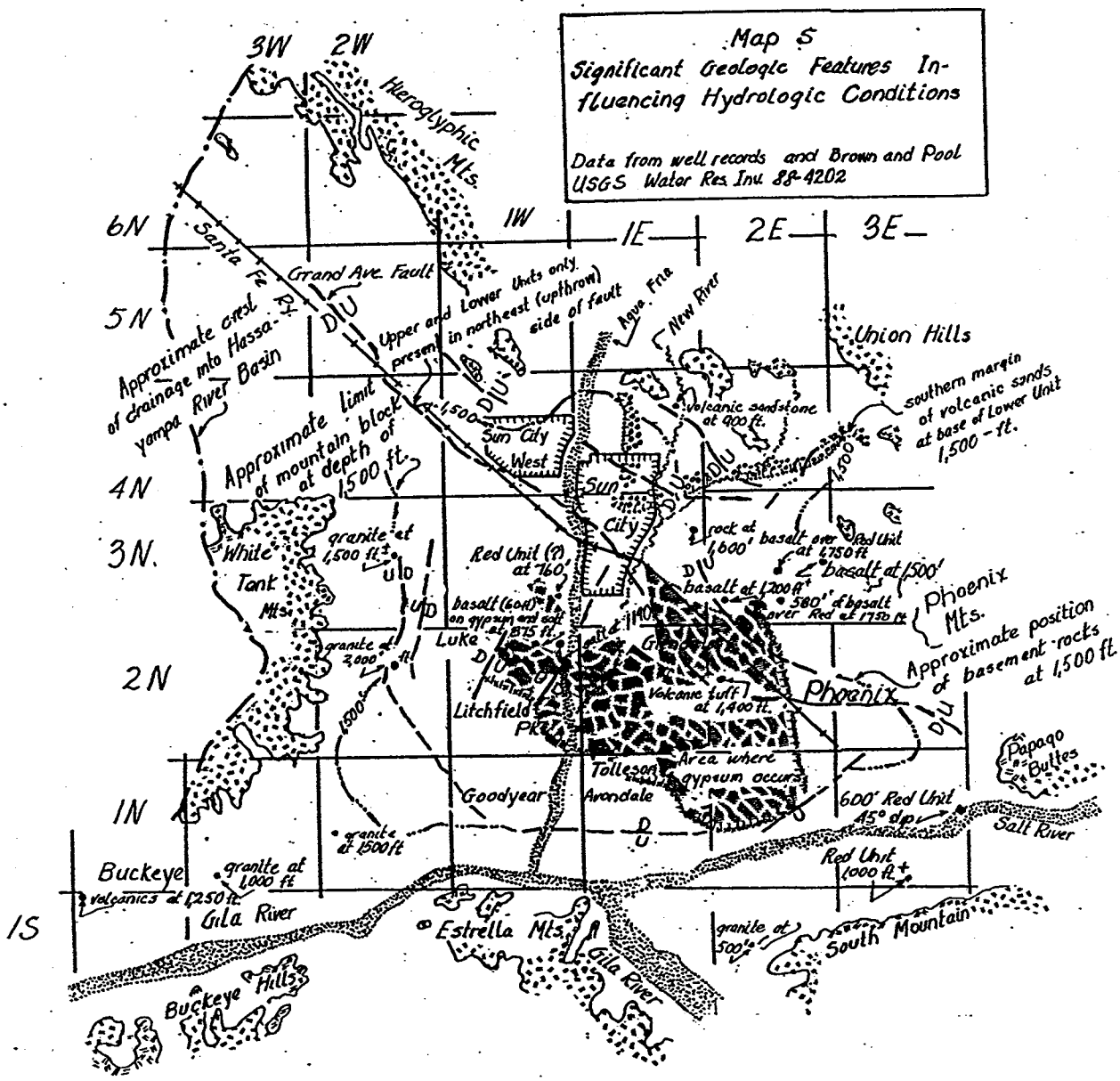


Map N
Distribution Of Total Dissolved Salts In Parts per Million From Wells in 1982 (combined for all depths). Data from Arizona Dept. Water Resources Rpt.# 12.

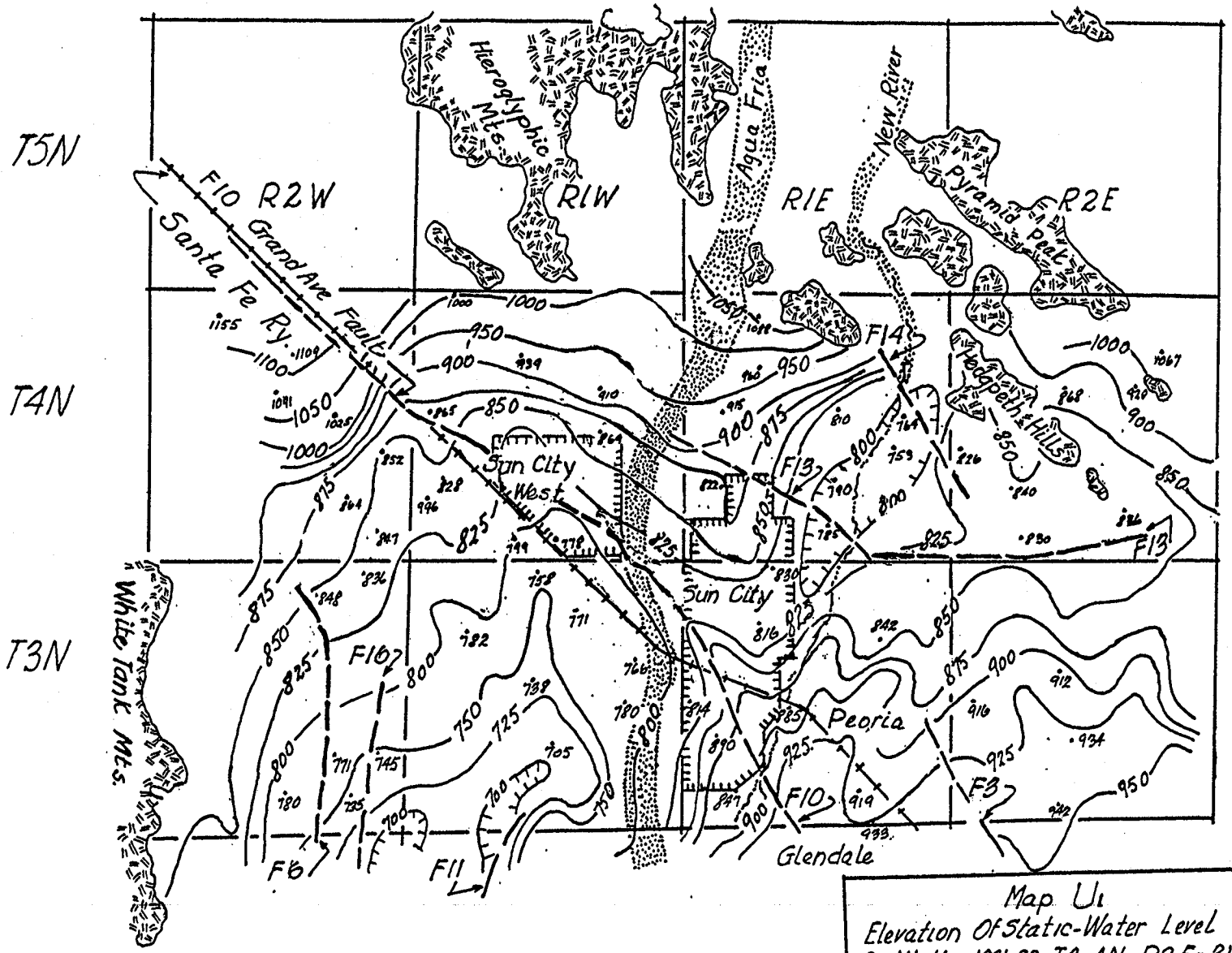


Map O
Approximate Distribution Of Total Dissolved Solids During 1985
Data from Brown and Pool, U.S.G.S. Water Res. Inv. 88-4202

C

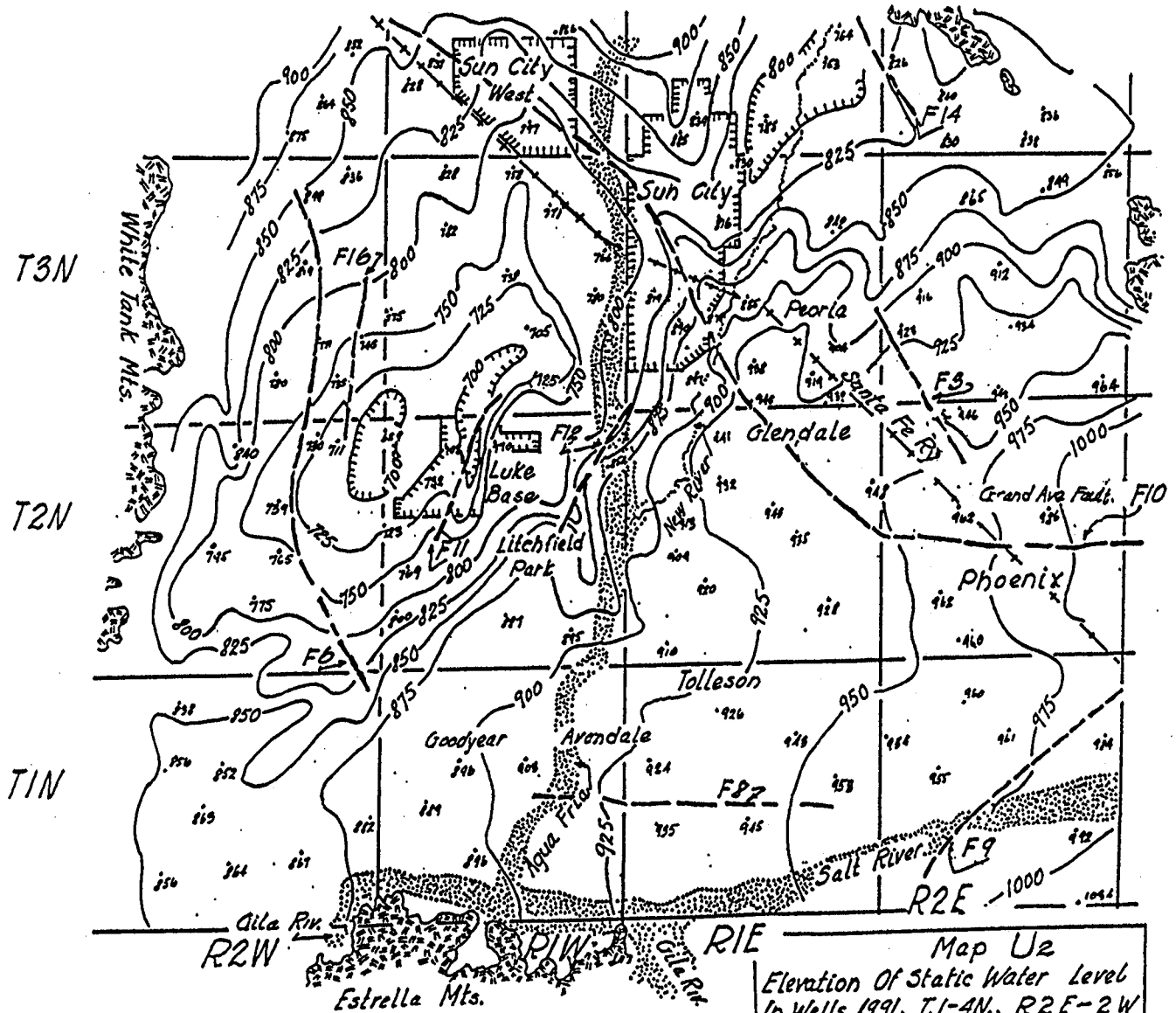

Map 5
Significant Geologic Features Influencing Hydrologic Conditions
Data from well records and Brown and Pool USGS Water Res. Inv. 88-4202
3W
2W
Hieroglyphic Mts.
6N
1W
1E
2E
3E
5N
Santa Fe R.R.
Grand Ave. Fault
Upper and Lower Units only present in northeast (upthrown) side of fault
Agua Fria
New River
Union Hills
Approximate east of drainage into Hassayampa River Basin
Approximate limit of mountain block at depth of 1,500 ft.
1,500
Sun City West
Sun City
volcanic sandstone at 400 ft.
southern margin of volcanic sands at base of Lower Unit 1,500 - ft.
4N
3N.
White Tank Mts.
granite at 1,500 ft.
Red Unit (?) at 760'
rock at 1,600'
basalt over Red Unit at 4750 ft
basalt at 1500'
basalt at 1200 ft
580' of basalt over Red at 1750 ft
Phoenix Mts.
basalt (60 ft) on gypsum and salt at 875 ft.
Luke
granite at 2,000 ft
2N
Litchfield Park
Volcanic tuff at 1,400 ft.
Phoenix
Approximate position of basement rocks at 1,500 ft
Papago Buttes
Tolleson
Area where gypsum occurs
Goodyear
Avondale
600' Red Unit 45° dip
Salt River
1N
granite at 1500 ft
Buckeye
granite at 1,000 ft
volcanics at 1250 ft.
Red Unit 1000 ft +
Gila River
1S
Estrella Mts.
Gila River
granite at 500'
South Mountain
Buckeye Hills

D



Map U1
Elevation Of Static-Water Level
In Wells, 1991-92, T3-4N-R2E-2W
Data from Arizona Dept Of Water Resources
and Citizen's Utilities

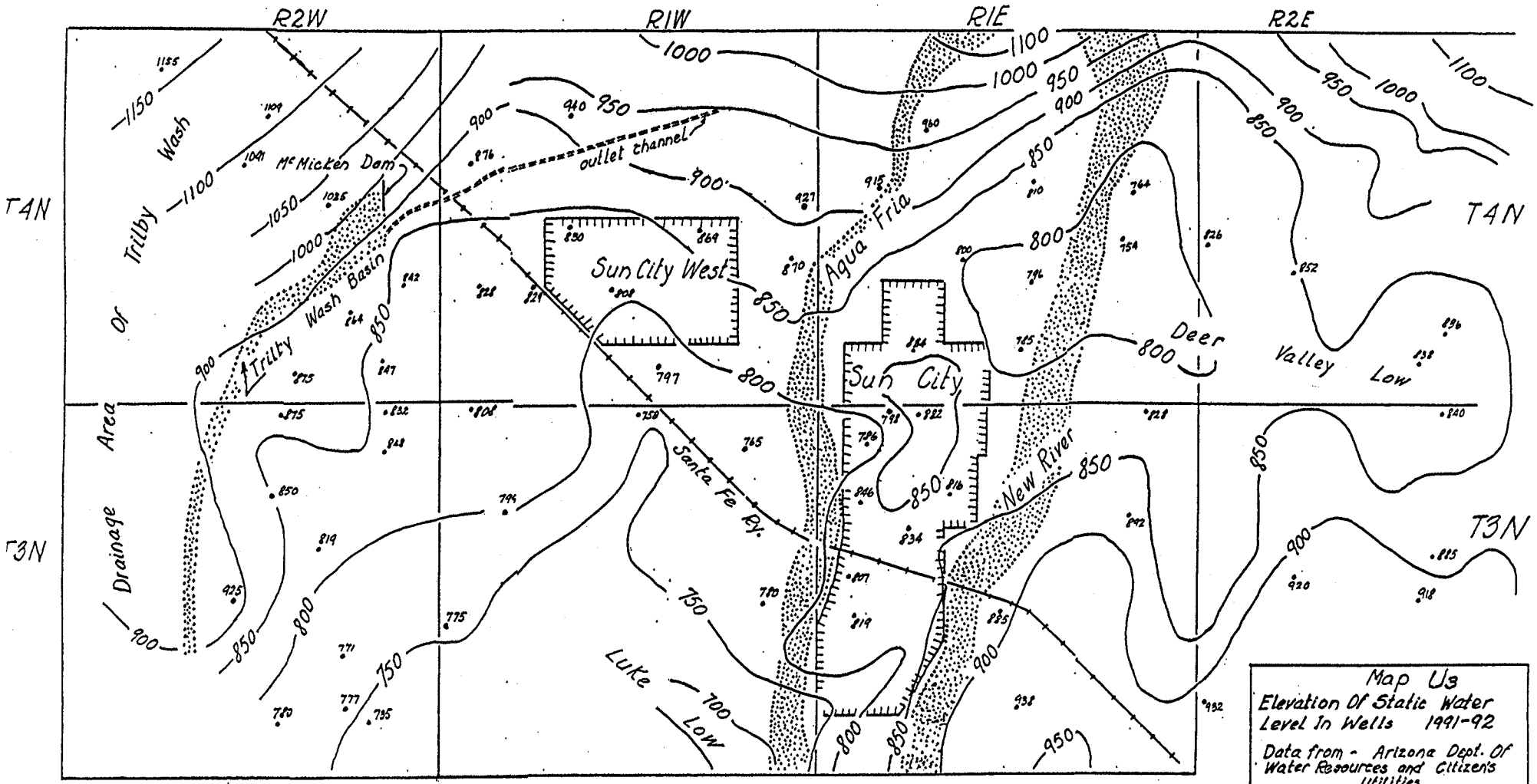
E



Map U2
Elevation Of Static Water Level In Wells 1991, T.1-4N., R2E-2W

Data from Arizona Dep't. Of Water Resources and Citizen's Utilities

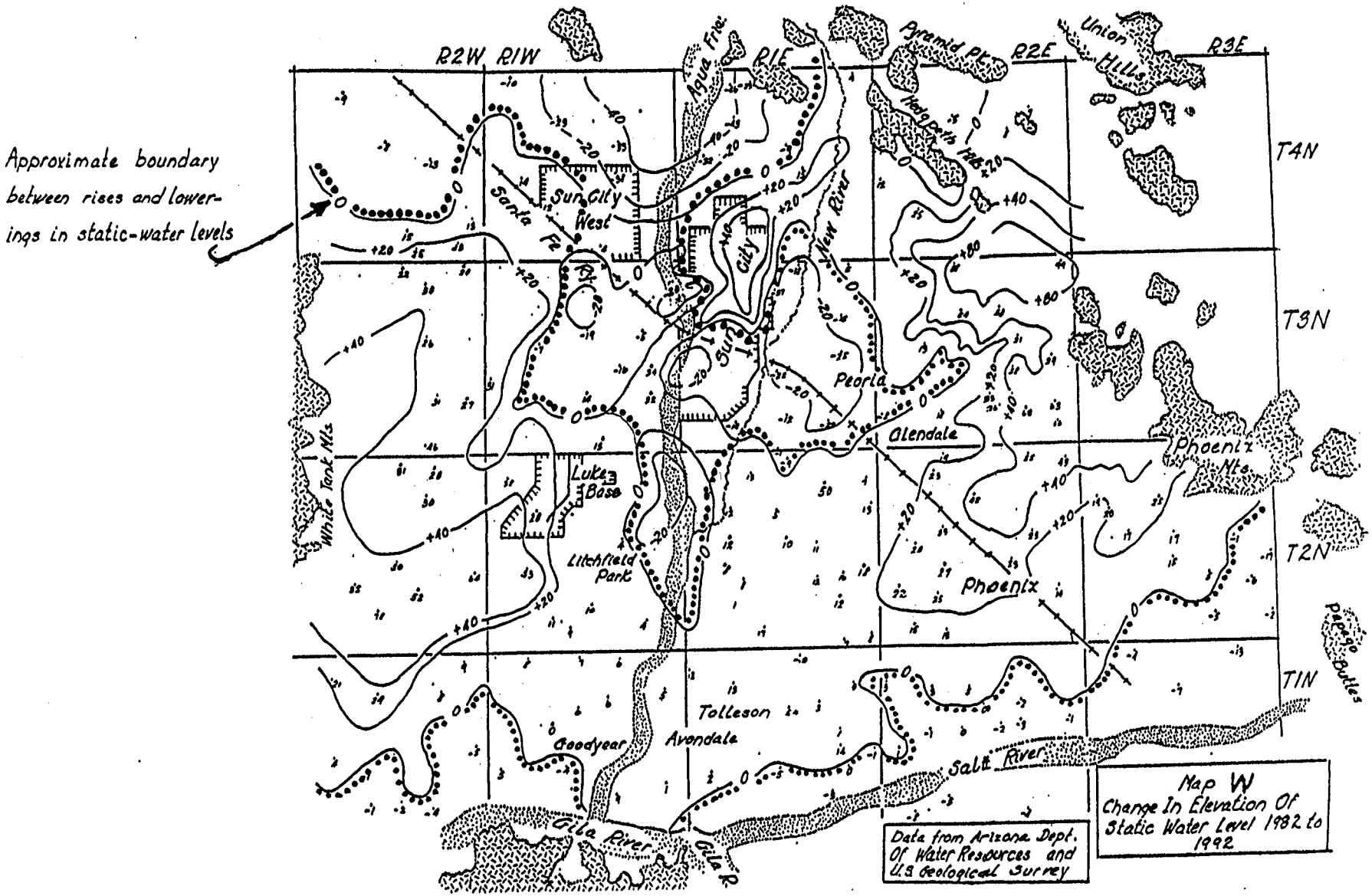
F



Map U3
Elevation Of Static Water Level In Wells 1991-92

Data from - Arizona Dept. Of Water Resources and Citizen's Utilities

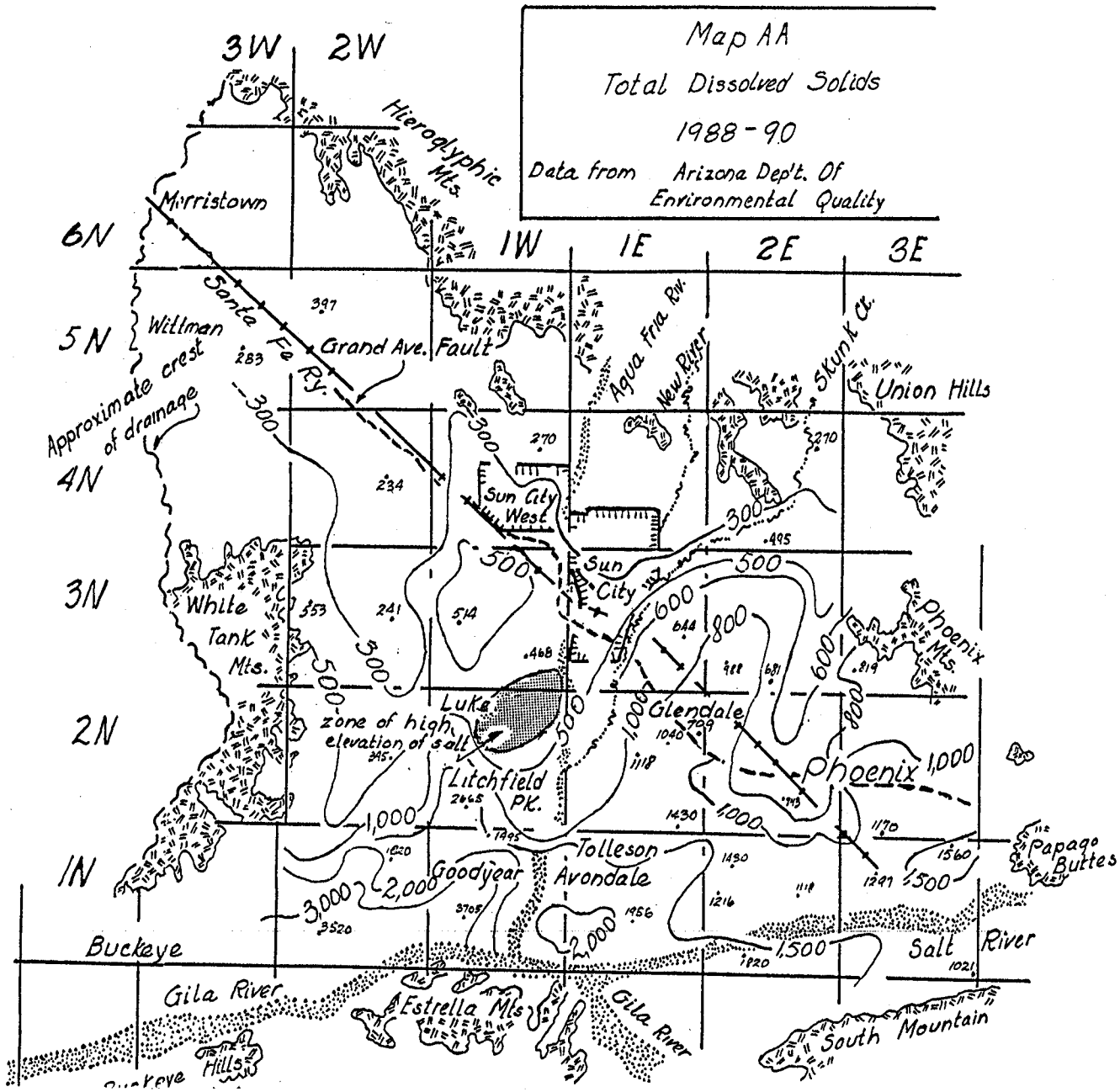
G



Data from Arizona Dept. Of Water Resources and U.S. Geological Survey

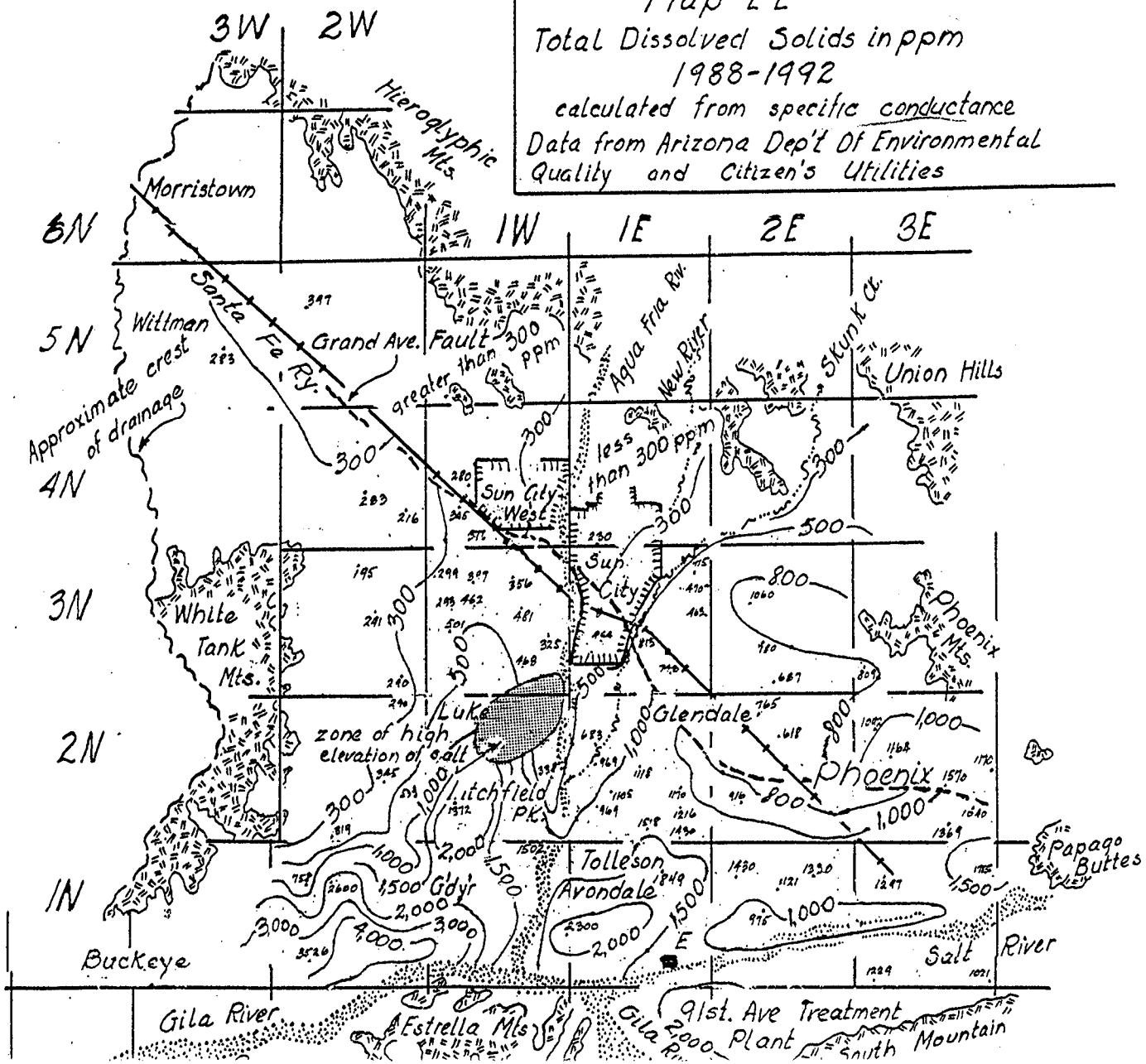
Map W
Change In Elevation Of Static Water Level 1982 to 1992

H


Map AA
Total Dissolved Solids
1988-90
Data from Arizona Dep't. Of Environmental Quality
3W
2W
1W
1E
2E
3E
6N
5N
4N
3N
2N
1N
1S
Hieroglyphic Mts.
Morristown
Wittman
Santa Fe Ry.
Grand Ave. Fault
Approximate crest of drainage
Agua Fria Riv.
New River
Skunk Cr.
Union Hills
Sun City West
Sun City
White Tank Mts.
Phoenix Mts.
Luke
zone of high elevation of salt
Glendale
Litchfield Pk.
Phoenix
Tolleson
Goodyear
Avondale
Papago Buttes
Buckeye
Gila River
Estrella Mts.
Salt River
South Mountain
Buckeye Hills
300
500
600
800
1,000
1,500
2,000
3,000

Map EE

Total Dissolved Solids in ppm
1988-1992
calculated from specific conductance
Data from Arizona Dep't Of Environmental Quality and Citizen's Utilities



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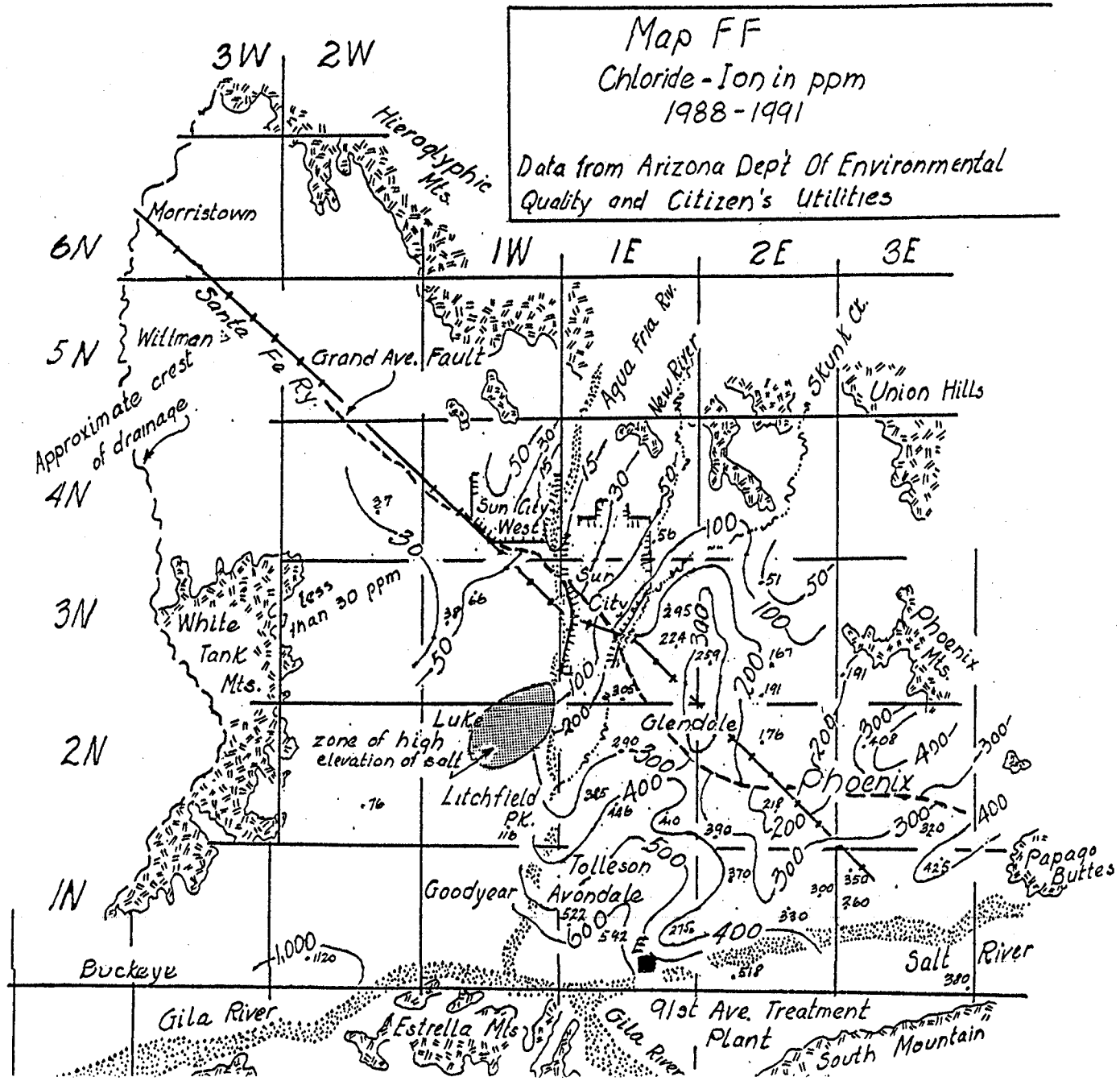
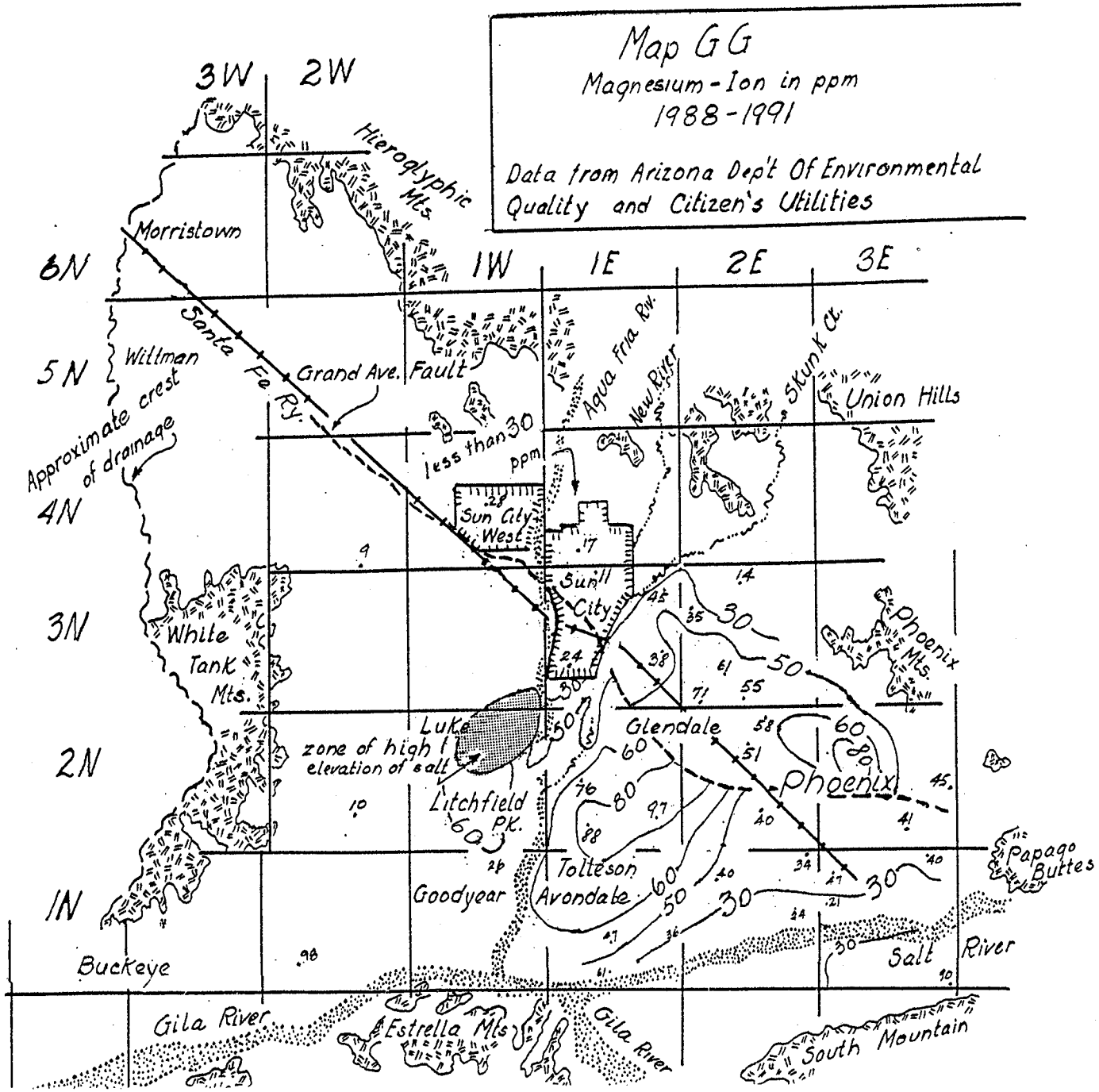
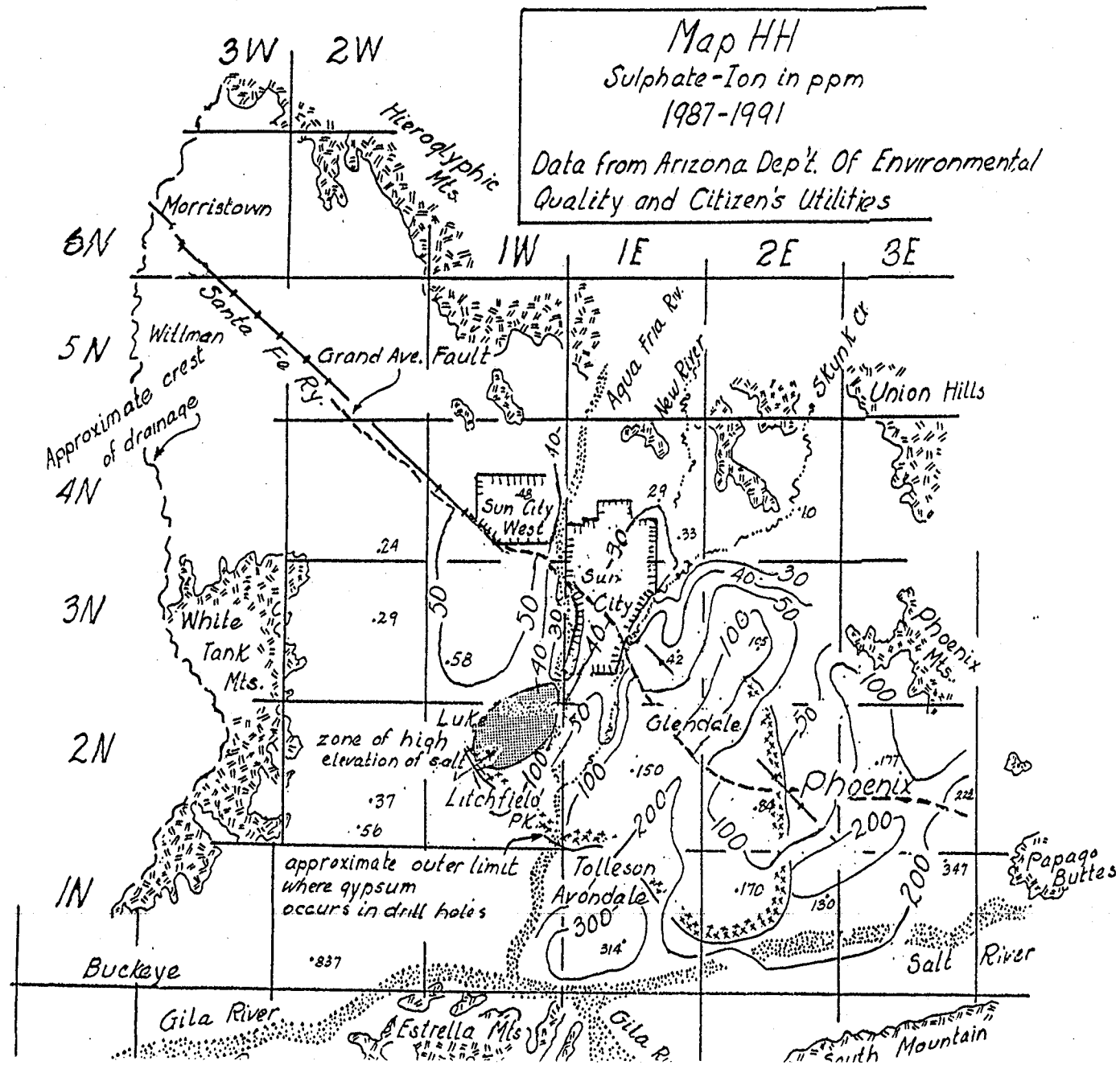

Map FF
Chloride - Ion in ppm
1988 - 1991
Data from Arizona Dept Of Environmental Quality and Citizen's Utilities
3W
2W
1W
1E
2E
3E
6N
5N
4N
3N
2N
1N
1S
Hieroglyphic Mts.
Morristown
Wilmen
Approximate crest of drainage
Santa Fe Ry.
Grand Ave.
Fault
Aqua Fria Rv.
New River
Skunk Cr.
Union Hills
Sun City West
Sun City
White Tank Mts.
less than 30 ppm
Phoenix Mts.
Luke
zone of high elevation of salt
Glendale
Phoenix
Litchfield Pk.
Tolleson
Avondale
Goodyear
Papago Buttes
Buckeye
Gila River
Estrella Mts
Gila River
91st Ave. Treatment Plant
South Mountain
Salt River

K


Map GG
Magnesium - Ion in ppm
1988 - 1991
Data from Arizona Dep't Of Environmental Quality and Citizen's Utilities
3W
2W
1W
1E
2E
3E
6N
5N
4N
3N
2N
1N
1S
Hieroglyphic Mts.
Morristown
Wittman
Santa Fe Ry.
Grand Ave.
Fault
Approximate crest of drainage
less than 30 ppm
Agua Fria Rv.
New River
Skunk Cr.
Union Hills
Sun City West
Sun City
White Tank Mts.
Phoenix Mts.
Luke
zone of high elevation of salt
Litchfield Pk.
Glendale
Phoenix
Tolleson
Goodyear
Avondale
Papago Buttes
Salt River
Buckeye
Gila River
Estrella Mts
South Mountain

L


Map HH
Sulphate-Ion in ppm
1987-1991
Data from Arizona Dep't. Of Environmental Quality and Citizen's Utilities
3W
2W
1W
1E
2E
3E
6N
5N
4N
3N
2N
1N
1S
Hieroglyphic Mts.
Morristown
Willman
Santa Fe Ry.
Grand Ave.
Fault
Aqua Fria Rv.
New River
Skunk Cr.
Union Hills
Approximate crest of drainage
Sun City West
Sun City
White Tank Mts.
Phoenix Mts.
Luke
Glendale
Phoenix
zone of high elevation of salt
Litchfield Pk.
Tolleson
Avondale
approximate outer limit where gypsum occurs in drill holes
Papago Buttes
Buckeye
Salt River
Gila River
Estrella Mts
Gila R.
South Mountain