STATE OF ARIZONA
DEPARTMENT OF WATER RESOURCES

PRELIMINARY FEASIBILITY STUDY OF GROUNDWATER RECHARGE POTENTIAL OF SURPLUS CENTRAL ARIZONA PROJECT WATER IN **AGUA FRIA RIVER**

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Open-File Report

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I. INTRODUCTION

A. Purpose

This study is a preliminary assessment of the technical feasibility of artificially recharging surplus Central Arizona Project (CAP) water. The possibility of utilizing the floodplain of the Agua Fria River for the infiltration and storage of excess waters is explored in an area where various entities could potentially beneficially use this water.

B. Scope

The focus of this study is on stream channel modification as a recharge option. Until the CAP Granite Reef Aqueduct is completed to Tucson in 1991, the capacity of the aqueduct is expected to exceed the users demands. After 1991, it is anticipated that the capacity will be fully utilized for deliveries. For this reason, the temporary, low cost option of stream channel recharge was preferred over alternative recharge techniques for the infiltration and storage of any surplus or undistributable CAP allotment.

C. Study Area

The geographic area studied within the scope of this report is located along the Agua Fria River about 30 miles northwest of Phoenix and 5.5 miles downstream of the existing Waddell Dam (Figure 1).

The study area encompasses a reach of the Agua Fria River floodplain adjacent to and downstream of the Granite Reef Aqueduct siphon across the Agua Fria River (Figure 2). The floodplain reach under study extends from the siphon crossing to about 4 miles south of it, in the vicinity of Calderwood Butte.

D. References and Data Sources

Published sources of data were used to estimate potential rates and volumes of recharge. Major sources of data were the Water Resources Division of the U.S. Geological Survey (U.S.G.S.), the Arizona Department of Water Resources (A.D.W.R.), and the U.S. Bureau of Reclamation (U.S.B.R.). Surface elevations were taken from U.S. Geological Survey 7.5' and 15' topographic maps. Depth to groundwater information was taken from published reports, well logs, or from ADWR files. Permeability information was based on either U.S.B.R. data or on average values taken from text and handbooks. Infiltration rates for the streambed recharge analysis were taken from published sources.

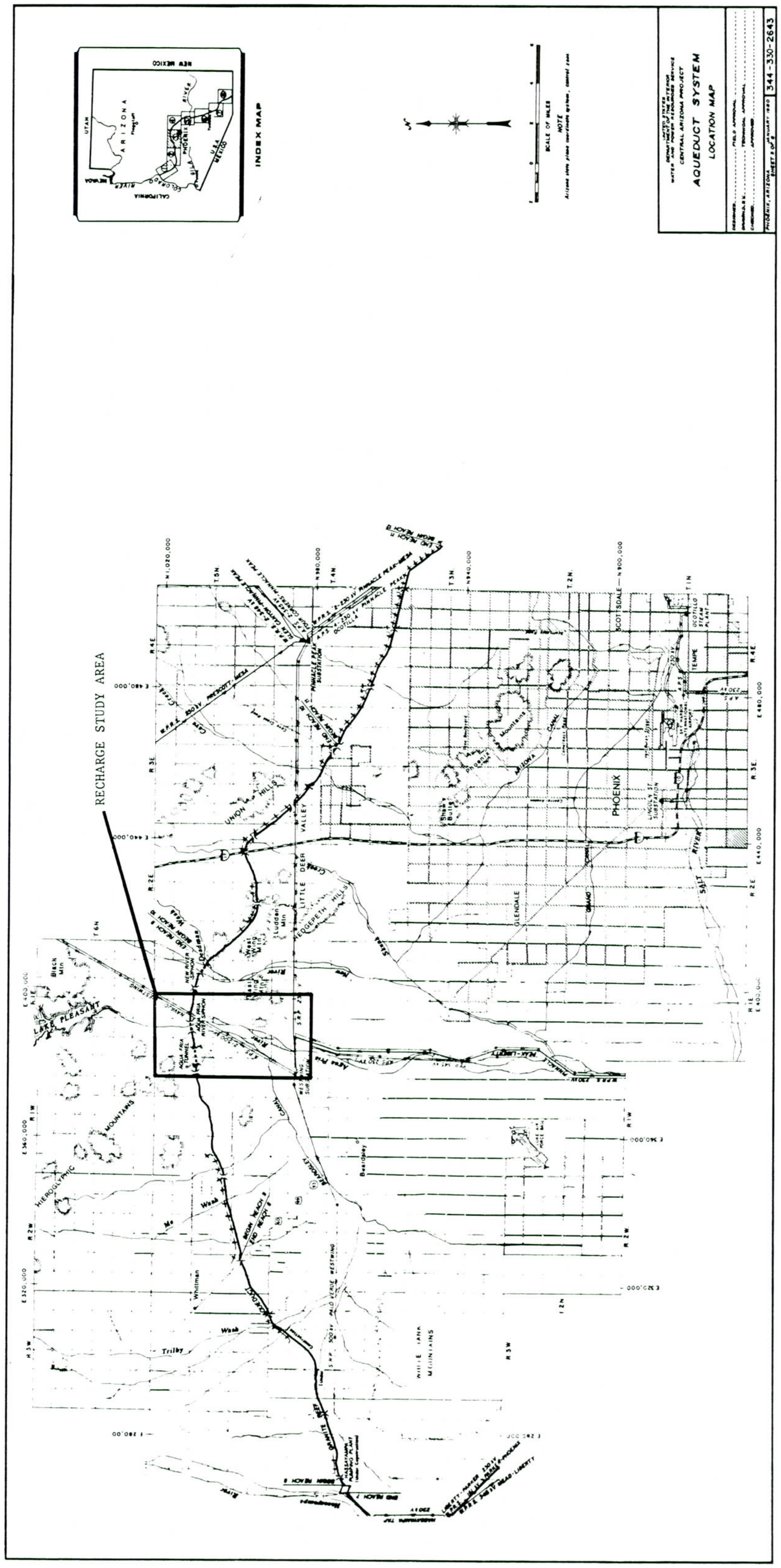
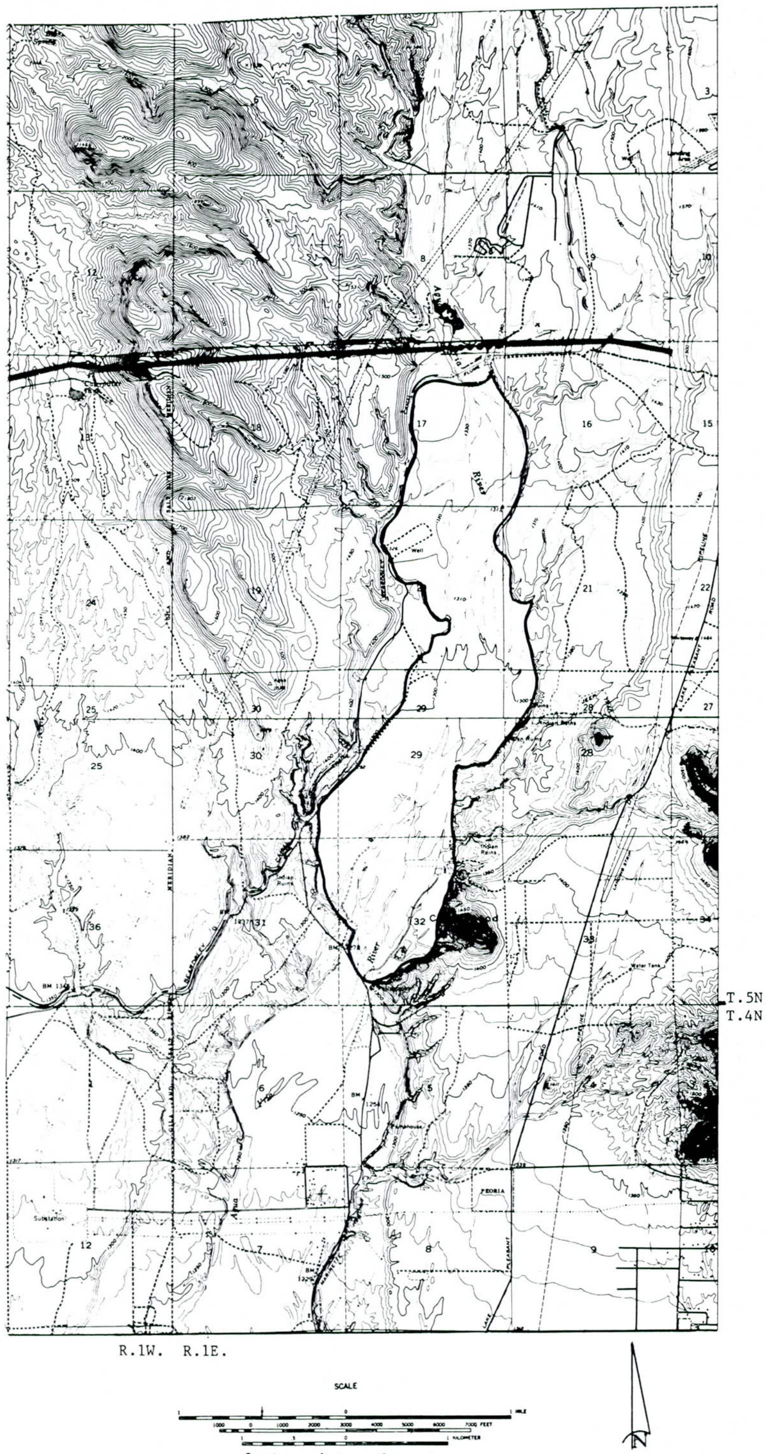


Figure 1.--Location map of Granite Reef Aqueduct



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Note: Base map from U.S.G.S. 7.5 min. quadrangle sheets Baldy Mountain and Calderwood Butte, Arizona

EXPLANATION*

Granite Reef Aqueduct

Agua Fria River Siphon

Floodplain boundary of recharge area

*Approximate locations

Figure 2.--Location map of recharge area

II. HYDROLOGIC REGIME

A. Geology

The Agua Fria River drains southward through a terraced valley overlying shallow bedrock immediately east of the Hieroglyphic Mountains. These step-like terraces are evidence of an older river channel outlying the present Agua Fria River channel. Rock units mapped in the Hieroglyphic Mountains include Precambrian granite and Quaternary-Tertiary conglomerate capped by a younger andesitic-basalt flow (U.S.B.R., 1977a, p. 8).

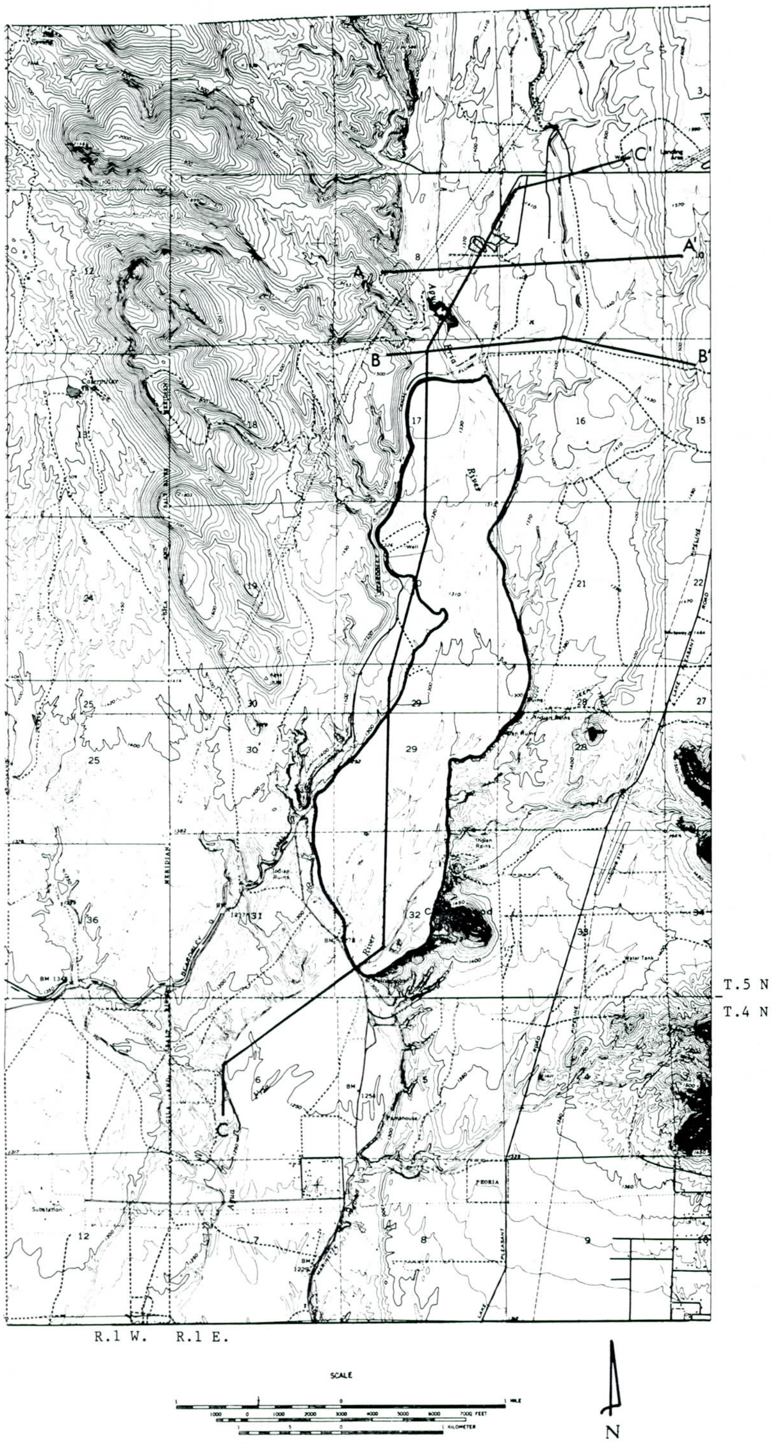
Previous geologic investigations conducted for the proposed Agua Fria Damsite and the Granite Reef Aqueduct's Agua Fria River siphon established general geologic conditions in the vicinity of the study area. These two investigations characterize the geology as a complex assemblage of volcanic rocks overlain by water-bearing conglomerates, terrace deposits and alluvium. The location of two geologic cross sections (A-A'; B-B') constructed from these investigations and their relation to the proposed recharge site can be seen in Figure 3. The location of a cross section constructed from driller's logs on file at ADWR is also shown (C-C').

The proposed Agua Fria Damsite, located in Sections 8, 9, and 10, T5N, R1E, was studied by the U.S. Bureau of Reclamation (U.S.B.R.) from 1975 through 1978 as an alternative storage site for CAP water but was deleted from further study because of high seepage and economic factors (U.S.B.R., 1977b, p. 17).

A geologic cross section was constructed by the U.S.B.R. (Figure 4) from exploration drilling data obtained at the damsite. Drill hole DH-104-AF shows the Agua Fria River bound to the west by loosely consolidated alluvial deposits to a depth of 57 feet. From 57 feet to 143 feet, a reddish brown fanglomerate is encountered which overlies a volcanic sequence consisting of agglomerate, andesitic basalt and tuff.

The river valley is composed of a water-bearing fanglomerate sloping from west to east. At DH-103-AF, approximately 1/3 mile east of the river, the fanglomerate is overlain with approximately 70 feet of alluvial deposits while at DH-102-AF, approximately 1 mile east of the river, 400 feet of alluvial deposits overlie fanglomerate. The nonporous volcanic sequence underlies the fanglomerate on the western side of the river valley, but was not found further east (U.S.B.R., 1977b, p. 8).

The Agua Fria River siphon site, located in Sections 15, 16, and 17, T5N, R1E, was investigated in 1972. Numerous test and core holes were drilled at irregular intervals based on geologic conditions. Cross section B-B' was constructed from 11 drill hole logs (Figure 5). Exploration drill hole depths are relatively shallow ranging from 38 feet to 62 feet below the land surface.



*Note: Base map from U.S.G.S.
7.5 min. quadrangle sheets
Baldy Mountain and Calderwood
Butte, Arizona.

EXPLANATION

A - A' Agua Fria Damsite
B - B' Agua Fria River Siphon
C - C' Agua Fria River Bed

Floodplain boundary of recharge area

Figure 3.--Location map of geologic cross section

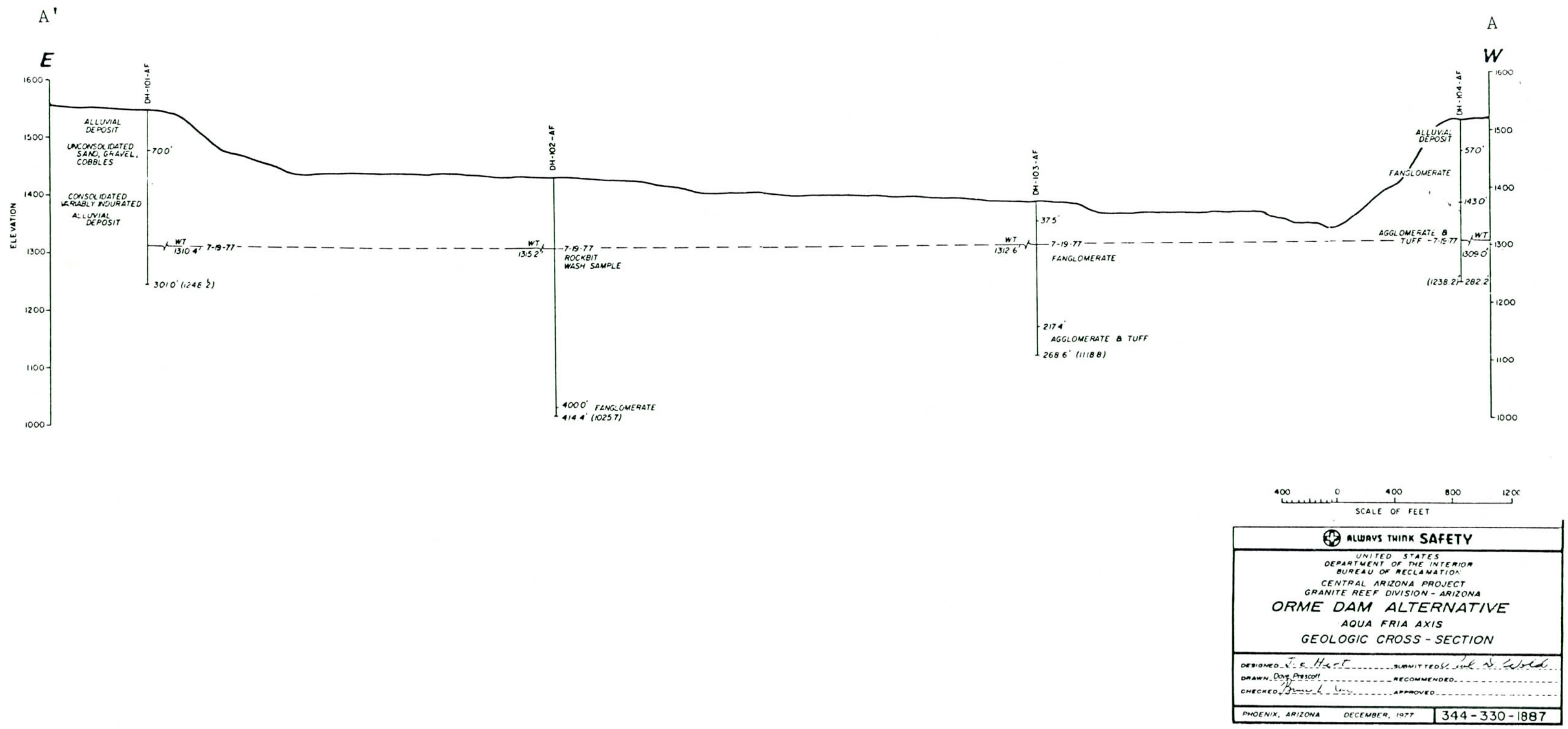


Figure 4.--Geologic cross section A-A'

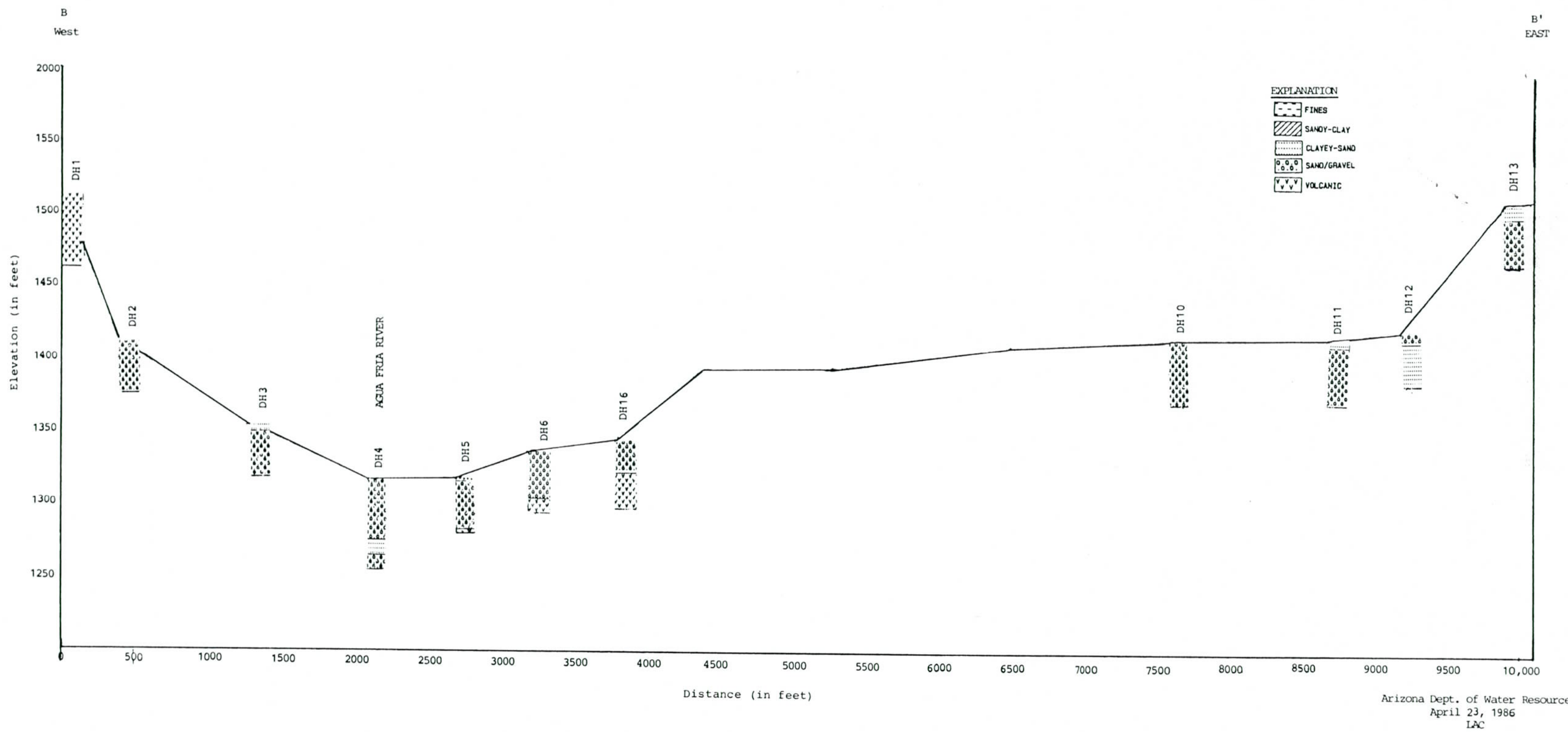


Figure 5.--Geologic cross section B-B'

As can be seen from this cross section, the alignment traverses stream channel and river terrace deposits.

Underlying the surface soil veneer, materials encountered in the Agua Fria channel consist primarily of sand and gravel. The gravels are generally unconsolidated but locally contain variably cemented zones of caliche. In some areas volcanic flows occur within the alluvial deposits. Below the river channel, a volcanic tuff was encountered at a depth of 33 feet and 35 feet in exploration holes DH5 and DH6, respectively (see Figure 5) and is also exposed along the east bank of the river channel. West of the river channel, the alignment traverses alluvial fan deposits comprised of silty gravel with cobbles and some clayey-sand (DH2 and DH3). These deposits vary from uncemented to moderately caliche cemented (U.S.B.R., 1972, p. 7).

Water levels were observed at a depth of 43 feet below the land surface in two exploration holes, DH4 and DH5. In DH4, water was encountered in the alluvial deposits, while in DH5, water was encountered in fractures in the tuff (U.S.B.R., 1972, p. 7).

A north-south geologic cross section showing similar geology was constructed from nine drillers logs in ADWR files (Figure 6). The geologic units penetrated by on-site wells are volcanic sequences overlain by 50 to 250 feet of conglomerates and about 25 to 50 feet of alluvial deposits. The conglomerate may be interbedded with the volcanic sequence of andesite, rhyolite, tuffs and agglomerates. Depth of the volcanic rocks varies from 155 feet to 80 feet below the land surface at wellsites, (A-5-1) 17abb and (A-5-1) 32cac, respectively.

B. Groundwater

A 1983 groundwater elevation map, presented in Figure 7, shows the groundwater surface gradient as south-southwest following the general course of the Agua Fria River (Reeter and Remick, 1986). Wellsites located in the vicinity of the recharge area are illustrated in Figure 8. Depth to water measurements shown for these sites reflect the most recent year for which data were available. Wells for which data had been collected in 1985 indicate a 5 to 35 foot rise in groundwater elevations since 1983.

Groundwater elevations east of the Agua Fria River are very poorly defined due to the lack of data. The data available for 1985 show that groundwater levels may rise east of the Agua Fria River floodplain, indicating some groundwater flow to the floodplain alluvium. Conditions need to be investigated to determine the interaction between the regional water table and the groundwater mound created by the recharge project.

In the reach of the Agua Fria River extending from the aqueduct siphon south to Calderwood Butte, depths to water ranged from 37 to 43 feet below the land surface in 1985. As previously discussed, depth to bedrock in this area is relatively shallow, ranging from about 155 feet at the siphon to about 80 feet below the land surface near Calderwood Butte.

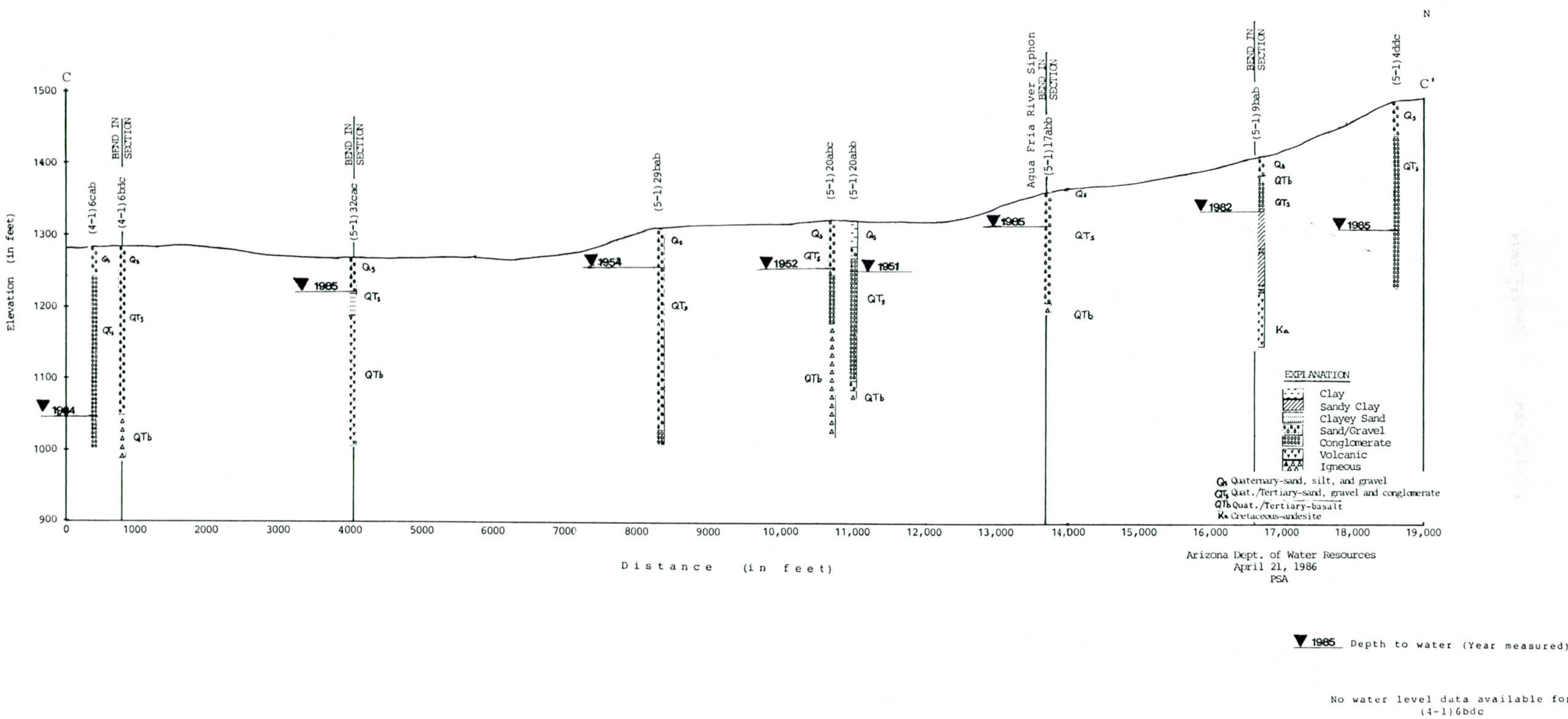


Figure 6.--Geologic cross section C-C'

EXPLANATION

59 (Depth to water in ft. below land surface)
1294 (Altitude of water level in ft. above mean sea level)

——1300—— Water level contour

— — — — — Generalized recharge area

Note: Map is modified from Reeter and Remick (1986)

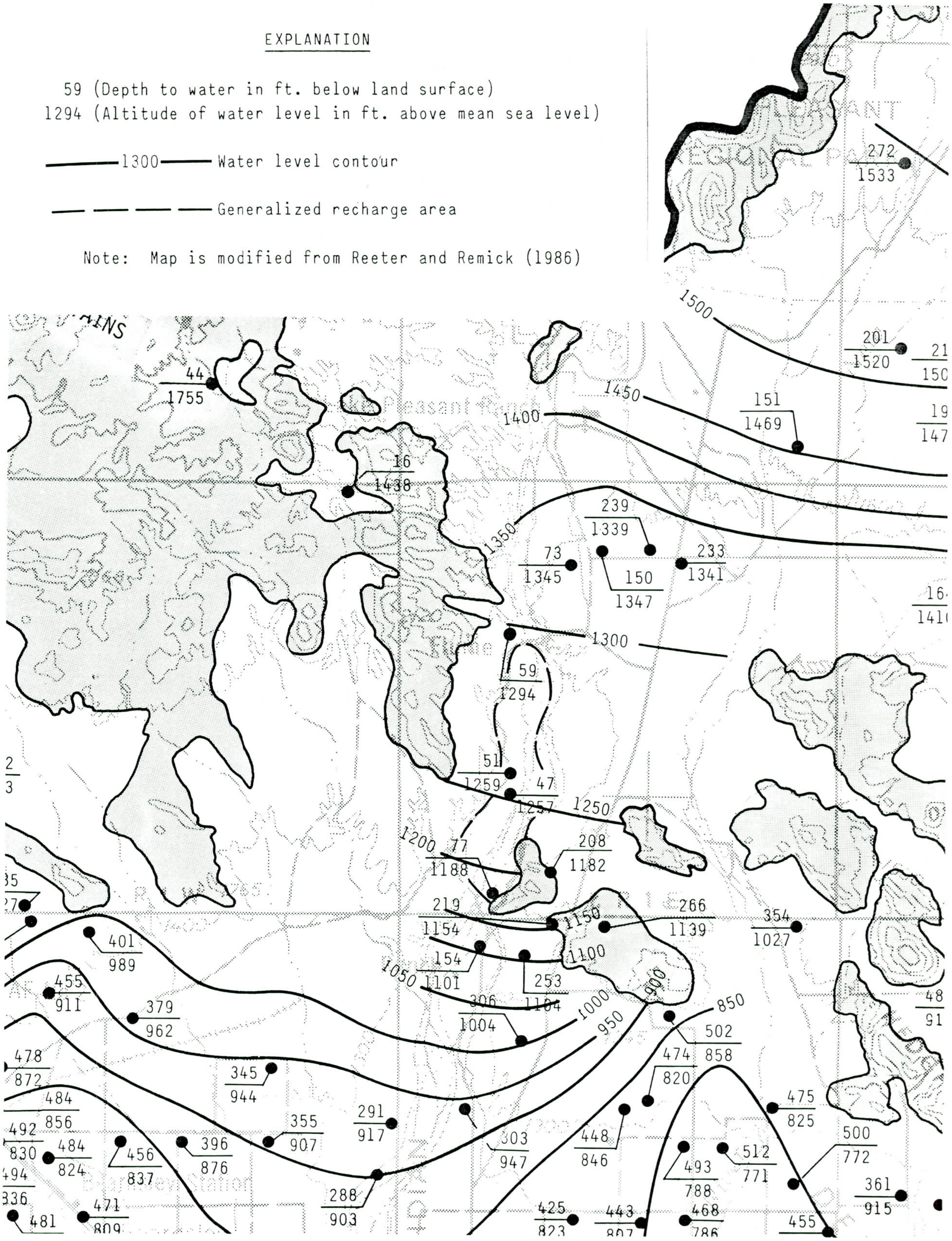
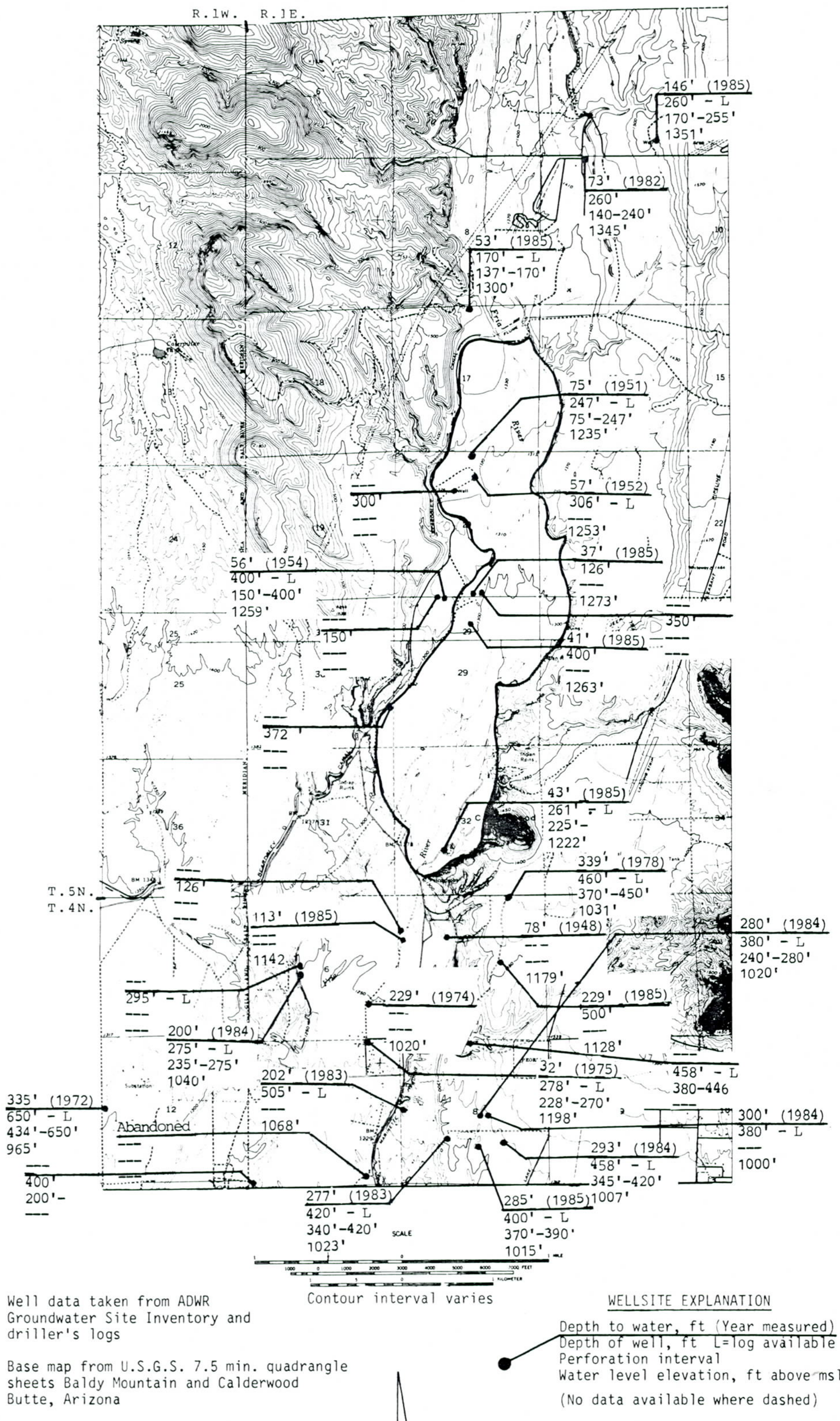


Figure 7.--Groundwater surface elevation map



Note: Well data taken from ADWR Groundwater Site Inventory and driller's logs

Base map from U.S.G.S. 7.5 min. quadrangle sheets Baldy Mountain and Calderwood Butte, Arizona

Figure 8.--Wellsites in the vicinity of the recharge area

South of Calderwood Butte where there are less geologic restrictions, the regional aquifer becomes deeper and much wider. In the floodplain of the Agua Fria River from Calderwood Butte to approximately two miles south, 1985 water level measurements ranged from 113 to 225 feet below the land surface.

C. Surface Water

The Agua Fria River drains approximately 1,500 square miles at the Granite Reef Aqueduct siphon. The river is ephemeral in this reach, flowing only in response to precipitation events or releases at the existing Waddell Dam. About 25 miles downstream of the siphon, the Agua Fria River becomes tributary to the Gila River. There has not been continuous flow at the mouth of the Agua Fria River since construction of Waddell Dam in 1927.

Within the study area, the Agua Fria River floodplain varies from 2/3 - 3/4 of a mile wide and slopes to the south at about 20 feet/mile.

D. Water Quality

This section presents a brief discussion of total dissolved solids (TDS) concentrations and the resultant impact of recharge on local groundwater quality. A more detailed assessment of the impacts of stream channel recharge on groundwater quality should be addressed during any further development of this study at this site.

Groundwater quality samples were collected from wells 1-1½ miles east of the study area in 1983 (Reeter and Remick, 1986). Data from these wells, located in Sections 10 and 33, T5N, R1E, indicate TDS levels of 250 milligrams/liter (mg/l) and 200 mg/l, respectively. In 1965, the U.S.G.S. collected water quality data from wells located two to three miles south of Calderwood Butte (Sections 13, 14, and 15, T4N, R1E). The TDS levels in this area ranged from 250 mg/l to 300 mg/l.

The TDS concentration of CAP water is estimated to be 500-600 mg/l (G. Crossman, Civil Engineer, Arizona Projects Office, U.S. Bureau of Reclamation, oral communication, 1986). Recharging CAP water with high TDS levels into the aquifer underlying the Agua Fria River where natural TDS values are less than 250 mg/l could cause a local degradation in groundwater quality. Blending CAP water (estimated TDS of 500-600 mg/l) with nearby Beardsley Canal water (estimated TDS of 300 mg/l) would allow the water recharged in the Agua Fria River floodplain to remain below 500 mg/l in TDS, and would minimize any degradation.

III. STREAM CHANNEL RECHARGE

A. Introduction

There are three general methods available for artificial recharge of water: 1) recharge wells, 2) recharge basins and 3) stream channel recharge.

Recharge wells have been used successfully for a number of years, but have higher installation and maintenance costs than basins or stream channel recharge. The recharge water requires a much greater amount of treatment before placement into the well than stream channel or basin recharge methods. The advantages of recharge wells are that they enable exact locations to be chosen for placement of water into the aquifer and that the potential for water quality problems is minimized. Recharge wells are considered too expensive to justify their use for the short term recharge project being studied in this report and will not be considered further.

Small recharge basins or spreading basins have been successfully used for groundwater recharge for a number of years. An example in Arizona is the Flushing Meadows experimental facility in Phoenix (Bouwer, 1978, p. 1-6). Such recharge facilities generally consist of a number of long, narrow basins bounded by berms. Recharge water fills the basins and infiltrates, eventually recharging the groundwater. The number of basins at each facility varies and the use of each basin is alternated to allow for control of algae and vegetation growth and for reworking the floor of each basin.

Stream channel recharge is the simplest of the three methods of groundwater recharge and consists of discharging water into a wash or riverbed at such a rate that the water available for recharge infiltrates within a given reach. This method is the least sophisticated of those available but is also the cheapest and the quickest to implement. A decline in infiltration rates can be caused by clogging of soil due to the accumulation of fine particles such as sediments or organic material from algal and bacterial growth. Maintenance work involving periodic drying or scraping off the surface layer of the soil may be necessary to restore infiltration rates. A minor amount of structural work for discharge structures and berms, may also need to be done, but on the whole, this method will require less maintenance than either basins or injection wells. It is therefore a cheaper method and is much better suited to the temporary nature of this proposed project. Its general disadvantages are the restricted number of suitable locations, reduction of infiltration rates caused by clogging of the surface soil or by a rise of the groundwater table due to mounding, possible odor and insect problems, traffic flow restrictions, the relatively long strips of land tied up in recharge facilities, and the crude degree of control over the location of recharge within the site. Advantages are low initial cost, quick implementation, low maintenance and repair costs, and the ease with which the facility can be dismantled when its usefulness is at an end.

B. Previous Studies

The idea of discharging excess surface water into natural channels in order to recharge the groundwater system is not new and has been practiced in various forms for a number of years. Most of these stream channel recharge projects use channel modification to retard flow velocities, control sediment deposition and encourage high recharge rates. Most literature on the subject deals with recharge basins or with natural stream channels. Recharge from modified stream channels should fall within the range provided by these two types of recharge.

A study along Queen Creek, east of Phoenix, on recharge rates by storm runoff events was conducted by Babcock and Cushing (1942, p. 54). This study found a range of infiltration rates over a 20 mile reach of 0.14 to 2.09 ft/day, with an average of 1.08 ft/day for floods of varying magnitudes. Infiltration rates were higher for winter floods than for thunderstorm runoff, presumably due to lower silt load in winter events and their longer duration, and lower intensity. Infiltration rates in upstream portions of the reach were almost 7 ft/day, but these rates rapidly decreased downstream as the bed material became finer. Infiltration rates from pools of runoff water that remained in the channel after the flood averaged 0.91 ft/day. The duration of flow for most of the events studied was one to two days; thus, long term infiltration rates are not available from this study.

A study of infiltration losses from a controlled release by the Salt River Project into the dry Salt River bed was conducted by Briggs and Werho (1966, p. 8-9). This study determined an average infiltration rate of 2.5+ ft/day for a 19 mile reach of channel between Granite Reef Dam and 48th Street in Phoenix. This rate was determined for a study period of 3.8 days. Total infiltration within this reach was 14,500 acre-feet or about 200 acre-feet per mile per day. A two mile reach of the channel further downstream was also studied. This reach consisted almost entirely of gravel pits, and infiltration during a 4 day period averaged 1.5 ft/day in the pits. Rates declined to 1.1 ft/day after about two weeks.

A number of stream recharge studies have been conducted in the Upper Santa Cruz Basin. Turner (1943, p. 47-50) determined seepage rates of 1.10 to 3.77 ft/day for flood flows on Rillito Creek between Wrightstown and the Santa Cruz River. In this study, the rates increased downstream. This was explained by the increasing depth to water downstream and the increased recharge opportunity afforded by this increase. Turner also studied infiltration from pools in stream channels and obtained rates of 0.31 ft/day for test lengths of 15-20 hours and 1.2 ft/day for periods of one to four hours. Infiltration rates on the Santa Cruz River below the Rillito gage were determined to be 0.78 to 3.17 ft/day for the first 4.3 miles below the gage and 1.03 to 1.35 ft/day for the next ten miles. These tests were for five days.

Data from a U.S.G.S. study on the Salt River bed between Granite Reef Dam and 48th Street in Phoenix gives an average infiltration rate of 1 ft/day for flows from February, 1978 to May, 1980. Flow was not continuous during this time but the period does include sustained flows during the spring of each of the three years (Mann and Rohne, 1983, p. 11). This rate of 1 ft/day is probably near the rate that would be expected over a long term from a streambed recharge project and, for purposes of this study, will be used in order to determine the total recharge rate for a particular site.

Other studies on stream channel recharge have been done that report recharge in acre-feet per reach per year for the streams studied. Available studies are Burkham, 1970; Aldridge and Brown, 1971; and Keith, 1981. These studies deal with recharge from natural runoff events; however they do not give wetted areas for the flow events, making rates of infiltration impossible to calculate.

Recharge studies on spreading basins report that basins are able to accept loading factors of 200 to 600 feet per year. Recharge rates for modified stream channels may approach those of spreading basins. A loading factor is an average infiltration rate that includes the time when no actual recharge is taking place due to maintenance and repair considerations, which in extreme cases have occupied up to two-thirds of the year. Infiltration rates reported at the Eaton Spreading Basin in Los Angeles County averaged 0.2 ft/day to 0.8 ft/day (Sherman, 1978, p. 26). A study of an experimental recharge basin near Lubbock, Texas showed a maximum infiltration rate of 3 ft/day after four months. The rate declined after six months due to clogging of pore spaces by suspended sediment. This study also pointed out that 80% of the recharge took place in the first seven months of the 14 month test. This points out the need for periodic re-working of the basin (Signor, 1978, p. 5). Spreading basins operated along the Salt River (the Flushing Meadows facility) by the U.S. Water Conservation Laboratory were used primarily to study water quality treatment of sewage effluent. Rates of 200-400 ft/year were common and rates up to 600 ft/year have been achieved. Lower rates were purposely maintained however at Flushing Meadows because of their higher efficiency in treating the sewage effluent (Wilson, 1978, p. 6). A basin recharge project conducted by Wilson at the Water Resources Research Center at the University of Arizona showed an average infiltration rate of 2.5 ft/day over a 142 day period (Wilson, 1978, p. 13). Rates ranged from 30 ft/day to 0.5 ft/day during this time.

A long term average infiltration rate of 1 ft/day is a conservative measure of the ability of ephemeral streambeds to recharge water (Mann, and Rohne, 1983; Briggs and Werho, 1965; Babcock and Cushing, 1942). Assuming that maintenance, flood control, and other considerations will allow recharge operations to take place only about 300 days of the year, a loading rate of about 300 feet of water per year can be achieved. Therefore, for every inundated acre of river bottom, 300 acre-feet of water per year can be infiltrated.

C. Recharge Site Evaluation

The general area of this recharge study is a four mile reach of the Agua Fria River floodplain, extending from where the Granite Reef Aqueduct crosses the Agua Fria River in Sections 16 and 17 of T5N, R1E downstream to the vicinity of Calderwood Butte. This area is shown in Figure 2. The floodplain alluvium in the reach of the Agua Fria River under study has a finite storage capacity that is dependent on the thickness and area of unsaturated alluvium and its storage coefficient.

To properly evaluate the feasibility of this site, the volume of unsaturated alluvium available to store recharged water needs to be assessed. East of the Agua Fria River groundwater levels are poorly defined. If regional groundwater flow is to the river floodplain from the east, the lateral spread of any recharge mound created by a project would be restricted by the rising water table to the east. If regional water levels slope to the east or southeast from the Agua Fria study area, water mounded by a recharge project will have a greater tendency to spread laterally, increasing the capacity of the study area to store recharged water. Geologic cross section A-A' illustrates this potential (Figures 3 and 4).

West of the recharge site, depth to bedrock is relatively shallow (see Figure 4). It seems likely that the predominant volcanics will inhibit lateral spread of recharged water to the west.

In the reach of the Agua Fria River extending from the aqueduct south to Calderwood Butte, unsaturated alluvium varied in depth from 37 to 43 feet under the site area in 1985 (Figure 8). Four miles downstream of the siphon the floodplain alluvial aquifer beneath the river is restricted in width by Calderwood Butte. If lateral spreading is limited, a rapid rise in groundwater levels may take place once recharge activity begins, greatly limiting available storage. Once the river enters T4N however, the regional aquifer becomes much wider, depths to water are 200-300 feet below land surface, and there are no apparent restrictions on the lateral dispersion of a recharge mound. About four miles of floodplain are available below the siphon crossing before groundwater levels decline steeply south of Calderwood Butte. Cultivation is apparently very limited in this reach of the Agua Fria River and would not be disturbed by the recharge activity. The remainder of this study concentrates on this reach.

The potential recharge area of the Agua Fria site was calculated by digitizing floodplain areas from U.S.G.S. topographic maps. This method of estimating potentials provides the maximum potential recharge area of the entire floodplain and would require the use of a modified channel approach to ensure that the full width of the floodplain is inundated. As an example, a diversion into the stream channel of only a few hundred cubic feet per second (cfs) would not naturally spread over the width of the site.

Channel modifications would be necessary to achieve the larger recharge areas potentially available under the calculations in the following paragraph. Modifications would take the form of low berms placed in the channel. These berms would be easily constructed of streambed materials and would have the advantage of allowing the recharge to be concentrated in the desired area. The berms would make the operation of each facility simpler by allowing a rotation in use of the bermed reaches and would allow road crossings and cultivated areas to be avoided.

The estimated maximum recharge potential for the Agua Fria streambed between the Granite Reef Aqueduct siphon and Calderwood Butte (see Figure 2) was calculated using a floodplain area of 1500 acres, an infiltration rate of 1.0 ft/day, and a period of 365 days or 1500 acres x 1 ft/day x 365 days/year = 547,500 acre-feet/year. A rough estimate of recoverable storage under the four mile reach of floodplain was made using a floodplain area of 1500 acres, an average depth of unsaturated alluvium of 40 feet (Figure 8), and an assumed storage capacity of 15%, or 1500 acres x 40 feet x 0.15 =

9,000 acre-feet recoverable storage under the site. This estimate is conservative. The recoverable volume of recharged water may actually be larger if the specific yield is found to be larger or if recharge water spreads to the east away from the floodplain and southward to the groundwater system lying to the south of Calderwood Butte. Not all water will be recoverable, due to the deficit caused by wetting the alluvium to field capacity. This loss is best explained as the difference between porosity (assumed to be 30%) and specific yield (assumed to be 15% in this study). The other 15% will not drain readily from the material, and is a one time loss that fills void spaces in the basin alluvium. The initial volume of recharged water that could be stored in the alluvium under the site may therefore be up to twice the 9,000 acre-feet quantity given above; half the initial stored volume will probably not be recoverable.

While the above calculations estimate maximum recharge potential, it should be noted that a smaller diversion of CAP water (100-200 acre-feet/day) would not require a recharge area of 1500 acres. Such a diversion would however require more subsurface storage than the estimated recoverable storage of 9,000 acre-feet. For example, an annual diversion of 100 acre-feet/day of CAP water (equivalent to a flow rate of 50.5 cfs) would require a subsurface storage capacity of 36,500 acre-feet. This is 27,500 acre-feet in excess of the estimated storage capacity available once field capacity is attained.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. This preliminary study indicates that utilizing the floodplain of the Agua Fria River in the area shown in Figure 2 for recharging surplus CAP water is technically feasible, however the available subsurface volume for storage of easily recoverable recharge water may be relatively small, unless sufficient lateral spreading occurs.

B. Geologic and hydrologic investigations conducted in the vicinity of the study area indicate the presence of approximately 40 feet of highly permeable, unsaturated alluvium underlying the river channel, although impeding layers of clay or tuff may be encountered locally. The unsaturated floodplain alluvium would accept an initial volume of about 18,000 acre-feet of recharged water. About half of this recharge would be recoverable due to losses to non-recoverable storage in the alluvium. The amount of additional subsurface storage space is dependent on the extent to which the recharged water can laterally spread to the east of the recharge site.

C. This study is not based on any fieldwork, which would be necessary if a second stage of this study is undertaken. Fieldwork would consist of obtaining channel cross sections and slopes to refine the estimated volumes of potential recharge area for each section of streambed considered, and reconnaissance level surveys to better determine site hydrogeology and available subsurface storage volumes. Borings would also be needed to assess subsurface conditions that may impede recharge.

D. Temporary gravel berms or levees will be needed to spread water over the site, thus increasing the quantity of water infiltrating the channel.

E. To assess the effectiveness of the recharge operation, it is recommended that a monitoring program be developed involving the gaging of inflow, the sampling of influent quality, the measurementof groundwater levels, and the sampling of groundwater quality. A network of observation wells should include wells near the center of the recharge area to monitor the elevation of the groundwater mound that will form, wells downgradient of the recharge area to monitor regional effects on groundwater levels and quality, and wells up to one to two miles east of the site to monitor any lateral spread of recharged water. Existing on-site wells should be inventoried for possible use as observation wells. If all existing wells are suitable as observation wells, the installation of two observation wells on site would be necessary; one in the W½ of Section 16 and another in the SW¼ of Section 21, T5N, R1E. Groundwater levels at the site should be monitored weekly during the first month of operation, bi-weekly during the second month, and monthly thereafter. Water quality should be analyzed in the receiving aquifer prior to the start of the operation. Analysis should include inorganics and standard field parameters at each of the observation wells selected. Similar analyses should be conducted on water discharged into the Agua Fria riverbed at the start of operations. These analyses should be repeated once per year. Field parameters should be collected from observation wells each time water levels are measured. All water quality monitoring should be coordinated with the Arizona Department of Health Services. Sampling frequency should be reassessed as the project progresses.

V. REFERENCES

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