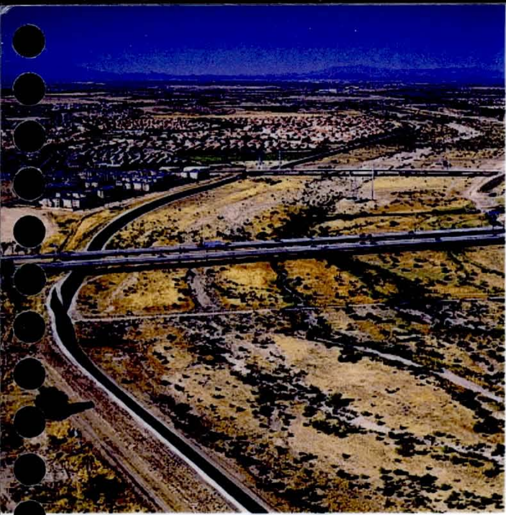

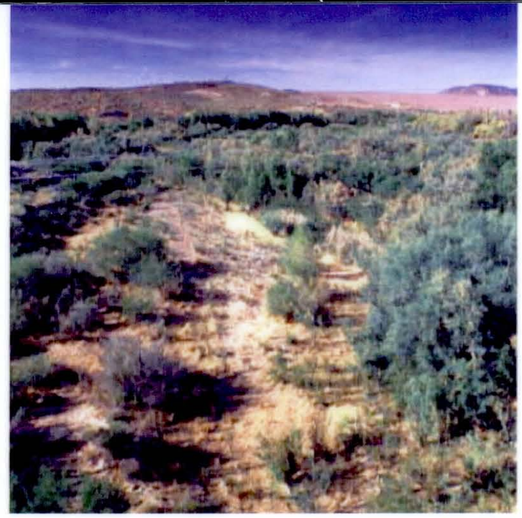

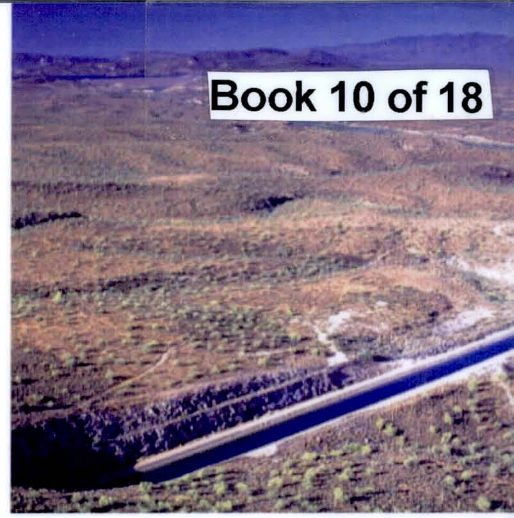

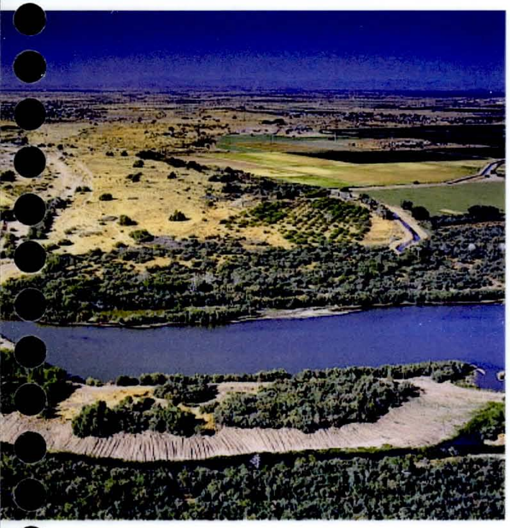

AGUA FRIA
WATERCOURSE MASTER PLAN

Groundwater Recharge Report

Prepared for

Flood Control District

September 2001

Fluid Solutions
Water • Wastewater • Engineering • Environmental Services

Kimley-Horn and Associates, Inc.

Acknowledgements

This watercourse master plan was prepared by a group of Maricopa County and Consulting professionals dedicated to improving the way we protect people and property from flood damages while meeting the multiple use needs of a growing population. The commitment to this ideal was demonstrated throughout this project by the Maricopa County Board of Supervisors and by leaders of the Flood Control District of Maricopa County. Finally, the plan for the West Valley Recreation Corridor captures the vision of John F. Long — a man who has spent his entire life trying to improve and promote quality of life for families in the West Valley.

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Groundwater Recharge Report

Agua Fria Watercourse Master Plan

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Table of Contents

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List of Tables

List of Figures

1.0 INTRODUCTION

The Aqua Fria River Watercourse Master Plan identifies and develops alternative plans for providing flood control along the Aqua Fria River. An additional aspect of the proposed Master Plan is evaluating the potential development of groundwater recharge facilities along the Aqua Fria river corridor. Recharge is the process of adding water to an aquifer system either through the infiltration of water from land surface, or injection into the subsurface via wells.

Groundwater is an important natural resource for domestic drinking water, agricultural irrigation, and industrial uses in the Salt River Valley. Historic pumping has depleted the groundwater system throughout much of the West Salt River Valley, including those areas around the Agua Fria River below New Waddell Dam. Water levels have declined significantly, which has resulted in an increasingly limited water supplies, the deterioration of water quality, land subsidence and development of earth fissures. Groundwater replenishment would become a significant attribute of the Agua Fria Watercourse Master Plan if recharge of renewable water sources were possible.

2.0 BACKGROUND

2.1 Definitions

"Natural" recharge is the movement of water from the surface through the soil zone to form or add to an aquifer. Natural recharge is the result of atmospheric precipitation that has escaped evaporation and uptake by plants (transpiration) and has infiltrated the soil. Ultimately, impermeable geologic materials impede the further downward movement of water and groundwater aquifers form. In the arid southwest, this type of recharge is generally limited to areas along the mountain fronts that define the basin peripheries and along flowing watercourses.

"Incidental" recharge occurs as a consequence of human activities. This type of recharge occurs by excess application of irrigation in agricultural fields and turfed areas, or as a result of leaks and/or losses within municipal distribution systems.

"Artificial" recharge is the act of deliberately augmenting the water supply of an aquifer. It has become an increasingly important water management tool in Arizona. Artificial recharge in Arizona has been characterized two ways: 1) the storage of water, or direct physical addition of water to an aquifer; 2) the saving of water, which is the act of indirectly saving groundwater by irrigating with renewable water sources and not pumping groundwater that would otherwise be pumped.

2.2 Benefits of Recharge

Very little natural recharge occurs in Arizona due to the hot, dry climate where evaporation and transpiration greatly exceed atmospheric precipitation. With the development of water supplies from existing aquifers, water has been withdrawn at a faster rate than it is being replenished, leading to groundwater deficits or "overdrafts". When these deficits become large relative to the uses in the basin, it becomes increasingly important to manage the use of groundwater carefully and to plan for safe groundwater supplies for future generations. Aquifer replenishment through artificial recharge of renewable water sources can be a cost-effective tool to ease the overdraft of a basin and augment a region's water supplies.

Groundwater recharge can also be used to assist in the timing of deliveries of water supplies. Storing water in an aquifer that already exists can lessen or eliminate the need for expensive water storage improvements, such as tanks or surface impoundments. Recharge and subsequent recovery of stored water can be used to balance water supplies and demands over the course of a year, or can be used to store currently available water supplies for future use at such time as demands increase to necessitate recovery.

Groundwater recharge and recovery can not only be used to increase a water provider's physical access to water supplies, but can also be used to provide administrative access to water within Arizona's Active Management Areas (AMAs). Recovery of stored water can provide a well owner with the legal authority to pump wells without having to secure a groundwater right. Recovery of stored water can, depending on the source of stored water, serve to alter the legal character of a pumping well from mined groundwater to a renewable water supply, such as CAP water or effluent. This can assist a water provider or developer in meeting the Assured Water Supply Rules, which require the use of renewable water supplies.

Recharge/recovery programs may also serve to decrease infrastructure costs. Accounting for recovered water does not require that the molecular water be recovered. Recovery can occur at distance from the stored water and in closer proximity to the end uses, so long as recovery well criteria are met. For example, a CAP Subcontractor could store water in a recharge facility near the Hayden Rhodes Aqueduct and, provided the groundwater supplies are physically available, recover this stored water at considerable distance from the canal from either existing or new wells within their service area. Under such a program, the cost of constructing the infrastructure to convey and treat raw CAP water could be avoided.

In the past, groundwater depletion has been severe in parts of central and southern Arizona. In these areas, the land can settle and subside as pore spaces in the de-watered aquifer collapse due to loss of grain buoyancy. Under certain circumstances earth cracks or fissures can develop. Subsidence and fissuring can destroy foundations, buildings, roads, piping, and flood-control structures and create efficient conduits for groundwater pollution. As the land subsides, drainage patterns can be altered, impacting the effectiveness of flood conveyance facilities. Recharge in areas of subsidence has the potential to lessen and perhaps cease land subsidence and the development and advancement of fissures.

Groundwater recharge can also be used for more specific applications such as: augmenting streamflow without the need for direct discharge, improving local water quality, and preventing sea water intrusion into potable aquifer along coastlines, to name a few.

2.3 Regulatory Framework

The Arizona Department of Water Resources (ADWR) governs the assessments of water supply, both groundwater and renewable sources, for the state of Arizona. Through its Underground Water Storage, Savings and Replenishment Program (more commonly known as the Recharge Program), ADWR administers the storage and recovery of artificially recharged water within the State. This program is intended to encourage the recharge of renewable water supplies and allow for the efficient, cost-effective management of water supplies.

The Arizona Department of Environmental Quality (ADEQ) reviews the quality of artificially recharged water and its effect on existing aquifers. Different sources of water require different types of review from ADEQ. Effluent is regulated through the administration of the Aquifer Protection Permit (APP) Program. The APP program specifically regulates the recharge of effluent and ensures that groundwater quality standards in the aquifer will not deteriorate under the influence of effluent recharge. Central Arizona Project (CAP) water and other types of surface water are exempt from the APP program. In these cases, ADEQ assists ADWR by reviewing the water quality of the water to be recharged and the existing aquifer under ADWR's Recharge Program.

The Flood Control District of Maricopa County has established a policy and permitting process for groundwater recharge, replenishment or underground storage activities on land leased from the District. The policy is designed to allow recharge activities, where appropriate, while protecting the District's structures and mission. The program is designed to complement ADWR's permitting process.

2.3.1 ADWR Permits

There are three types of permits that make up the Recharge program. These are: 1) Facility Permits; 2) Water Storage Permits and; 3) Recovery Well Permits. These permits work in unison with one another to create a flexible way to store and recover water.

There are two types of facility permits, Underground Storage Facility (USF) Permits and Groundwater Savings Facility (GSF) permits. A USF can be created anywhere throughout the state of Arizona, but a GSF can only be operated within an Active Management Area or an Irrigation Non-expansion Area. Neither facility permit can be used without associated Water Storage Permit(s).

USFs can either be classified as "managed" or "constructed". A managed USF utilizes a natural stream course for the infiltration of water into an aquifer and does not contain structures that impound water to specific areas, such as berms and levees. Managed USFs must meter the quantity of water that is released to the stream course, but due to the scourering effects of flood flows, are not generally required to maintain the area to enhance recharge capabilities (except for the removal of macrophytes in some instances).

A constructed facility utilizes structures specifically designed to add water to an aquifer, such as a recharge basin or an injection well, and are maintained to promote infiltration of recharged water. Where space is limited, or in cases where the groundwater aquifer is confined between impermeable layers, recharge may only be achieved by injecting water directly into the aquifer. Metering must also be done on all water entering constructed facilities.

The second type of facility permit is the Groundwater Savings Facility (GSF) Permit, sometimes called "in-lieu" facilities. Under this type of permit, a groundwater user, typically an agricultural irrigator, agrees to accept a renewable supply of water "in-lieu" of pumping their wells, thereby saving groundwater. The entity providing the renewable water supply to the irrigator is credited for the groundwater that remains in storage.

A Water Storage Permit (WS) must be secured at "permitted facilities" to actually recharge water. A WS permit holder must prove they have legal authority to the water and must agree to comply with the plan of operation of the facility at which they are storing. Multiple water storage permits are allowable at a facility, so long as the sum of all water stored at the facility does not exceed the permitted capacity of the facility.

Recovery well (RW) permits provide the authority for recovering recharged water. A RW permit designates well(s) as recovery well(s). Provided recovery occurs in the same AMA and operation of the recovery well(s) does not negatively impact surrounding well owners, the RW permit does not limit recovery to the same area as the water was recharged. Recovery wells can be new wells dedicated to recovery of recharged water, or may be existing wells, associated with prior groundwater right or permits.

The end product of these recharge permits are recharge credits. There are two types of recharge credits, annual storage and recovery (ASR) credits or long-term storage (LTS) credits. An annual storage and recovery credit is an acre-foot of water that was stored at a permitted facility, pursuant to a WS permit, and was recovered within the same year as it was stored. Due to surface water laws, surface water (Salt, Verde, and Agua Fria water) is not eligible to become a LTS credit and must be recovered within the month that it was stored. These activities are handled through ASR. LTS credits are those credits that meet the criteria of "water that cannot be reasonably used directly" and water that has been not been recovered within the year it was stored. LTS credits can be bought and sold within the AMA credits were stored in and may only be recovered with a recovery well permit.

LTS credits of CAP water provide additional benefits to the aquifer in which water is stored through a required 5% "cut to the aquifer". In other words, the storer of CAP LTS credits is only allowed to recover 95% of the water stored. Effluent is not subject to this aquifer donation, except when it is stored at a managed facility and then 50% of water stored is donated the aquifer.

2.3.2 ADEQ Permits

Discharges to surface waters of the United States generally require a National Pollution Discharge Elimination System (NPDES) Permit. Most dry washes in Arizona are considered "waters of the US." While this is a federal program administered by the US Environmental Protection Agency (EPA), ADEQ conducts permit application reviews and writes the permits. The NPDES Permit is signed and issued through the EPA and is required for all discharges to surface waters where treated wastewater effluent or stormwater is introduced. The permit includes parameters and limits based on surface water quality standards for a particular reach of a stream. Under most situations, existing surface water (like CAP water) that is diverted to another wash will not require a

NPDES Permit. However, if CAP is combined with either effluent or stormwater, a NPDES Permit may be required.

As stated above, ADEQ will review the water quality of all recharged water irrespective of the source. If the source is effluent, an individual APP issued through ADEQ will be required. In general, individual APPs are issued for the life of the facility; however, at the discretion of ADEQ, individual APPs for pilot effluent recharge projects may be issued for a shorter time duration, usually on the order of two years. These projects are designed to evaluate long-term recharge feasibility. If the source is stormwater, ADEQ will determine if either an individual or a general APP will be required. The review for an individual APP requires more time and technical information. This equates to higher costs for the applicant. If the source is CAP water, and possibly other existing surface waters, the facility is exempt from individual APPs. For recharge facilities exempt from the APP Program, ADEQ will review the water quality of the source water and the potential impact to groundwater, and advise ADWR on each USF Permit issued by that agency. Both the APP and/or the USF Permit will require discharge monitoring before waters are recharged and groundwater monitoring in a well downgradient of the recharge site. If CAP or other surface water is the source water, the monitoring requirements for the USF Permit may be lessened if there are no elevated chemical concentrations after the first year or two.

ADEQ also administers permitting activities related to the reuse of reclaimed wastewater. Reuse refers to the use of reclaimed wastewater transported from the point of treatment to the point of use without an intervening discharge to surface waters of the state. Under this program, ADEQ establishes different discharge limits for different types of reuse. Examples of types of reuse would include irrigation on orchards, pastures, or landscaped areas with restricted or open access, to name a few. Typical parameters to be monitored are biological, like fecal coliform, enteric viruses, and tapeworms. Although a Reuse Permit may not be required from ADEQ under most recharge scenarios along the Aqua Fria River, the applicant for recharge permits may want to impose some of the reuse standards on the quality of the in-channel water and reused water piped from the Aqua Fria. This action would act as additional protection of human health and may assist in the public perception and acceptance of an effluent recharge project along the Aqua Fria River.

2.4 Water Rights in the West Valley

Much of the land in the western portions of the Salt River Valley (SRV) has historically been irrigated. The majority of this irrigation has occurred within the large irrigation districts that cover the area, the Salt River Project (SRP), the Maricopa Water District (MWD), the Roosevelt Irrigation District (RID) and the Buckeye Irrigation Company (BIC). Significant irrigated acreage also exists outside of the boundaries of these districts.

SRP member lands have rights to the water supplies of the Salt and Verde Rivers. SRP members are also entitled to groundwater pumped from within the boundaries of the Project.

MWD is located in the far west SRV. Its member lands are entitled to the flows of the Agua Fria River and to groundwater pumped from within its borders. Water from the Agua Fria is not as plentiful for MWD as Salt and Verde waters are for SRP. Consequently, the District has historically relied more heavily on groundwater for irrigation supply. Groundwater pumping (by MWD and others) within and in the vicinity of MWD has resulted in significant water level declines. As previously discussed, these groundwater declines have significantly reduced the groundwater in storage in the basin and have caused land subsidence and the development of earth fissures.

RID and BIC serve water for irrigation use in the southwest Valley. RID has historically served groundwater, and was formed to de-water the southwest portions of SRP. In recent years, treated wastewater from the City of Phoenix 23rd Avenue Wastewater Treatment Plant (WWTP) has become a supply source for RID through a water exchange made as part of the settlement of the water rights claims of the Salt River Pima Maricopa Indian Community and through in-lieu arrangements with Phoenix.

BIC diverts the flows of the Gila River for irrigation use immediately downstream of its confluence with the Salt. At the present time, these flows are primarily comprised of the discharges from the 91st Avenue WWTP. By contract, Phoenix is obligated to maintain discharges of at least 30,000 acre-feet per year for diversion by BID. Shallow groundwater levels along the Gila River have resulted in the land within BID being declared waterlogged by the Arizona State Legislature.

Prior to the recent construction of a CAP treatment plants by the City of Glendale, all municipal uses in the west SRV located outside of the boundaries of the Salt River Project have relied on groundwater as the sole source of supply. Groundwater is a finite resource, which is being used at a rate in excess of its replenishment. Portions of the West Valley do not have sufficient groundwater reserves relative to the anticipated demands to satisfy the requirements of ADWR's Assured Water Supply Program. In addition, much of the groundwater supplies in the West Valley are not of suitable quality for municipal use. There is limited reuse/recharge of effluent going on today in the West Valley.

Planning efforts are underway to increase the utilization of CAP water in the West Valley. WESTCAPS, a consortium of 11 West Valley water utilities, has been formed to work cooperatively and develop a regional plan for CAP utilization. WESTCAPS has adopted a regional strategy that, in the long run, relies on direct use of CAP supplies. Groundwater recharge is anticipated to be a significant component in the next couple of decades. Additionally, other groundwater recharge efforts have been initiated and are discussed in Section 2.6 below.

2.5 Site Considerations

Prior to the implementation of a recharge program, there are a number of site considerations that must be addressed based on technical design and regulatory concerns. These include the following:

- The project will not cause unreasonable harm to surrounding land and water users,
- The proposed facility's recharge infiltration rates are sufficiently high enough to ensure that losses will not exceed or approach the estimated storage at the facility,
- There is adequate storage potential within the aquifer for the proposed recharge volume,
- The facility can physically recharge the volume of water requested in the application, and
- The recharged water will not migrate to an area where it cannot be available for subsequent recovery and use.

"Unreasonable harm" may be interpreted to mean that the rise in groundwater due to recharge does not cause (1) localized flooding of basements, septic systems, or quarry and landfill excavations, or (2) the leaching and mobilization of contaminants from the soil above the aquifer to the groundwater system. The term may also be interpreted as the induced movement of an existing contaminant plume in the aquifer to a well that is used as a domestic drinking water source. For managed or constructed facilities located in a river or wash, if there are potential flooding issues which could result in unreasonable harm, a surface water modeling analysis may be required. Vector and nuisance issues such as insects and odors could also be construed as unreasonable harm.

The proximity of the recharge facility to the legislatively declared waterlogged areas is also a site consideration. Any recharge activities found to contribute to the waterlogging may have difficulty securing the requisite permits from ADWR, or the recharged water may be ineligible for recharge credit accumulation. In addition, exacerbating this waterlogged condition may be interpreted as causing unreasonable harm.

2.6 Existing and planned recharge projects along the Aqua Fria

There are a number of existing facilities that are permitted to conduct recharge and underground storage in the vicinity of the Aqua Fria River. These are discussed sequentially from north to south and are listed in Table 1.

TABLE 1

Permitted Recharge Facilities Along Agua Fria River

Facility name	River Reach[1]	Distance from River (miles)	Facility Type	Type of Construction	Water Source	Permitted Volume (ac-ft/yr)
Aqua Fria CAWCD[2]	upper	0	managed		CAP	100,000
Aqua Fria CAWCD[2]	upper	0	constructed	basins	CAP	100,000
Sun City West	upper	< 0.5 (east)	constructed	basins	effluent	3,042
Peoria Beardsley	upper	< 0.5 (east)	constructed	basins	effluent	2,470
Surprise South Plant	middle	2 (west)	constructed	basins	effluent	3,584
Glendale West	middle	< 0.5 (east)	constructed	basins, trenches, vadose wells, injection wells	effluent	5,000
Avondale	lower	< 0.5 (west)	constructed	basins	CAP, SRP	10,000
Goodyear SAT	lower	3.5 (west)	constructed	basins	effluent	3,360

(1) The Upper Reach is from New Waddell Dam to Bell Road. The Middle Reach is from Bell R to New River confluence. The Lower Reach is from New River Confluence to Gila Confluen
(2) Facility not yet operational.

CAWCD's facility with managed and constructed components, known as the Aqua Fria Recharge Project (AFRP), is located in the upper reach. Upon its completion, the AFRP will be a capable of recharging up to 100,000 acre-feet per year of CAP water for twenty years. CAWCD will deliver water to the facility through the blow off structure in the siphon under the Agua Fria River. The water discharged from the siphon will flow in the Agua Fria River bottom through the managed portion of this facility for roughly 4 miles. The volume of water discharged from the siphon will be metered and the fate of the water as it flows downstream and infiltrates into the riverbed will be monitored. At the southern termination of this managed reach, basins will be built to capture and recharge the water that has not either infiltrated or been lost to evapotranspiration through the managed reach. These basins are to be developed within the Agua Fria floodplain, but outside the floodway. The facility is anticipated to store excess CAP water for future recovery and use in times of supply shortage along the Colorado River; replenish the groundwater pumping of members of the Central Arizona Groundwater Replenishment District (CAGRD); and be available to other CAP contractors and subcontractors.

South of these facilities, but still in the upper reach of the Aqua Fria, are the Del Webb Sun City West and City of Peoria Beardsley recharge facilities. Sun City West is permitted for 50 years; whereas the Peoria facility is permitted for twenty years. Both facilities recharge effluent through basins (constructed facilities). The Sun City West and the City of Peoria recharge facilities are permitted to recharge up to 3,042 and 2,470 acre-feet per year, respectively. They are both located east of the Agua Fria River Floodplain.

Two miles west of the middle reach of the Aqua Fria lies the City of Surprise South WWTP. This facility is permitted to recharge up to 3,584 acre-feet per year, for twenty years, of treated effluent through basins.

Further south, but along the middle reach of the Aqua Fria, lies the City of Glendale West Artificial Recharge Facility. This facility is permitted as a pilot project to recharge up to 10,000 acre-feet over a two-year period. This facility currently utilizes basins, trenches, vadose zone wells and injection wells to recharge treated effluent. (Vadose zone wells deliver water to the unsaturated interval between the land surface and the water table. Injection wells deliver water directly to an aquifer, below the water table.) The results of the pilot project inferred that constructed basins provided adequate infiltration rates and could be used in the full-scale project without adverse environmental consequences. The City has recently applied for a full-scale project to recharge up to 7,842 acre-feet per year in basins using treated effluent.

Along the lower reach of the Aqua Fria lies the City of Avondale facility, which is permitted to recharge up to 10,000 acre-feet per year for twenty years. This facility will recharge Avondale's CAP and SRP waters water using infiltration basins. The water is delivered though SRP's Grand Canal and purified in the constructed wetlands at the Crystal Gardens subdivision prior to delivery for recharge

Three and one-half miles west of the lower Aqua Fria lies the City of Goodyear Soil Aquifer Treatment (SAT) facility. This is project is permitted to recharge treated effluent up to 3,360 acre-feet per year for twenty years through basins.

With the exception of the Sun City West facility, these recharge facilities have been permitted and have become operational since 1996. The Sun City West facility was permitted in 1993 and became operational soon thereafter.

The Sub Regional Operating Group (SROG), the entity that owns the 91st Avenue WWTP, is evaluating recharge of treated effluent along a large reach of the Agua Fria south of Bell Road. This facility could potentially recharge up to 80,000 acre-feet annually. This facility may be developed as a managed facility, potentially resulting in significant flows along the Agua Fria River.

SRP has proposed the development of a recharge facility beginning at the terminus of the Grand Canal and extending along the southern portion of New River and into the Aqua Fria River floodplain. The New River/Aqua Fria Underground Storage and Recovery Project (NAUSRP) is anticipated to be both a managed and constructed facility with an expected capacity of 100,000 acre-feet per year. The NAUSRP will be utilized for the long-term storage of CAP water and ASR of SRP supplies.

In addition to recharge sites along the Aqua Fria, there are a few proposed sites along New River. The City of Glendale is proposing a two-year project utilizing injection or vadose-zone wells to recharge treated effluent from the Arrowhead Ranch Wastewater Treatment Plant (WWTP). The City of Phoenix and SRP are also looking at options to recharge along New River.

2.7 *Potential water sources*

There are three primary water sources available for recharge in the Agua Fria River. They are: (1) surface water from the Agua Fria and Salt and Verde watersheds; (2) Colorado River water imported through the CAP aqueduct; and (3) treated wastewater effluent generated by the municipalities and private utilities in the Phoenix metropolitan area. In addition, less significant sources may also be capable of contributing water to the Agua Fria channel, including local runoff and agricultural tail water. Each of the water sources present opportunities and challenges and are examined in some detail below. Additionally, within each class of water, significant differences exist in the quantity, quality and reliability of these water supplies throughout the study area.

2.7.1 Surface Water

Currently, all of the normal flows of the Agua Fria and Salt River are fully appropriated. In addition, regulatory surface reservoirs have been constructed for the benefit of these surface water right holders. Waddell Dam on the Agua Fria River was constructed to store and develop its waters to the benefit of the lands that now comprise the Maricopa Water District. New Waddell Dam was constructed to store CAP water. However, MWD retains its original storage pool and the rights to Agua Fria flows. The entire Salt and Verde river reservoir system has been constructed primarily to benefit the Salt River Project member lands. Both the MWD and SRP systems have interconnections with the CAP delivery system. MWD and SRP have, through water exchanges and other regulatory vehicles, been able to incorporate CAP water into conjunctively managed water supply systems to the benefit of both their members and the CAP.

As stated above, these systems are fully appropriated. As such, the ability to divert significant volumes of these water supplies from their current uses to recharge along the Agua Fria River is limited. There are, however, times when storm flows or snowmelt occur in excess of the reservoir systems' ability to contain these flows. During these times, "spillwater" is typically declared. Far fewer restrictions are imposed on the use of spillwater. SRP has recharged spillwater in the Granite Reef Underground Storage Project (GRUSP). Unfortunately, spillwater does not represent a reliable water supply, either physically or administratively.

Agua Fria River flows in excess of MWD's ability to divert or capture in their Lake Pleasant storage space are available to CAWCD to augment the water supplies of the CAP. Spills have and will occur from New Waddell Dam. At the present time, with the exception MWD's customers along the Beardsley Canal, no facilities exist to formally recharge any New Waddel spills. Infiltration of flood flows along the Agua Fria has historically been an important part of the replenishment of the West Salt River Valley groundwater system. The increased ability to capture these flows behind New Waddell has potentially reduced this natural source of groundwater replenishment.

Locally, tributary drainages contribute water to the Agua Fria River during storm events. These drainages do not represent a reliable water supply, but can, at times, result in the contribution of significant volumes of water to the channel.

2.7.2 Central Arizona Project Water

The CAP was constructed to deliver 1.4 million acre-feet (MAF) of the State's 2.8 MAF entitlement to Colorado River water to central Arizona. The aqueduct crosses the Agua Fria River roughly 1 mile south of the Carefree Highway alignment. Additionally, the original Waddell Dam was replaced by New Waddell Dam creating a larger Lake Pleasant to provide regulatory storage for the CAP delivery system in addition to the storage of MWD's Agua Fria River flows.

There is a water priority system in place to allocate the supplies of the Colorado River to all 7 basin states. Internally, Arizona's CAP supply is distributed between Indian, municipal and industrial (M&I), and agricultural users. The Indian tribes contract directly with the Secretary of Interior for their portion of the CAP supply. CAWCD has contracted with Interior on behalf of the State parties whose individual rights and access to water are governed by their subcontracts with CAWCD. At the present time, roughly 625,000 acre-feet of the CAP supply is earmarked for State party M&I purposes (558,511 acre-feet is under contract), approximately 310,000 acre-feet is allocated to Indian entities, with the remainder either unallocated or allocated to State party agricultural interests.

Two parallel negotiations are ongoing at this time related to the CAP: (1) the settlement of disputes over CAWCD's repayment obligation to the Federal Government for its portion of CAP construction costs and (2) attempts to settle the water rights claims of the Gila River Indian Community. These settlement efforts are intended to avoid further litigation on both issues and have the potential to significantly alter the makeup of the CAP and the allocation of its water supplies. Table 2 contains a list of current CAP subcontract holders in the general vicinity of the Agua Fria River.

Not all of these volumes are intended for West Valley use, such as the allocations of the State Land Department, City of Phoenix and the Maricopa County Parks and Recreation Department.

Several of these entities are actively pursuing increases to their CAP allocation in response to anticipated demands. Only the cities of Avondale (through recharge/recovery), Glendale, Peoria (through purchase of capacity in Glendale's Pyramid Peak WTP), and Phoenix have the ability to take CAP water into their distribution systems. Those cities and several of the remaining providers are actively pursuing the planning and development of additional CAP treatment, delivery, and recharge infrastructure.

None of the West Valley agricultural interests exercised their options to subcontract for CAP supplies. Until recently neither the state subcontractors nor the federal contractors were fully utilizing their CAP allocations. This underutilization of the CAP supply created some concern among Arizona's water interests in that Arizona's unused entitlement to Colorado River water was being diverted for use in Southern California and Nevada. Arizona was concerned that, to the extent the neighboring states' economies became reliant on Arizona's water, it may have been difficult to retrieve this unused entitlement once Arizona's growth and development necessitated its importation and use. A Task Force was created to examine the underutilization of the CAP supply,

TABLE 2

WEST VALLEY CAP SUBCONTRACTORS

Subcontracts	Allocation (acre-feet)
Municipal and Industrial Subcontracts	
Arizona State Land Department	33,076
Arizona Water Company - White Tanks	968
City of Avondale	4,746
Brooke Water L.L.C.	3,932
Town of Buckeye	25
City of Glendale	14,183
City of Goodyear	3,381
Litchfield Park Service Company	5,580
Maricopa County Parks and Recreation Department	665
New River Utility Company	1,885
City of Peoria	18,709
City of Phoenix	113,914
Sunrise Water Company	944
City of Surprise	7,373
Water Utility of Greater Buckeye	43
Water Utility of Greater Tonopah	64
West End Water Company	157
TOTAL	**209,645**

Source: CAP, 1998

which ultimately resulted in the formation of the Arizona Water Banking Authority (AWBA).

The AWBA was created to store unused Arizona Colorado River water to meet future needs for:

- Assuring adequate supply to municipal and industrial users in times of shortages or disruptions of the CAP system;
- Meeting the management plan objectives of the Arizona Groundwater Code;
- Assisting in the settlement of Indian water rights claims; and
- Exchanging water to assist Colorado River communities.

In addition to these functions, the AWBA can also undertake additional water banking activities. Since its creation the AWBA has stored over 775,000 acre-feet of water in Central Arizona. Much of this storage (between 60 and 70 percent annually) has been conducted in the most economical way possible, through in-lieu arrangements with irrigation districts. SRP's GRUSP is the sole constructed facility in Maricopa County to have received AWBA water. Over 134,000 acre-feet of water have been stored by the AWBA in GRUSP through 1999.

The Central Arizona Groundwater Replenishment District (CAGRD) was formed in response to anticipated difficulties the development community would have in complying with the new Assured and Adequate Water Supply Rules, enacted by ADWR in February 1995. These rules required the use of renewable water supplies in order to demonstrate that proposed development was consistent with the Management Goal of Safe Yield by the year 2025. The CAGRD provides access to renewable water supplies for entities that do not hold subcontracts for CAP water. The CAGRD is obligated to provide replenishment services for its members. It has up to 3 years to replenish the groundwater that its members pump. At the present time, the CAGRD does not hold permanent allocation of water itself. It is anticipated that excess CAP water will be its primary source of supply for the foreseeable future. However, as the District's membership grows and CAP subcontractors' use increases, it will face increasing difficulty in securing the requisite supplies to fulfill its mission.

2.7.3 Effluent

Recharge of treated effluent is becoming an increasingly common practice in Arizona. It can often represent a cost effective means of effluent disposal while augmenting local groundwater supplies. Table 3 below, contains a summary of the wastewater treatment facilities in close proximity to the Agua Fria River.

The 91^{st} Avenue WWTP is the largest in the State. It is operated by the City of Phoenix and owned the Sub Regional Operating Group (SROG) whose members are the cities of Glendale, Mesa, Phoenix, Scottsdale, and Tempe. At the present time, much of the effluent produced at 91^{st} Avenue is transported in a large pipeline to the Palo Verde Nuclear Generating Station (PVNGS) where it serves as the sole source of cooling water for the reactors. The effluent not delivered to Palo Verde is discharged to the Salt River. Under normal conditions, this discharged water flows downstream, is met by small flows from the Gila River at 115^{th} Avenue, and is diverted by the Buckeye Irrigation Company immediately below the confluence of the Gila and Agua Fria. Phoenix discharges a minimum of 30,000 acre-feet per year to fulfill a contractual obligation to the BIC. Any water not diverted by the BIC continues downstream and exits the AMA at Gillespie Dam.

Table 3. Inventory of Potential Water Suppliers

Water Source	Ownership	Location of Diversion, End of Pipe, or Outfall	Quantity	Quality	Availability/Reliability Short/Long Term	Notes
Surface Water						
Aqua Fria River	Maricopa Water District (MWD)	New Waddell releases; Beardsley Canal; and diversion to CAP/SRP canal system	Limited quantity available for recharge, if any; already fully appropriated	Agua Fria and CAP supplies intermingled in Lake Pleasant and Beardsley Canal; Generally suitable for recharge without treatment; Direct potable use requires treatment; in 1997 at Granite Reef CAP water met aquifer water quality standards.	Limited availability, if any; unreliable source; short-term spillwater may be available to Aqua Fria CAWCD Recharge project	
Salt and Verde Rivers	Salt River Project	Arizona and Grand Canals	SRP states that no water is available for recharge (when refering to the proposed New River and Aqua Fria Underground Storage and Recovery Project (NAUSRP).	1997 data from SRP: Arzona Canal @ 72nd Ave.: meets AWQS, except possibly cadium=0.005 mg/l (TDS up to 751 mg/l, Cl up to 299 mg/l, and pH up to 8.6 mg/l). Grand Canal @ 99th Ave.: meets AWQS, except possibly cadium=0.005 mg/l, (Cl up to 302 mg/l, pH up to 8.7 mg/l, and TDS up to 753 mg/l).	Not available; Limited spillwater may be available	
Gila River	Buckeye Irrigation Company; Arlington Canal Company; other downstream appropriators	Gila River	uncertain	Probably poor quality (effluent dominanted and irrigation return flows); additional water treatment may be required.	uncertain	Water quality along the Gila River may change if the Tres Rios and El Rio flood control projects move forward.
Floodwater/Spillwater						
Aqua Fria River	CAP (or CAP and MWD); Downstream appropriators	Bypass Aqua Fria CAWCD Recharge project or Beardsley Canal and diversions to CAP/SRP canal system	uncertain	Uncertain; however, may be high in suspended solids and other constituents	Limited availability, if any; unreliable source	
New River	Downstream appropriators	Confluence of the New and Aqua Fria Rivers	uncertain	Uncertain; however, may be high in suspended solids and other constituents	Limited availability, if any; unreliable source	

Table 3. Inventory of Potential Water Suppliers

Water Source	Ownership	Location of Diversion, End of Pipe, or Outfall	Quantity	Quality	Availability/Reliability Short/Long Term	Notes
Other Aqua Fria Tributaries	Downstream appropriators; Bordering landowners	Four major tributaries north of Bell Rd. coming directly from mountains; 3 minor tributaries south of Bell Rd. (at the town of El Mirage, Hwy 60, and south of Peoria Rd.)	uncertain	Uncertain; however, may be high in suspended solids and other constituents	Limited availability, if any; unreliable source	
Salt and Verde Rivers	SRP; Downstream appropriators	Arizona and Grand Canals; Gila River	uncertain	Base water quality described above under Salt and Verde Rivers; however, under flood or spill conditions may be high in suspended solids and other constituents	Limited availability, if any; unreliable source	
Gila River	Buckeye Irrigation Company; Arlington Canal Company; other downstream appropriators	Gila River	uncertain	Uncertain, but probably will remain poor quality due to effluent domination and agricultural runoff. May be high in suspended solids and other constituentsunder flood or spill conditions	Limited availability, if any; unreliable source	See above under Gila River
			CAP			
Municipal and Industrial (M&I)	Arizona Water Company - White Tanks	CAP, Beardsley, Arizona, and Grand Canals	968 AF/yr allocated, but not currently used	Generally good quality, but will be dependent on the source location	If available, this water would be a reliable, long-term source at least until 2025. After 2050, shortages are expected to exist.	Seek partnership
	City of Avondale	CAP, Beardsley, Arizona, and Grand Canals	4,746 AF/yr allocated and most, if not all, is recharged after polishing at Crystal Gardens subdivision constructed wetlands	1997 data: Grand Canal @ 99th Ave.: meets AWQS (nitrate as N=3.73 mg/l), except possibly cadium=0.005 mg/l, but Cl up to 302 mg/l, pH up to 8.7 mg/l, and TDS up to 753 mg/l.; currently uses wetland treatment to upgrade nitrate qulality during certain times	Probably not available	Inquire

Table 3. Inventory of Potential Water Suppliers

Water Source	Ownership	Location of Diversion, End of Pipe, or Outfall	Quantity	Quality	Availability/Reliability Short/Long Term	Notes
	Brooke Water L.L.C.	CAP, Beardsley, Arizona, and Grand Canals	3,932 AF/yr allocated, but not currently used	Generally good quality, but will be dependent on the source location	If available, this water would be a reliable, long-term source at least until 2025. After 2050, shortages are expected to exist.	Seek partnership; aka Circle City Water Co.
	Town of Buckeye	CAP, Beardsley, Arizona, and Grand Canals	25 AF/yr allocated, but not currently used	Generally good quality, but will be dependent on the source location	If available, this water would be a reliable, long-term source at least until 2025. After 2050, shortages are expected to exist.	Allocation is miniscule and declines
	City of Glendale	CAP, Beardsley, Arizona, and Grand Canals	14,183 AF/yr allocated and is used	Pulled from CAP canal at Glendale Pyramid WTP; similar to typical CAP water quality which generally meet AWQS with the possible exception of cadmium	Probably not available	Inquire
	City of Goodyear	CAP, Beardsley, Arizona, and Grand Canals	3,381 AF/yr allocated, but not currently used	Generally good quality, but will be dependent on the source location	If available, this water would be a reliable, long-term source at least until 2025. After 2050, shortages are expected to exist.	Seek partnership; current short-term plans are for recharge adjacent to Beardsley Canal
	Litchfield Park Service Company	CAP, Beardsley, Arizona, and Grand Canals	5,580 AF/yr allocated, but not currenly used	Generally good quality, but will be dependent on the source location	If available, this water would be a reliable, long-term source at least until 2025. After 2050, shortages are expected to exist.	Seek partnership
	Maricopa County Parks and Recreation Dept.	CAP, Beardsley, Arizona, and Grand Canals	665 AF/yr allocated, but not currently used	Generally good quality, but will be dependent on the source location	If available, this water would be a reliable, long-term source at least until 2025. After 2050, shortages are expected to exist.	Seek partnership
	New River Utility Compay	CAP, Beardsley, Arizona, and Grand Canals	1,885 AF/yr allocated, but not currently used	Generally good quality, but will be dependent on the source location	If available, this water would be a reliable, long-term source at least until 2025. After 2050, shortages are expected to exist.	Seek partnership; Located within Peoria
	City of Peoria	CAP, Beardsley, Arizona, and Grand Canals	18,709 AF/yr allocated and is partially used	Pulled from CAP canal at Glendale Pyramid WTP; similar to typical CAP water quality which generally meet AWQS with the possible exception of cadmium	Probably not available	Inquire

Table 3. Inventory of Potential Water Suppliers

Water Source	Ownership	Location of Diversion, End of Pipe, or Outfall	Quantity	Quality	Availability/Reliability Short/Long Term	Notes
	City of Phoenix	CAP, Beardsley, Arizona, and Grand Canals	113,914 AF/yr allocated and is used	Pulled from CAP canal at Phoenix Union Hills WTP; similar to typical CAP water quality which generally meet AWQS with the possible exception of cadmium	Probably not available	Inquire
	Sunrise Water Company	CAP, Beardsley, Arizona, and Grand Canals	944 AF/yr allocated, but not currently used	Generally good quality, but will be dependent on the source location	If available, this water would be a reliable, long-term source at least until 2025. After 2050, shortages are expected to exist.	Seek partnership; Located within Peoria
	City of Surprise	CAP, Beardsley, Arizona, and Grand Canals	7,373 AF/yr allocated, but not currently used	Generally good quality, but will be dependent on the source location	If available, this water would be a reliable, long-term source at least until 2025. After 2050, shortages are expected to exist.	Seek partnership; current short-term plans are for recharge behind McMicken Dam along Beardsley Canal
	Water Utility of Greater Buckeye	CAP, Beardsley, Arizona, and Grand Canals	43 AF/yr allocated, but not currently used	Generally good quality, but will be dependent on the source location	If available, this water would be a reliable, long-term source at least until 2025. After 2050, shortages are expected to exist.	Seek partnership
	Water Utility of Greater Tonopah	CAP, Beardsley, Arizona, and Grand Canals	64 AF/yr allocated, but not currently used	Generally good quality, but will be dependent on the source location	If available, this water would be a reliable, long-term source at least until 2025. After 2050, shortages are expected to exist.	Seek partnership
	West End Water Compay	CAP, Beardsley, Arizona, and Grand Canals	157 AF/yr allocated, but not currently used	Generally good quality, but will be dependent on the source location	If available, this water would be a reliable, long-term source at least until 2025. After 2050, shortages are expected to exist.	Seek partnership
Agricultural	None					
Excess CAP statewide	Arizona Water Banking Authority (AWBA)	CAP, Beardsley, Arizona, and Grand Canals	estimated 245,738 AF available in 2000	Generally good quality, but will be dependent on the source location	This water is anticipated to be available in decreasing quantities thould 2025. After that time, its long-term availability and reliability are unlikely.	Seek partnership
Excess CAP statewide	Central Arizona Groundwater Replenishment District (CAGRD)	CAP, Beardsley, Arizona, and Grand Canals	estimated 33,000 AF of committed West Valley replenishment obligation as of 2001. Replenishment Obligation (and recharge capacity requirements) will continue to increase.	Generally good quality, but will be dependent on the source location	At the present time must rely on excess water. CAGRD is working on secruing more reliable long-term supplies. May include sources other than CAP water.	Seek partnership. Significant beneficiary of CAP Agua Fria Recharge Project

Table 3. Inventory of Potential Water Suppliers

Water Source	Ownership	Location of Diversion, End of Pipe, or Outfall	Quantity	Quality	Availability/Reliability Short/Long Term	Notes
Indian	Ak-Chin, Camp Verde, Fort McDowell, Gila River Indian Community, Pascua Yaqui, San Carlos-Apache, Tohono O'Odham, San Xavier, Schuk Toak, Tonto-Apache, Yavapai-Prescott Maricopa, Ak Chin?, and Salt River	CAP, Beardsley, Arizona, and Grand Canals	309,828 AF, will likely increase significnatly with pending settlements	Generally good quality, but will be dependent on the source location	A portion of supply may be available for lease. If available, this water would be a reliable, long-term source at least until 2025. After 2050, shortages are expected to exist. Short-term unused approtionments will be available as excess water through CAP or AWBA	Seek partnership?
Effluent						
Luke Air Force Base WWTP	United States Air Force	Glendale Ave. and El Mirage Rd. (Sec. 1, T2N, R1W)	1.2 MGD or 1,344 AF/yr (permitted flow)	denitrified, filtered, UV disinfection; appears suitable for recharge and open access; suitable for surface discharge	effluent is currently reused consumptively and discharged to a tributary to the Aqua Fria	Seek partnership
Litchfield Rd. WWTP	City of Surprise	Bell Rd. and Litchfield Rd. (Sec. 33, T4N, R1W)	0.43 MGD or 482 AF/yr (permitted flow)	tertiary treatment with filtration and chlorination; may require additional treatment to be suitable for recharge and surface discharge; appears suitable for open access	effluent is reused consumptively	Seek partnership
City of Avondale WWTP	City of Avondale	Broadway Rd. and Dysart Rd. (Sec. 27, T1N, R1W)	2.4 MGD or 2,688 AF/yr (current actual flow from the City of Avondale)	denitrified and chlorinated/ dechlorinated with possible plans for filtration in the future (from 208 Plan); with filtration appears suitable for recharge and open access; suitable for surface discharge	all effluent is currently discharged to the Aqua Fria; future plans may include some consumptive reuse	Seek partnership

Table 3. Inventory of Potential Water Suppliers

Water Source	Ownership	Location of Diversion, End of Pipe, or Outfall	Quantity	Quality	Availability/Reliability Short/Long Term	Notes
Sun City West Water Reclamation Plant	Citizens Utilities	NE of 115th Ave. and Beardsley Rd. (Sec. 19, T4N, R1E)	3.14 MGD or 3,517 AF/yr (permitted flow)	denitrified, filtered, and slightly chlorinated; suitable for recharge; appears suitable for open access; may require dechlorination for surface discharge	all effluent is currently recharged to basins	Inquire
Glendale West Water Reclamation Plant (construction near completion)	City of Glendale	N of the confluence of New and Aqua Fria Rivers (Sec. 18, T2N, R1E)	4.3 MGD or 4,816 AF/yr (permitted flow)	denitrified, filtered, and UV disinfection; suitable for recharge; appears suitable for open access and surface discharge	effluent is permitted for pilot recharge project using basins, trenches, vadose wells, and injection wells; future plans may include some consumptive reuse	Inquire
South Surprise WWTP	City of Surprise	NE of Peoria Ave. and Litchfield Rd. (Sec 22, T3N, R1W)	3.2 MGD or 3,584 AF/yr (permitted flow); planned increase to 36.0 MGD (40,328 AF/yr) by 2020	denitrified, filtered, and UV disinfection; suitable for recharge; appears suitable for open access and surface discharge	effluent is reused consumptively up to 0.66 MGD and the rest is recharged to basins	Inquire
Beardsley Rd. WWTP	City of Peoria	S of 111th Ave. and Beardsley Rd. (Sec. 30, T4N, R1E)	2.0 MGD or 2,240 AF/yr (permitted flow)	denitrified, filtered, and UV disinfection; suitable for recharge; appears suitable for open access and surface discharge	effluent is currently recharged to basins	Inquire
City of El Mirage WWTP	City of El Mirage	SE of Peoria Ave. and El Mirage Rd. (Sec. 25, T3N, R1W)	2.2 MGD or 2,464 AF/yr (from APP application in review); planned increase to 3.6 MGD (4033 AF/yr)	denitrified (proposed in APP), filtration, and chlorination/ dechlorination; with denitrification appears suitable for recharge and open access; suitable for surface discharge	effluent is consumptively reused and the facility has a NPDES permit to discharge to Aqua Fria; planned recharge	Seek partnership
91st Ave. WWTP	City of Phoenix	planned piping to Aqua Fria River for constructed USF between Bell and Indian School Roads	At least 27,000 to 47,000 AF will be available for recharge now and in the future	denitrified and chlorination; may require additional treatment to be suitable for recharge or open access; suitable for surface discharge	If City of Phoenix commits unallocated amount to recharge, this would be a very reliable source.	Seek partnership
Nuisance Waters						
Dysart Drain (Flood Control Drainage)	Drain owned by FCDMC	north side of Luke Air Force Base to Aqua Fria River 0.5 mile south of Northern Ave.	Discharge is not stready (regular) and occurs only during rainfall events as runoff.	agricultural return flow; fish consumption advisory; may be poor quality with elevated nitrates and pesticides	ephemeral; likely to decline some with continued urbanization	

Table 3. Inventory of Potential Water Suppliers

Water Source	Ownership	Location of Diversion, End of Pipe, or Outfall	Quantity	Quality	Availability/Reliability Short/Long Term	Notes
Colter Channel (Flood Control Drainage)	Drain owned by FCDMC	From just east of Litchfield Road to Aqua Fria River	Discharge is not stready (regular) and occurs only during rainfall events as runoff.	may be poor quality with elevated nitrates and pesticides	ephemeral; likely to decline some with continued urbanization	
I-10 (Stormwater Drainage)	Drain owned by ADOT	From Aqua Fria River east to I-17 on north side of I-10	There is steady discharge, but is unmetered. The drainage area is 45 square miles (Hydrology Re-Evaluation, Papago Freeway, ADOT, 1978). Using the metered Price Drain which drains the Superstition Stormwater Drainage as an analog, steady flow from the I-10 Drain should be 1 to 3 cubic feet per second (cfs).	may receive agricultural returns and urban runoff; may be poor quality with elevated nitrates and pesticides	perennial; flows may diminish some as the remaining agricultural areas are converted to developments.	Largest nuisance water source.
Durango Channel	Drain owned by FCDMC	Buckeye Road on the east side of the river.	Discharge is not stready (regular) and occurs only during rainfall events as runoff.	may be poor quality with elevated nitrates and pesticides	ephemeral; availability uncertain; likely to decline with continued urbanization	
Irrigation Return Flows	SRP is primary source	0.5 miles south of the Durango Channel; 0.5 miles south of Lower Buckeye Road on the east and west side of the river.	Discharge is not stready (regular) and occurs only during rainfall events as runoff.	may be poor quality with elevated nitrates and pesticides	perennial; availability uncertain; likely to decline with continued urbanization	

Phoenix is evaluating alternatives to these Salt River discharges and is considering piping up to 80,000 acre-feet north from the WWTP for recharge along the Agua Fria River.

With continued urban development in the West SRV, effluent production will increase. WESTCAPS estimates that urban water demands will increase by 200,000 to 300,000 acre-feet by the year 2025. There will be a commensurate increase in effluent production, likely on the order of 100,000 to 150,000 acre-feet. The cost and/or lack of other available renewable supplies will likely necessitate the reclamation of this effluent.

2.7.4 Nuisance Waters

The location of nuisance waters along the Aqua Fria River are noted on Table 3. These include Dysart Drain, Colter Channel, the I-10 Stormwater Drain, the Durango Channel at Buckeye Road, and three irrigation return flows south of the Durango Channel. The largest source of perennial flow comes from the I-10 Drain, which has a drainage area of 45 square miles (Arizona Department of Transportation, 1978). The drain is unmetered; however, based on the metered Price Drain, served by SRP lands, which drains an area similar to the I-10 area, steady flow should range from 1 to 3 cubic feet per second (or 724 to 2172 acre-feet per year). Flow from storm events may supplement the steady flow from the irrigation runoff. This steady flow will decline with continued urbanization. The interpreted perennial flow from the three agricultural return flows south of the Durango Channel are not considered a significant source of nuisance water. This flow may in fact be ephemeral.

2.8 Testing for Recharge Feasibility

Once a proposed site is chosen for recharge, a number of tests must be conducted to evaluate the feasibility and appropriate method of recharge. Soil borings are typically drilled to document the types of soil and rock in the vadose zone, the unsaturated material between the land surface and the water table. The geologic characteristics of the vadose zone are then described. If desired, laboratory tests can be conducted on collected soil samples to evaluate hydrologic characteristics of the vadose zone. Hydrologic characteristics can also be evaluated using small ring infiltrometers, measuring one to two feet in diameter, or in larger test pits or trenches. These tests are conducted on undisturbed soils in the natural environment. Wells may also be drilled to conduct hydrologic testing of deeper horizons in the vadose zone or in the aquifer. All of these data are then synthesized to evaluate recharge feasibility and the method of recharge. Usually if these steps have been taken, a full-scale project is proposed. If some of these steps are deleted or if there are still questions that need to be resolved, a pilot recharge project is generally proposed.

2.9 *Types of Possible Recharge*

The two general types of recharge facilities are managed and constructed recharge facilities. Managed systems pipe source water to existing rivers or washes, and there is little to no construction along the stream's reach to enhance infiltration. Streamflow is monitored before infiltration and at the end of the permitted reach of the river. Groundwater replenishment credits are only issued for that water that can be demonstrated to have infiltrated though the channel bottom and contributed water to an aquifer.

There are two general types of constructed facilities: those within and those outside of stream channels. In-channel systems may include weirs, dams, or T-levees. Weirs are constructed when stream channels are narrow and steep. Dams are typically proposed for wider, mildly sloping washes. T-levees are used in wide, flat channels and are designed to reduce the velocity of the water thereby maximizing the opportunity for recharge.

Infiltration basins, infiltration galleries (or trenches), vadose zone wells, or injection wells are generally used for off-channel recharge; however, in some situations they may be designed for in-channel use. Basins are relatively inexpensive to build and maintain, but must have the correct hydrologic conditions and adequate land availability. Trenches require similar hydrologic conditions and land space as basins, but are slightly higher in cost. Because trenches are subsurface structures, they may serve as a substitute for basins when the land needs to be used or if there are flooding issues. Trenches have been incorporated into the design of golf courses and parks, allowing multiple use of the land for both recreational and recharge. Wells are generally a last resort because of the high maintenance costs. However, if hydrologic conditions or land availability is not adequate, this method of recharge may be the only option. Hydrologic conditions and predicted recharge rates are used to decide between vadose zone and injection wells. Clogging is the most important factor in high maintenance costs for subsurface methods of recharge.

3.0 RANKING CRITERIA AND METHOLOGY

Evaluation of recharge potential along the AFR was limited to that area between Bell Road and the confluence with the Gila River. For the purposes of this study a "reach" was arbitrarily defined as that portion of the river contained in each one-mile section as measured in a north-south direction. Hence, the major east-west roads starting at Bell Road bound each reach, creating a total of eighteen reaches. These reaches are later regrouped into longer "reaches," based on the results of other AFWCMP team members efforts.

Twelve questions critical to the assessment of recharge were evaluated for each reach. These questions addressed regulatory ("unreasonable harm," odor, bird strike, and vector) concerns, infiltration rate, aquifer storage, benefit of recharge, proximity to existing water sources, impacts of flooding, and impacts on other watercourse users (Table 4). For each question, several sub categories (i.e., issues) were ranked. A summary of the ranking criteria and methodology for all reaches is shown in Table 4. There are a few issues that are stippled in Table 4 that will need to be evaluated during the implementation phase of the Watercourse Master Plan.

The ranking begins with the assessment of issues. An issue is designated as either a "+," "-," or "±" based on the quantitative limits shown in Table 1. A "+" is favorable, "-" is unfavorable, and "±" indicates possible or potential. The results of this assessment are shown with a white background on Table 4.

Next, the designations for each issue were averaged, resulting in either a "+," "-" or "±" for each question (shown in gray on Table 5). If the average is half way between two values, the rank is assigned the lower value.

The evaluation of some questions utilizes subjectivity instead of mathematically averaging. One example applies to the issue "depth to groundwater" for the question "are aquifer characteristics favorable for adequate storage for recharged water." As ambient groundwater levels approach ground surface, less water can be recharged. Such mounding may result in "unreasonable harm" to nearby wells or landowners, or a negative impact on the hydrologic feasibility of the project. This issue would not eliminate a reach from consideration, but would require additional contingency plans in the Underground Storage Facility Permit (ADWR) and, if effluent is recharged, the Aquifer Protection Permit (ADEQ).

Table 4. Ranking Methodology for Each Reach

	Questions		Issues for Each Question	Ranking: Issue[1] +	Ranking: Issue[1] ±	Ranking: Issue[1] -	Ranking: Question[2]	Ranking: Reach[3]
1	Are aquifer characteristics favorable for adequate storage for recharged water?	1a	depth to groundwater (ft)	>150	50-150	<50	'+', '±', or '-'	(1) Quantitativie Average and (2) Semi-Quantitative Average Ranking
		1b	UAU specific yield (dimensionless)	>0.01	0.005-0.01	<0.005		
		1c	UAU hydraulic conductivity (ft/day)	>25	8-25	<8		
2	Are the vadose zone characteristics favorable to prevent surface ponding and the formation of perched aquifers?	2a	potential for perching (cumulative feet of clay thickness in upper 100 ft)	<10	10-30	>30	'+', '±', or '-'	
		2b	inferred infiltration rates from in-channel soils (in/hr)	>20	2-20	<2		
		2c	distance to nearby sand and gravel operations and landfills (mi)	>1	0.25-1	<0.25		
3	Will drinking water wells be impacted by leaching and mobilization of contaminants in soil?	3a	distance to landfills, Superfund, UST, and RCRA sites (mi)	>1	0.25-1	<0.25	'+', '±', or '-'	
		3b	potential for groundwater to intersect contamination (based on average ranking of depth to groundwater and potential for perching)	+	±	-		
		3c	distance from soil contamination site to downgradient drinking water wells (mi)	>2	1-2	<1		
4	Will drinking water wells be impacted by the recharge induced movement of existing groundwater plumes?	4a	distance to existing plumes (mi)	>1	0.5-1	<0.5	'+', '±', or '-'	
		4b	distance from plume to downgradient drinking water wells (mi)	>2	1-2	<1		
5	What is the potential for fissure formation?	5a	distance to closest existing fissures (mi)	>1	0.25-1	<0.25	'+', '±', or '-'	
6	Will surface water quality standards be violated by recharge to the Aqua Fria River?	6a	current surface water quality standard[4]	agricultural irrigation and livestock watering	partial and full body contact	domestic water source; fish consumption	'+', '±', or '-'	
7	Could existing problems be mitigated?	7a	quality of ambient groundwater	more than one parameter does not meet AWQS	at least one parameter either does not meet, or is close to not meeting, AWQS	easily meets AWQS	'+', '±', or '-'	
		7b	predicted depth to groundwater in 100 yrs (ft bgs using MAU 2100 Base Case of Westcaps 1/1/00)	600 to 1000	300 to 600	-50 to 300		
		7c	existence of land subsidence	present		not present		
		7d	existence of fissures	present		not present		
8	Is the reach in close proximity to existing source water conveyance?	8a	distance to source water outfall (mi)	<1	1-2	>2	'+', '±', or '-'	
9	What is the impact of river flows and flooding on a proposed facility?	9a	does stormwater conveyance intersect reach	no		yes	'+', '±', or '-'	
		9b	does tailwater conveyance intersect reach	no		yes		
		9c	will predicted later migration impact a facility	no	some	significantly		
		9d	will predicted flooding impact a facility	no	some	significantly		
10	Will there be vector and nuisance (odor) concerns?	10a	distance to residences (mi)	>3	1-3	<1	'+', '±', or '-'	
		10b	what are the vector issues with the source water[5]	no issue				
		10c	baseline insect problems[6]					
11	Could recharge activities promote bird strikes by airplanes?	11a	orientation of runway relative to reach	does not cross reach		crosses reach	'+', '±', or '-'	
		11b	distance from runway to reach (mi)	>2		<2		
12	Will recharge activities impact existing watercourse users?	12a	does stormwater conveyance intersect reach	no		yes	'+', '±', or '-'	
		12b	does tailwater conveyance intersect reach	no		yes		
		12c	do utility corridors cross below ground	no		yes		
		12d	do utility corridors cross above ground	no		yes		
		12e	distance to nearby sand and gravel operations and landfills (mi)	>1	0.25-1	<0.25		
13	Will recharge activities adversely impact other master plan features?[7]	13a	elevation of flood protection structures				'+', '±', or '-'	
		13b	lateral migration of stream					
		13c	recreational facilities					
		13d	watercourse users, public access and safety					

[1] Each issue is ranked as Positive (+), Uncertain (±), or Negative (-) depending on qualitative/quantitative criteria.

[2] Each question is ranked as Positive (+), Uncertain (±), or Negative (-) depending on the qualitative average of the ranking of all issues.

[3] Each reach is ranked based on (1) the quantitative average ('+' = 3, '±' = 2, and '-' = 1) and (2) semi-quantitative average ranking, resulting in a Favorable (F), Potential (P), or Unfavorable (U).

[4] The current surface water standards along the Aqua Fria River may change if the uses or impacts of the river change.

[5] Vector issues can be controlled with larvacide, i. e., Tres Rios; hence, vectors do not appear to be an issue at this time.

[6] Fluid Solutions is not aware of an existing baseline vector study along the Aqua Fria River, but such a study should be done prior to starting each future recharge project.

[7] This question will be addressed after the final Preliminary Overlays are completed.

(shaded box) Evaluations that shall be completed at a later date after the Final Preliminary Overlays are completed.

Table 5A. Ranking Evaluation

		Questions/Issues	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
1		**Are aquifer characteristics favorable for adequate storage for recharged water?**	±	+	+	+	+	+
	1a	depth to groundwater	+	+	+	+	+	+
	1b	UAU specific yield	±	+	+	+	+	+
	1c	UAU hydraulic conductivity	±	±	±	±	±	±
2		**Are the vadose zone characteristics favorable to prevent surface ponding and the formation of perched aquifers?**	±	±	±	+	±	±
	2a	potential for perching	ND[1]	+	+	+	ND	ND
	2b	inferred infiltration rates from in-channel soils	+	±	+	+	+	+
	2c	distance to nearby sand and gravel operations and landfills	-	-	-	+	±	-
3		**Will drinking water wells be impacted by leaching and mobilization of contaminants in soil?**	±	±	-	±	±	-
	3a	distance to landfills, Superfund, UST, and RCRA sites	-	±	-	±	±	-
	3b	potential for groundwater to intersect contamination	+	±	+	+	+	+
	3c	distance from soil contamination site to downgradient drinking water wells	±	±	-	±	±	-
4		**Will drinking water wells be impacted by the recharge induced movement of existing groundwater plumes?**	+	±	-	-	+	+
	4a	distance to existing plumes	+	±	-	±	+	+
	4b	distance from plume to downgradient drinking water wells	+	+	-	-	+	+
5		**What is the potential for fissure formation?**	+	+	+	+	+	+
	5a	distance to closest existing fissures	+	+	+	+	+	+
6		**Will surface water quality standards be violated by recharge to the Aqua Fria River?**	±	±	±	±	±	±
	6a	current surface water quality standard	±	±	±	±	±	±
7		**Could existing problems be mitigated?**	+	+	+	+	+	+
	7a	quality of ambient groundwater	+	±	-	±	+	+
	7b	predicted depth to groundwater in 100 yrs	+	+	+	+	+	+
	7c	existence of land subsidence	-	-	-	-	-	-
	7d	existence of fissures	-	-	-	-	-	-
8		**Is the reach in close proximity to existing source water conveyance?**	+	+	+	+	+	+
	8a	distance to source water outfall	+	+	+	+	+	+
9		**What is the impact of river flows and flooding on the proposed facility?**	±	-	±	±	-	-
	9a	does stormwater conveyance intersect reach	+	+	+	+	+	+
	9b	does tailwater conveyance intersect reach	+	+	+	+	+	+
	9c	will predicted lateral migration impact a facility	±	±	+	±	-	-
	9d	will predicted flooding impact a facility	±	-	±	±	±	±
10		**Will there be vector and nuisance (odor) concerns?**	-	-	-	-	±	-
	10a	distance to residences	-	-	-	-	±	-
	10b	what are the vector issues with the source water	+	+	+	+	+	+
11		**Could recharge activities promote bird strikes by airplanes?**	+	+	+	+	+	+
	11a	orientation of runway relative to reach	+	+	+	+	+	+
	11b	distance from runway to reach	+	+	+	+	+	+
12		**Will recharge activities impact existing watercourse users?**	-	-	-	+	±	-
	12a	does stormwater conveyance intersect reach	+	+	+	+	+	+
	12b	does tailwater conveyance intersect reach	+	+	+	+	+	+
	12c	do utility corridors cross below ground	+	+	+	+	+	+
	12d	do utility corridors cross above ground	-	-	+	+	+	+
	12e	distance to nearby sand and gravel operations and landfills	-	-	-	+	±	-
Number of "+" in Reach			**5**	**5**	**5**	**7**	**6**	**6**
Number of "-" in Reach			**2**	**3**	**4**	**2**	**1**	**4**
Quantitative Average ("+"=3, "±"=2, and "-"=1)			**2.25**	**2.17**	**2.08**	**2.42**	**2.42**	**2.17**
Relative Quantitative Average (1=best)			**3**	**4**	**5**	**2**	**2**	**4**
Semi-Quantitative Average Ranking			**P[2]**	**P**	**P**	**P**	**F**	**P**

[shaded cell] Identifies the question and the qualitative average ranking of all issues addressing that question.

[1] ND - No data.

[2] Total rank evaluation: P = potential and F = favorable.

Table 5B. Ranking Evaluation

		Questions/Issues	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11	Reach 12
1		**Are aquifer characteristics favorable for adequate storage for recharged water?**	+	±	±	±	±	±
	1a	depth to groundwater	+	±	±	±	±	±
	1b	UAU specific yield	+	+	+	±	±	±
	1c	UAU hydraulic conductivity	±	±	±	±	+	+
2		**Are the vadose zone characteristics favorable to prevent surface ponding and the formation of perched aquifers?**	±	±	±	±	±	±
	2a	potential for perching	+	+	+	+	±	±
	2b	inferred infiltration rates from in-channel soils	+	+	+	+	+	+
	2c	distance to nearby sand and gravel operations and landfills	-	-	-	-	-	±
3		**Will drinking water wells be impacted by leaching and mobilization of contaminants in soil?**	-	+	+	-	-	+
	3a	distance to landfills, Superfund, UST, and RCRA sites	±	+	+	-	-	+
	3b	potential for groundwater to intersect contamination	+	+	+	+	±	±
	3c	distance from soil contamination site to downgradient drinking water wells	-	+	+	-	-	+
4		**Will drinking water wells be impacted by the recharge induced movement of existing groundwater plumes?**	+	+	+	+	+	+
	4a	distance to existing plumes	+	+	+	+	+	+
	4b	distance from plume to downgradient drinking water wells	+	+	+	+	+	+
5		**What is the potential for fissure formation?**	±	±	+	+	+	+
	5a	distance to closest existing fissures	±	±	+	+	+	+
6		**Will surface water quality standards be violated by recharge to the Aqua Fria River?**	±	±	±	±	±	±
	6a	current surface water quality standard	±	±	±	±	±	±
7		**Could existing problems be mitigated?**	+	+	±	±	±	±
	7a	quality of ambient groundwater	-	-	-	-	-	-
	7b	predicted depth to groundwater in 100 yrs	±	±	±	±	±	±
	7c	existence of land subsidence	+	+	-	-	-	-
	7d	existence of fissures	+	+	-	-	-	-
8		**Is the reach in close proximity to existing source water conveyance?**	+	+	+	+	+	+
	8a	distance to source water outfall	+	+	+	+	+	+
9		**What is the impact of river flows and flooding on the proposed facility?**	-	-	-	±	+	+
	9a	does stormwater conveyance intersect reach	-	+	-	+	+	+
	9b	does tailwater conveyance intersect reach	+	+	+	+	+	+
	9c	will predicted lateral migration impact a facility	-	-	-	±	+	+
	9d	will predicted flooding impact a facility	-	-	-	±	+	+
10		**Will there be vector and nuisance (odor) concerns?**	±	-	±	-	-	-
	10a	distance to residences	±	-	±	-	-	-
	10b	what are the vector issues with the source water	+	+	+	+	+	+
11		**Could recharge activities promote bird strikes by airplanes?**	-	-	-	-	+	+
	11a	orientation of runway relative to reach	+	+	-	-	+	+
	11b	distance from runway to reach	-	-	-	-	+	+
12		**Will recharge activities impact existing watercourse users?**	-	-	-	-	-	+
	12a	does stormwater conveyance intersect reach	-	+	-	+	+	+
	12b	does tailwater conveyance intersect reach	+	+	+	+	+	+
	12c	do utility corridors cross below ground	+	+	-	+	+	+
	12d	do utility corridors cross above ground	-	+	+	+	+	+
	12e	distance to nearby sand and gravel operations and landfills	-	-	-	-	-	±
Number of "+" in Reach			**4**	**4**	**4**	**3**	**5**	**7**
Number of "-" in Reach			**4**	**4**	**3**	**4**	**3**	**1**
Quantitative Average			**2.00**	**2.00**	**2.08**	**1.92**	**2.17**	**2.50**
Relative Quantitative Average (1=best)			**6**	**6**	**5**	**7**	**4**	**1**
Semi-Quantitative Average Ranking			**P[1]**	**P**	**P**	**P**	**P**	**F**

(Shaded cell) Identifies the question and the qualitative average ranking of all issues addressing that question.

[1] Total rank evaluation: P = potential and F = favorable.

Table 5C. Ranking Evaluation

		Questions/Issues	Reach 13	Reach 14	Reach 15	Reach 16	Reach 17	Reach 18
1		**Are aquifer characteristics favorable for adequate storage for recharged water?**	±	±	-	-	-	-
	1a	depth to groundwater	±	±	-	-	-	-
	1b	UAU specific yield	±	±	+	+	+	+
	1c	UAU hydraulic conductivity	+	+	+	+	+	+
2		**Are the vadose zone characteristics favorable to prevent surface ponding and the formation of perched aquifers?**	+	+	±	±	±	+
	2a	potential for perching	+	±	ND[1]	-	±	+
	2b	inferred infiltration rates from in-channel soils	+	+	±	±	±	+
	2c	distance to nearby sand and gravel operations and landfills	+	+	+	+	+	+
3		**Will drinking water wells be impacted by leaching and mobilization of contaminants in soil?**	+	-	-	-	-	-
	3a	distance to landfills, Superfund, UST, and RCRA sites	+	±	±	±	+	+
	3b	potential for groundwater to intersect contamination	±	±	-	-	-	-
	3c	distance from soil contamination site to downgradient drinking water wells	+	-	-	-	-	-
4		**Will drinking water wells be impacted by the recharge induced movement of existing groundwater plumes?**	±	-	-	-	-	-
	4a	distance to existing plumes	±	±	±	±	+	+
	4b	distance from plume to downgradient drinking water wells	+	-	-	-	-	-
5		**What is the potential for fissure formation?**	+	+	+	+	+	+
	5a	distance to closest existing fissures	+	+	+	+	+	+
6		**Will surface water quality standards be violated by recharge to the Aqua Fria River?**	±	±	-	-	-	-
	6a	current surface water quality standard	±	±	-	-	-	-
7		**Could existing problems be mitigated?**	±	±	±	±	±	±
	7a	quality of ambient groundwater	±	±	±	±	±	±
	7b	predicted depth to groundwater in 100 yrs	-	-	-	-	-	-
	7c	existence of land subsidence	-	-	-	-	-	-
	7d	existence of fissures	-	-	-	-	-	-
8		**Is the reach in close proximity to existing source water conveyance?**	+	±	-	-	+	+
	8a	distance to source water outfall	+	±	-	-	+	+
9		**What is the impact of river flows and flooding on a proposed facility?**	±	+	±	+	-	-
	9a	does stormwater conveyance intersect reach	-	+	+	+	+	+
	9b	does tailwater conveyance intersect reach	-	+	+	+	+	+
	9c	will predicted lateral migration impact a facility	+	+	±	+	±	±
	9d	will predicted flooding impact a facility	+	+	±	+	-	-
10		**Will there be vector and nuisance (odor) concerns?**	-	-	-	-	-	-
	10a	distance to residences	-	-	-	-	-	-
	10b	what are the vector issues with the source water	+	+	+	+	+	+
11		**Could recharge activities promote bird strikes by airplanes?**	±	-	-	-	-	+
	11a	orientation of runway relative to reach	-	+	+	+	+	+
	11b	distance from runway to reach	+	-	-	-	-	+
12		**Will recharge activities impact existing watercourse users?**	±	+	+	+	+	+
	12a	does stormwater conveyance intersect reach	-	+	+	+	+	+
	12b	does tailwater conveyance intersect reach	-	+	+	+	+	+
	12c	do utility corridors cross below ground	+	+	+	+	+	+
	12d	do utility corridors cross above ground	-	-	+	+	+	+
	12e	distance to nearby sand and gravel operations and landfills	+	+	+	+	+	+
Number of "+" in Reach			**4**	**4**	**2**	**3**	**3**	**5**
Number of "-" in Reach			**1**	**4**	**7**	**7**	**7**	**6**
Quantitative Average ("+"=3, "±"=2, and "-"=1)			**2.25**	**2.00**	**1.58**	**1.67**	**1.67**	**1.92**
Relative Quantitative Average (1=best)			**3**	**6**	**9**	**8**	**8**	**7**
Semi-Quantitative Average Ranking			**P[2]**	**P**	**U**	**U**	**U**	**U**

[shaded cell] Identifies the question and the qualitative average ranking of all issues addressing that question.

[1] ND - No data.

[2] Total rank evaluation: P = potential and U = unacceptable.

Other issues that have utilized similar subjectivity include:

- #3c (potential impact of leaching of soil contamination on downgradient drinking water wells),
- #4b (potential impact of groundwater plumes on downgradient drinking water wells),
- #9c (potential impact of lateral migration of the river on the facility,
- #9d (potential impact of 100-year flood event on the facility),
- #10a (potential impact of odor on nearby residences),
- #11b (potential of more frequent bird strikes near airports), and
- #12e (potential of impacting nearby sand and gravel operations and landfills).

These issues are not considered "fatal flaws" in a strict sense, i.e., a ranking of "-" would not preclude a reach from consideration. However, if one of these issues are ranked as "-," the accompanying question is ranked as "-," independent of the average of all issues for that particular question (shown in gray on Table 5).

Subjectivity is also used in an opposite way from that described above. For the question "could existing problems be mitigated," if any issue is graded as a "+," then the question is assigned a "+" for that reach, regardless of the average of all issues. Therefore, if any problems in a reach can be mitigated, then that reach would be viewed as favorable in regards to that particular question.

In order to assess the final ranking, each "+," "±" and "-" are summed for each one-mile reach (shown in black on Table 5). Two approaches are used to assess the final ranking. First is the Semi-Quantitative Average approach. If there are more "-" than "+," then the reach is ranked as "unacceptable." If there are more "+" than "-" and if there is no more than one "-," then that reach is ranked as "favorable." All other reaches are ranked as "potential." Reach #13 would have been ranked as "favorable," but because the I-10 Stormwater Drain intersects the reach, this reach was downgraded to "potential."

The second approach is the Quantitative Average approach. Each "+" is assigned a value of 3, each "±" is assigned a value of 2, and each "-" is assigned a 1. These numbers are average for each reach (shown in black in Table 5). There are nine different averages, and the averages range between 2.50 and 1.58. These averages are ranked relative to one another from 1 (optimum) to 9 (least optimum) (shown in black in Table 5).

4.0 DATA COLLECTION

Data sources used to address the above issues come primarily from existing resources and reports. These data and resources are listed in Table 6. These data have already been compiled and copies are on file with Kimley Horn and the Maricopa County Flood Control District. Additional references are noted at the end of this report.

5.0 RESULTS OF REACH EVALUATION

5.1 Ranking

Using the Semi-Quantitative Average approach, Peoria to Olive Avenues and Thomas to McDowell Roads are ranked as "favorable" for groundwater recharge (Table 7). The area from Van Buren Street southward to the Gila River is ranked as "unfavorable." All other portions of the AFR are ranked as "potential." Using the Quantitative Average approach, Thomas to McDowell Roads has the highest favorable ranking and Cactus Road to Olive Avenue ranked second (Table 7).

Potential water suppliers are identified for all reaches. Existing water suppliers in close proximity to the above favorable areas for recharge along the AFR include the El Mirage WWTP at Peoria Road (effluent) and the City of Avondale Recharge Site at McDowell Road (wetland treated SRP and CAP water). Both the City of Phoenix 91st Avenue WWTP and the City of Avondale WWTP have future plans to recharge in these areas. The potential benefits of recharge are identified for all reaches. Between Cactus Road and Olive Avenue the benefits of recharge include raising groundwater elevations in the area of the Luke cone of depression and improving groundwater quality.

Table 6. Data Collection Summary

Data	Title	Description	Author	Date	Source	Format	Date Collected	Collected by
1	Underground Storage Facility (USF) Permits	Excerpts from the following USF (recharge) facility permits: CAWCD Aqua Fria (managed), CAWCD Aqua Fria (constructed), Del Webb Sun City West (constructed), City of Peoria Beardsley (constructed), City of Surprise South (constructed), City of Avondale (constructed), and City of Goodyear (constructed)	ADWR	variable	ADWR files	Hardcopy Report	Jan-00	Fluid Solutions
2	Aquifer Protection Permits (APP)	Excerpts from the following APPs for wastewater treatment plants (WWTP): Luke Air Force Base WWTP, City of Surprise-Litchfield Rd. WWTP, South Surprise WWTP, and City of Peoria-Beardsley Rd. WWTP	ADEQ	variable	ADEQ files	Hardcopy Report	Jan-00	Fluid Solutions
3	Aquifer Protection Permit (APP) applications	Excerpts from the APP application for the City of El Mirage WWTP	El Mirage	variable	ADEQ files	Hardcopy Report	Jan-00	Fluid Solutions
4	Aquifer Protection Permits (APP)	Excerpts from the following APPs for recharge facilities: Del Webb Sun City West Underground Storage and Recovery Project and City of Glendale West Aquifer Recharge Facility	ADEQ	variable	ADEQ files	Hardcopy Report	Jan-00	Fluid Solutions
5	Well Drilling Reports and Log of Wells	Well construction details and subsurface stratigraphic lithologies	ADWR	variable	ADWR files	Hardcopy Report	Jan-00	Fluid Solutions
6	A Regional Groundwater Flow Model of the Salt River Valley-Phase I, ADWR Modeling Report No. 6	Figs. 4 and 11-14 which show subsurface stratigraphic units, index maps, and cross sections in the Aqua Fria area	ADWR	Apr-93	ADWR files	Hardcopy Report	Jan-00	Fluid Solutions
7	A Regional Groundwater Flow Model of the Salt River Valley-Phase II, ADWR Modeling Report No. 8	Figs. 6-9, maps which show distribution of hydraulic conductivity and specific yield of aquifers	ADWR	Mar-94	ADWR files	Hardcopy Report	Jan-00	Fluid Solutions
8	An Application of the Regional Groundwater Flow Model of the Salt River Valley, Arizona, ADWR Modeling Report No. 11	Figs. 6 and AIII-3, maps which show depth to groundwater	ADWR	Oct-96	ADWR files	Hardcopy Report	Jan-00	Fluid Solutions
9	Preliminary Feasibility Study of Groundwater Recharge Potential of Surplus Central Arizona Project Water in Aqua Fria River, Open File Report No. 3	ADWR study of recharge potential along the upper Aqua Fria River	ADWR	Jul-87	ADWR files	Hardcopy Report	Jan-00	Fluid Solutions
10	Hydrogeology of the western part of the Salt River Valley area, Mariciopa and Pinal Counties, Arizona: US Geological Survey Water-Resources Investigation Report 88-4202, 5 sheets	All maps and cross sections are included. This publication is an excellent reference covering several aspects of hydrogeology of Aqua Fria River area	J.G. Brown and D.R. Pool	1989	US Geological Survey	Hardcopy Report	Jan-00	Fluid Solutions
11	Maps showing groundwater conditions in the Phoenix Active Management Area: Maricopa, Pinal, and Yavapai Counties, Arizona: Hydrologic Map Series Report Number 27	Groundwater elevation, depth to groundwater, changes in groundwater elevation, and water quality maps	ADWR	Jul-95	ADWR	Hardcopy Report	Jan-00	Fluid Solutions
12	Estimated vs. actual infiltration rates: observations from ADWR's recharge program	paper discussing infiltration rates	Cassandra Martin and Drew Swieczkowski, ADWR	Jun-99	Symposium Proceedings on Artificial Recharge of Groundwater	Hardcopy Report	Jan-00	Fluid Solutions
13	Subregional Operation Group 91st Avenue Wastewater Treatment Plant Aqua Fria Linear Recharge Project	Summary paper on recharge feasibility for 91st effluent along Aqua Fria	Michael Gritzuk and others	Jun-99	Symposium Proceedings on Artificial Recharge of Groundwater	Hardcopy Report	Jan-00	Fluid Solutions
14	Treatment and recharge at the wetlands of Avondale	Summary paper discussing Avondale's recharge activities	Timothy Thompson	Jun-99	Symposium Proceedings on Artificial Recharge of Groundwater	Hardcopy Report	Jan-00	Fluid Solutions
15	Trends and issues in effluent recharge for the Phoenix and Tucson Active Management Areas	Status of USF Permit facilities that use effluent as source water: methods of recharge, credits, effluent production, etc.	Leslie Unangst and others	Jun-99	Symposium Proceedings on Artificial Recharge of Groundwater	Hardcopy Report	Jan-00	Fluid Solutions
16	City of Peoria Beardsley Road Quarterly Report for USF Permit	Excerpts from report that discusses infiltration rates	City of Peoria	1999	ADWR files	Hardcopy Report	Jan-00	Fluid Solutions
17	City of Avondale Quarterly Report for USF Permit	Excerpts from report that discusses infiltration rates	City of Avondale	Aug-99	ADWR files	Hardcopy Report	Jan-00	Fluid Solutions
18	Hydrologic Report City of Avondale's USF Permit Application	Excerpts from report that discusses proposed impact of recharge on groundwater elevation rise	BCI Geonetics, Inc.	Jul-93	ADWR files	Hardcopy Report	Jan-00	Fluid Solutions
19	Memorandum from Drew Swieczkowski to Greg Wallace regarding Avondale Recharge USF Permit application	Discusses, among other critical issues with this facility, the potential problems with perching	ADWR	Aug-97	ADWR files	Hardcopy Report	Jan-00	Fluid Solutions

Table 6. Data Collection Summary

Data	Title	Description	Author	Date	Source	Format	Date Collected	Collected by
20	Waste Programs Division: Superfund Programs: Site Info: Phoenix Area Site	WQARF and NPL (Superfund) Sites within the Aqua Fria study area that have contaminated soil and/or groundwater and status of remediation	ADEQ	Jan-00	ADEQ website	Hardcopy Report	Jan-00	Fluid Solutions
21	City of Surprise South Annual Report for USF Permit	Excerpts from report that discusses infiltration rates	City of Surprise	Mar-99	ADWR files	Hardcopy Report	Jan-00	Fluid Solutions
22	USF Permit Application for City of Surprise South Wastewater Reclamation Facility	Excerpts from the report that discusses area of influence and shows WWTP site map	RT International	unknown	ADWR files	Hardcopy Report	Jan-00	Fluid Solutions
23	Hydrologic Evaluation of the South Surprise Wastewater Treatment Plant	Groundwater hydrologic evaluation of recharge at site	Manera, Inc.	Apr-96	ADWR files	Hardcopy Report	Jan-00	Fluid Solutions
24	City of Surprise Recharge Project Phase I Study	Groundwater hydrology and predicted infiltration rates of Surprise South Recharge Site	Bouwer and others	May-95	ADWR files	Hardcopy Report	Jan-00	Fluid Solutions
25	City of Surprise Recharge Project Phase II Study	Groundwater hydrology and infiltration rates of Surprise South Recharge Site	Bouwer	Dec-96	ADWR files	Hardcopy Report	Jan-00	Fluid Solutions
26	1997 Annual Water Quality Report	Water quality evaluation of canals and wells	SRP	Jun-05	SRP	Hardcopy Report	Feb-00	Fluid Solutions
27	Westside Plant - Blue Circle West, Inc. (UST Evaluation)	Contamination evaluation and well log information at 11771 West Indian School Rd. at Aqua Fria River	ENSR	Jun-90	ADEQ files	Hardcopy Report	Feb-00	Fluid Solutions
28	Unocal Service Station No. 4650, Sun City, AZ (UST Evaluation)	Contamination evaluation and well log information at 107th Ave. and Hwy. 60	Harding Lawson Associates	Aug-95	ADEQ files	Hardcopy Report	Feb-00	Fluid Solutions
29	Site Characterization Report for Unocal Service Station No. 6197 (UST Evaluation)	Contamination evaluation and well log information at 15001 North Del Webb Blvd., Sun City, AZ	Horizon Environmental SW, Inc.	Feb-96	ADEQ files	Hardcopy Report	Feb-00	Fluid Solutions
30	Site Characterization Investigation Industrial Asphalt (UST Evaluation)	Contamination evaluation and well log information at West Grand Ave. and the Aqua Fria River, El Mirage, AZ	Environmental Science and Engineering, Inc.	Jun-91	ADEQ files	Hardcopy Report	Feb-00	Fluid Solutions
31	Site Characterization Report Chevron Products Company Former Service Station #9-9058 (UST Evaluation)	Contamination evaluation and well log information at 14046 North 111th Ave., Youngtown, AZ	Holguin, Fahan & Associates, Inc.	Jul-99	ADEQ files	Hardcopy Report	Feb-00	Fluid Solutions
32	Baseline Assessment Report Chevron Products Company Service Station #9-9058 (UST Evaluation)	Contamination evaluation and well log information at 14047 North 111th Ave., Youngtown, AZ	Holguin, Fahan & Associates, Inc.	Apr-98	ADEQ files	Hardcopy Report	Feb-00	Fluid Solutions
33	Revised Site Characterization Report Form Volume I - Appendices A - F, Circle K Corporation, Convenience Food Store #822 (UST Evaluation)	Contamination evaluation and well log information at 3 East Main Street (Highway 85), Avondale, AZ	Industrial Compliance	Apr-95	ADEQ files	Hardcopy Report	Feb-00	Fluid Solutions
34	Revised Quarterly Ground Water Monitoring Report April-June 1995 Circle K Corporation, Convenience Food Store #822 (UST Evaluation)	Contamination evaluation and well log information at 3 East Main Street (Highway 85), Avondale, AZ	Industrial Compliance	Aug-95	ADEQ files	Hardcopy Report	Feb-00	Fluid Solutions
35	Results of Investigation and Characterization Activities Circle K Store #822 (UST Evaluation)	Contamination evaluation and well log information at 3 East Main Street (Highway 85), Avondale, AZ	Quest Environmental, Inc.	Jul-98	ADEQ files	Hardcopy Report	Feb-00	Fluid Solutions
36	Study Summary: 91st Avenue Wastewater Treatment Plant Reclaimed Water Study: Appendix A-11	Injection well feasibility	Earth Technology Corp. and Greely and Hansen	Nov-91	City of Phoenix file	Hardcopy Report	Feb-00	Fluid Solutions
37	Study Summary: 91st Avenue Wastewater Treatment Plant Reclaimed Water Study: Appendix A-12	Hydrogeologic evaluations of potential areas for irrigation and underground storage of effluent	Ken Schmidt and Associates and Greely and Hansen	Nov-91	City of Phoenix file	Hardcopy Report	Feb-00	Fluid Solutions
38	Study Summary: 91st Avenue Wastewater Treatment Plant Reclaimed Water Study: Appendix A-13	Soil infiltration systems	Richard P. Arber Associates and Greely and Hansen	Nov-91	City of Phoenix file	Hardcopy Report	Feb-00	Fluid Solutions
39	Element B Summary: 91st Avenue Wastewater Treatment Plant Reclaimed Water Study: Phase II	On-site investigations, facility plan, and implementation plan for pilot percolation basin studies	Greely and Hansen	Apr-94	City of Phoenix file	Hardcopy Report	Feb-00	Fluid Solutions
40	Element D Summary: 91st Avenue Wastewater Treatment Plant Reclaimed Water Study: Phase II	Summary of total reuse facility plan	Greely and Hansen	Sep-94	City of Phoenix file	Hardcopy Report	Feb-00	Fluid Solutions
41	Water quality data	Spreadsheet of water quality data from wells	data search by Fluid Solutions through ADEQ	Jan-00	ADEQ files	Hardcopy Report	Feb-00	Fluid Solutions
42	Drinking water wells and providers	Spreadsheet of drinking water wells and water service providers	data search by Fluid Solutions through ADWR	Jan-00	ADWR files	Hardcopy Report	Feb-00	Fluid Solutions

Table 7. Results of Reach Evaluation

Reach Number (JEF)	Reach Number (FS)	Roads on Nothern Boundary	Ranking (Semi-Quantitative)	Relative Ranking (Quantitative Average)								
				1 (2.50) Optimum	2 (2.42)	3 (2.25)	4 (2.17)	5 (2.08)	6 (2.00)	7 (1.92)	8 (1.67)	9 (1.58) Least Optimum
8	1	Bell Rd.	Potential			■						
	2	Greenway Rd.	Potential				■					
	3	Thunderbird Rd.	Potential					■				
9	4	Cactus Rd.	Potential		■							
	5	Peoria Ave.	Favorable		■							
10	6	Olive Ave.	Potential				■					
	7	Northern Ave.	Potential						■			
	8	Glendale Ave.	Potential						■			
	9	Bethany Home Rd.	Potential					■				
11	10	Camelback Rd.	Potential							■		
12	11	Indian School Rd.	Potential				■					
	12	Thomas Rd.	Favorable	■								
	13	McDowell Rd.	Potential			■						
13	14	Van Buren St.	Unacceptable						■			
14	15	Buckeye Rd.	Unacceptable									■
	16	Lower Buckeye Rd.	Unacceptable								■	
15	17	Broadway Rd.	Unacceptable								■	
	18	Southern Ave.	Unacceptable							■		

5.2 Potential Water Suppliers for Each Reach

Following is a complete list of potential water suppliers for each accompanying reach.

Reach 1

- CAP Canal
- Beardsley Canal
- Peoria WWTP effluent
- Sun City West WWTP effluent
- SROG Linear Recharge Project (L.R.P.; planned)

Reaches 2 through 4

- SROG L.R.P. effluent (planned)

Reach 5

- El Mirage WWTP effluent
- SROG L.R.P. effluent (planned)

Reach 6 and 7

- SROG L.R.P. effluent (planned)

Reach 8

- Luke Air Force Base WWTP effluent
- SROG L.R.P. effluent (planned)
- City of Glendale West Water Reclamation Facility (WRF) effluent

Reach 9

- Grand Canal (via New River)
- Glendale West WRF effluent
- SROG L.R.P. effluent (planned)

Reach 10

- SROG L.R.P. effluent (planned)

Reach 11

- RID Canal water
- SROG L.R.P. effluent (planned)

Reach 12

- City of Avondale Wetlands CAP and SRP water
- SROG L.R.P. effluent (planned)

Reach 13

- City of Avondale Wetlands (SRP-phase 2; effluent-phase 3)
- SROG L.R.P. effluent (planned)

Reaches 14 through 18

- City of Avondale effluent
- SROG L.R.P. effluent (planned)

One of the optimum locations for recharge, Reaches 4 and 5, have two water sources: El Mirage WWTP effluent and City of Phoenix 91^{st} Ave. effluent. The other optimum location, Reach 12, potentially has SRP water from the City of Avondale Wetlands and the planned City of Phoenix 91^{st} Ave. effluent as a potential water sources. In the future the City of Avondale has planned to recharge effluent generated at the City's WWTP, located 4.5 miles to the south. Avondale has preliminary plans to pipe the effluent to recharge basins, located on the north side of the I-10 stormwater drain. Due to the fact that these are very preliminary plans, this effluent is considered another potential water supplier for Reach 12.

5.3 Benefits

The benefits of recharge include (a) raising the groundwater elevations in the area of the Luke cone of depression, (b) potentially mitigating the effects of land subsidence and earth fissuring in the Luke area, and (c) improving groundwater quality along some reaches. Recharge in Reaches 1 through 5 offers the best opportunity to benefit groundwater declines. Recharge in Reaches 7 and 8 would potentially assist in mitigating land subsidence and fissuring. Recharge in Reaches 1, 2, 3-6, and 13-18 offer opportunities to improve groundwater quality in close proximity to the Aqua Fria River.

6.0 OVERLAYS

6.1 Recharge Potential

Analysis of the recharge potential along the AFR is summarized in one graphic overlay (Figure 1). This overlay displays the following

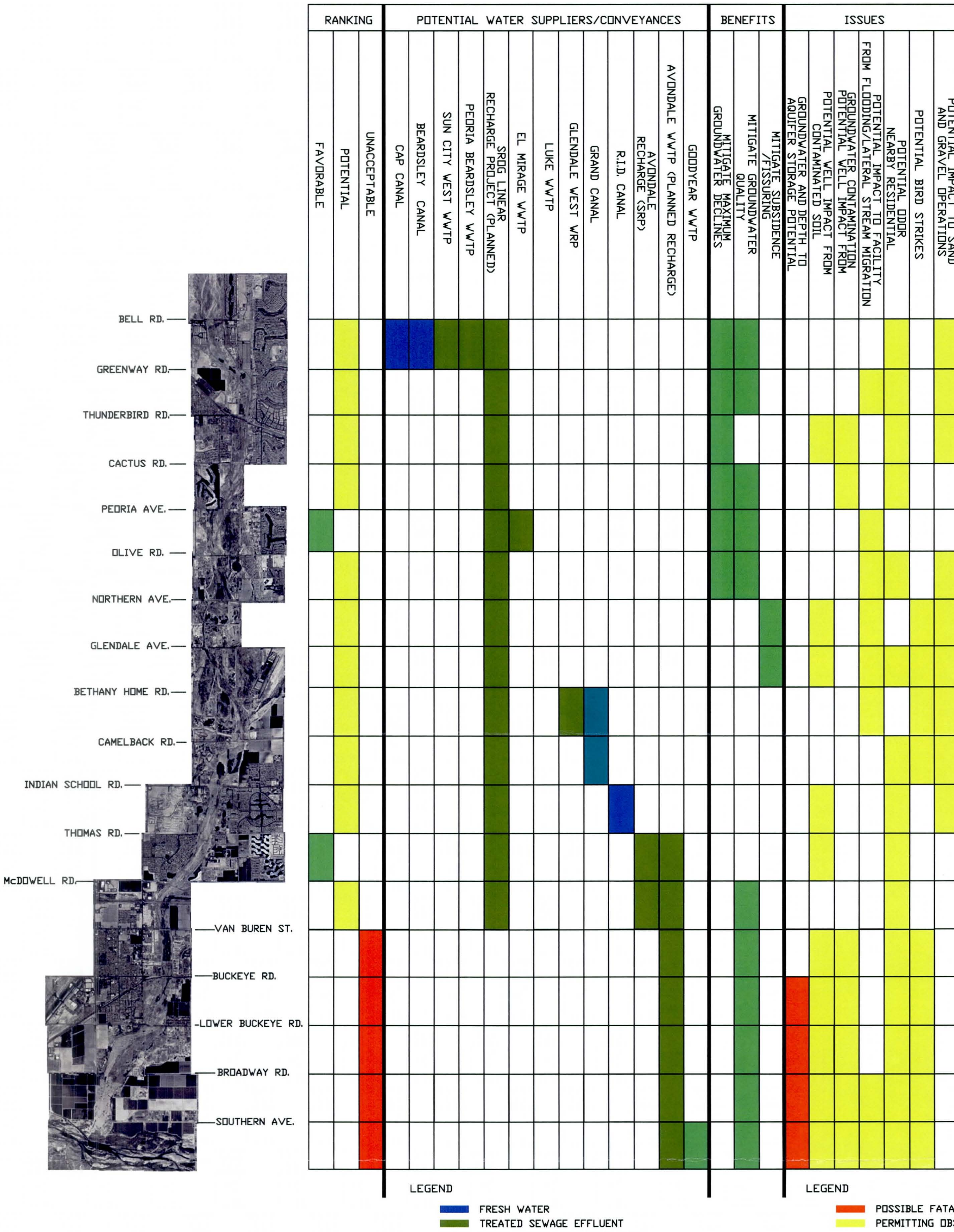

FIGURE 1

RANKING OF RECHARGE POTENTIAL
AQUA FRIA WATERCOURSE
MASTER PLAN

SCALE: 1 INCH = 10,000 FEET

0 5,000 10,000 20,000 FEET

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CLIENTS/KIMLEY-HORN/ACAD/RANKING RECHARGE POTENTIAL 6/21/01 in a tabular format for each one-mile reach bounded by major east-west roads:

- Ranking (Favorable, Potential, and Unacceptable),
- Potential water supplies and conveyances,
- Benefits of recharge, and
- Important issues that influenced the ranking.

6.2 Potential Water Supplies

Another graphic overlay was created that shows the following features adjacent to the AFR (Figure 2):

- The location of existing and planned recharge projects,
- The location of wastewater treatment plants,
- The location of surface water canals, and
- The location of wastewater discharges, stormwater and tail water drains, and ephemeral tributary washes.

7.0 RECHARGE DESIGN CONCEPT

Conceptual recharge designs in the AFR are completed for two areas: (1) Thomas to McDowell Roads and (2) Cactus Road to Olive Avenue. Both designs are for constructed, in-channel facilities. These designs shall meet the Floodway Development Standards (Floodplain Regulations for Maricopa County, Article IX, Section 902).

"No structure, excavation or fill material (including fill material for roads, dikes, and levees), deposit, obstruction, storage of material or equipment or other uses shall be permitted which alone or in combination with existing or future uses, in the opinion of the Floodplain Administrator, would cause an increase in the base flood elevations or flood damage potential." Consequently, in channel improvements, such as the concepts presented herein, will either need to be constructed below grade or of sacrificial materials that will not increase flood potential.

All recharge techniques required in Article XV, Section 1503 (Floodplain Regulations for Maricopa County) were evaluated.

"All Watercourse Master Plans shall consider recharge techniques including but not limited to gabions, swales, dry wells, sand tanks and small dams."

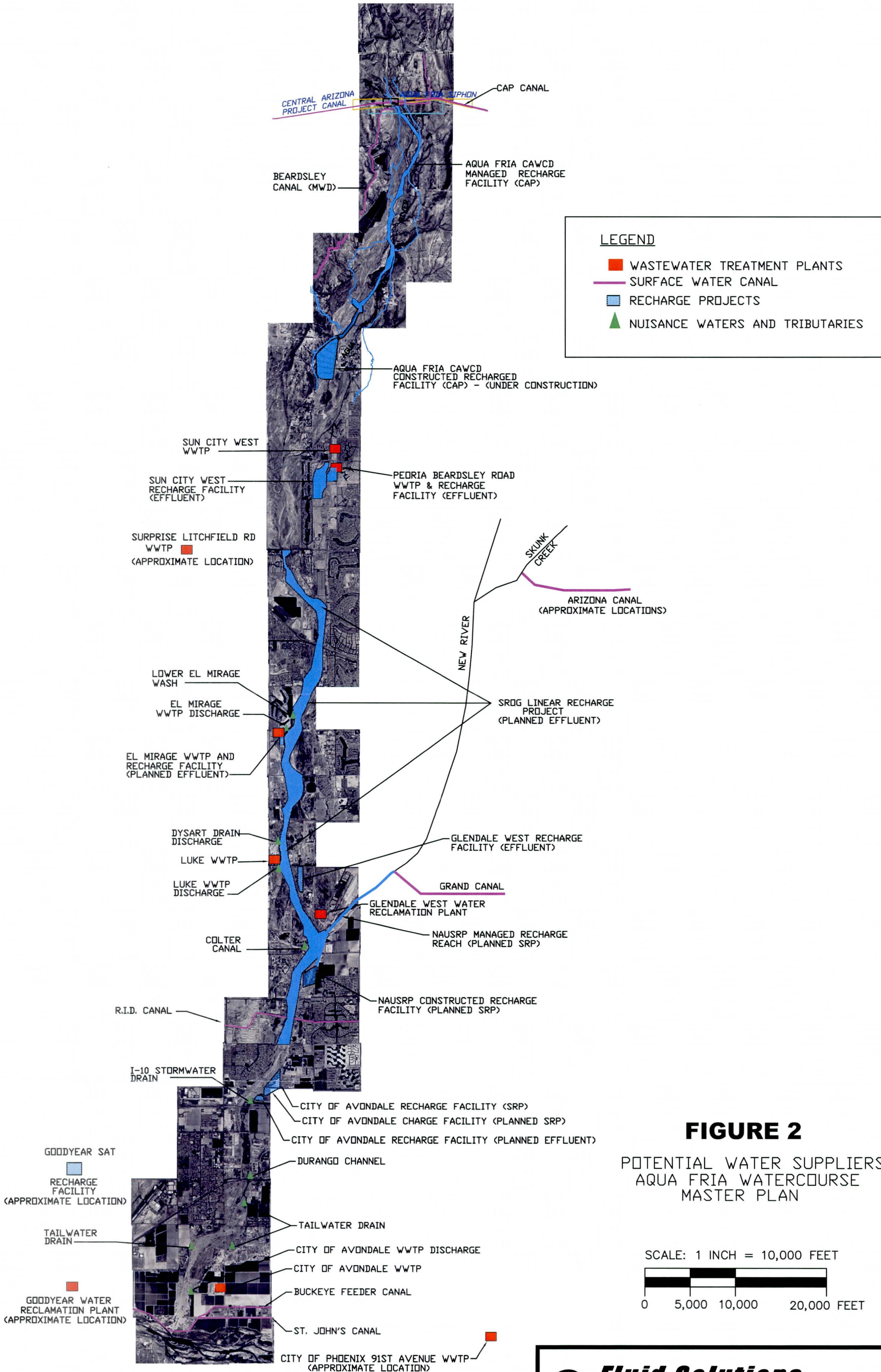

FIGURE 2

POTENTIAL WATER SUPPLIERS
AQUA FRIA WATERCOURSE
MASTER PLAN

SCALE: 1 INCH = 10,000 FEET

0 5,000 10,000 20,000 FEET

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CLIENTS/KIMELY HORN/ACAD/POTENTIAL WATER SUPPLIERS 6/25/01

Both design concepts include excavating sedimentary material from the floodway (creating a swale). A series of T-levees is proposed for the reach between Thomas to McDowell Roads because of the low gradient, 10 feet per mile (Figure 3). In areas where topographic gradient is low, the use of a T- or L-levee design is appropriate (Bouwer, 1999). The location of the T-levees in the floodway was chosen based on the geometry of the wash, and shall accommodate the introduction of additional surface flows from tributaries. An example of the use of T-levees is shown below in Figure 4.

Figure 4. T-levees used along the Santa Ana River, Los Angeles, California.

Between Cactus Road to Olive Avenue the gradient is also very low, ~15 feet per mile, and the channel widens. The design concept incorporates modified (curved) L-levees in the floodway and formal constructed recharge basins in a portion of the flood fringe (Figure 5). Water would be delivered to the channel downstream of Cactus Road. It would cascade downstream through the levees. Diversion works would be constructed in close proximity to Peoria Road, which would allow the operator to direct water to either the constructed basins or the levee system.

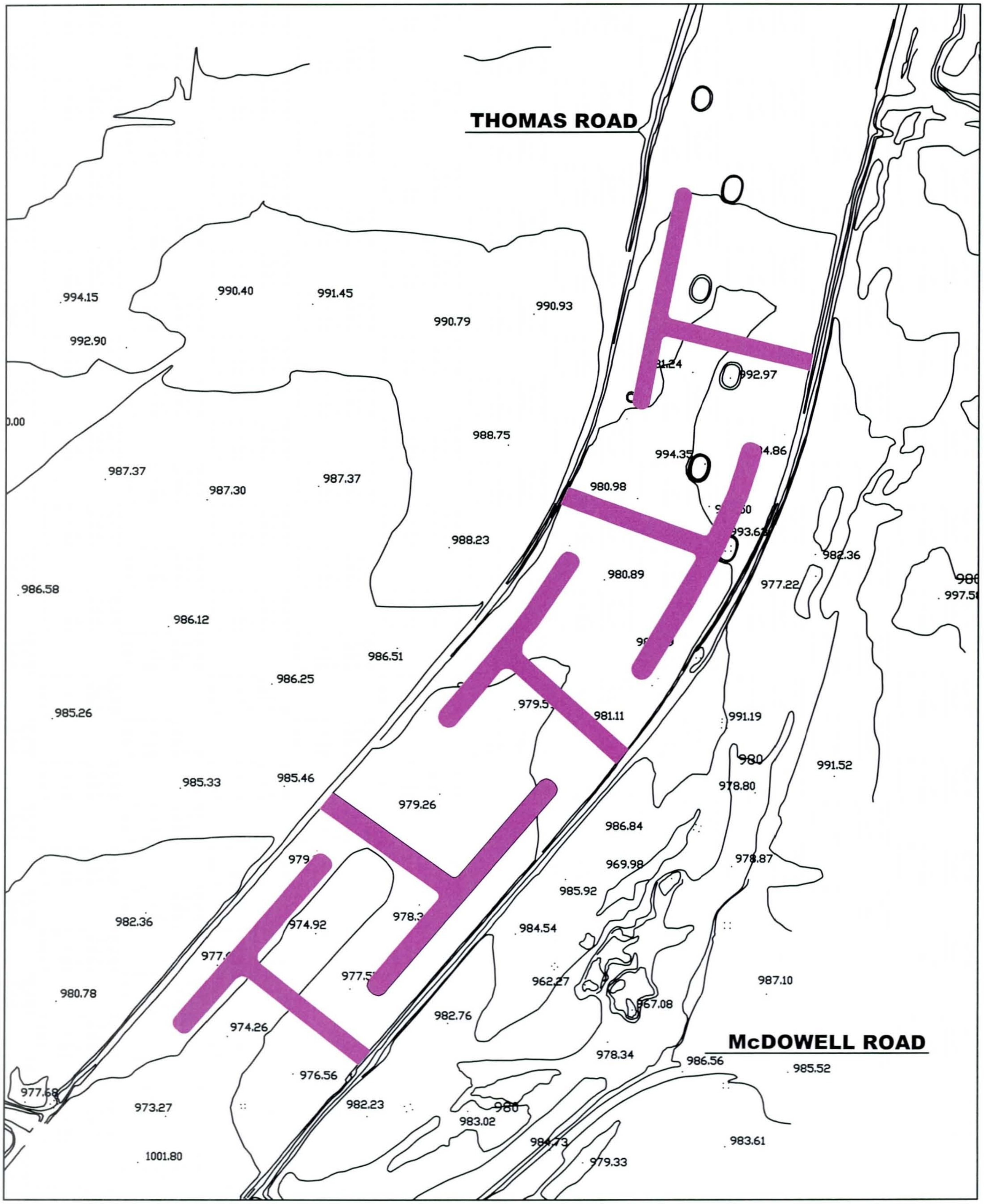

FIGURE 3

CONCEPTUAL IN-CHANNEL
RECHARGE T-LEVEE DESIGN
THOMAS RD. TO McDOWELL RD.

SCALE: 1 INCH = 800 FEET

0 800 1600 FEET

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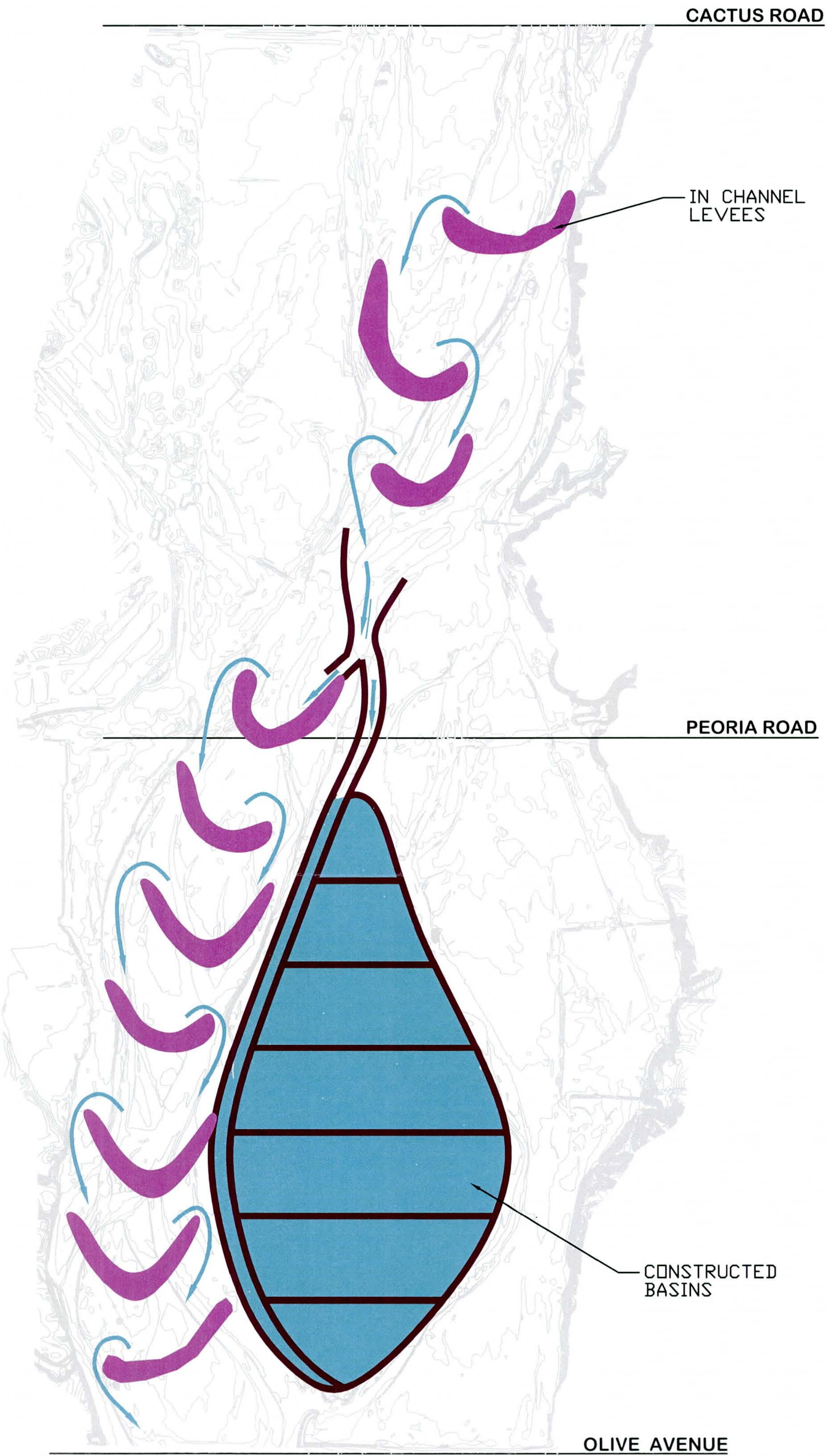

FIGURE 5

CONCEPTUAL IN-CHANNEL RECHARGE DESIGN
CACTUS ROAD TO OLIVE AVENUE

SCALE: 1 INCH = 1,000 FEET

0 500 1000 2000 FEET

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CLIENTS/KIMELY HORN/ACAD/CACTUS-OLIVE 6/21/01

8.0 IMPLEMENTATION STRATEGY

The following strategies are recommended to optimize the development of artificial recharge as a part of the AFWCMP.

Creating a favorable regulatory environment for recharge is a beneficial strategy and could be achieved through the following actions:

- clearly define how recharge must be conducted to preserve the flood control functions of the AFR,
- create a comprehensive overlay for Army Corps of Engineers permitting for the recharging entities,
- accommodate and encourage "constructed" in-channel recharge facilities within the AFWCMP, resulting in a greater crediting to entities recharging effluent within the corridor,
- encourage recharge in locations that will minimize "unreasonable harm" to surrounding land and well owners, and
- seek and secure buy-in from the Arizona Department of Water Resources for the multi-use aspects of the AFWCPM in a comprehensive manner.

Presenting the AFWCMP to potentially impacted parties and the general public with recharge as a significant plan element is another potential implementation strategy. The acceptance of recharge projects (particularly effluent recharge projects) by the general public will likely be enhanced by addressing these projects in a forum where they are part and parcel of a much grander vision that includes other elements, including flood control, recreation, transportation, and wildlife habitat.

Creating of a regional vision, through adoption of the AFWCMP with a significant recharge element, will likely increase the potential for buy-in by the various jurisdictions.

Demonstrating that sand and gravel operations' concerns are addressed within the AFWCMP will also increase their potential to embrace recharge projects consistent with the plan.

Finally, stressing the benefits of recharge for the community as a whole will be important. This would include the a summary of:

- the potential reduction in operations and maintenance costs for recharge facilities normally operated by municipalities that would be passed on to the public,
- the potential cost savings to municipalities and taxpayers of recovered recharged groundwater versus treated surface water,

- the reduction in the depletion and subsequent augmentation of the regional groundwater aquifer system, and
- the potential of ensuring water supplies for future generations in this desert environment is increased.

9.0 ADDITIONAL REFERENCES

Arizona Department of Transportation, 1978, Hydrology Re-Evaluation, Papago Freeway West.

Bouwer, Herman, 1999, Artificial recharge of groundwater: systems, design, and management, *in* Larry Mays, ed., Hydraulic Design Handbook, Chapter 24.