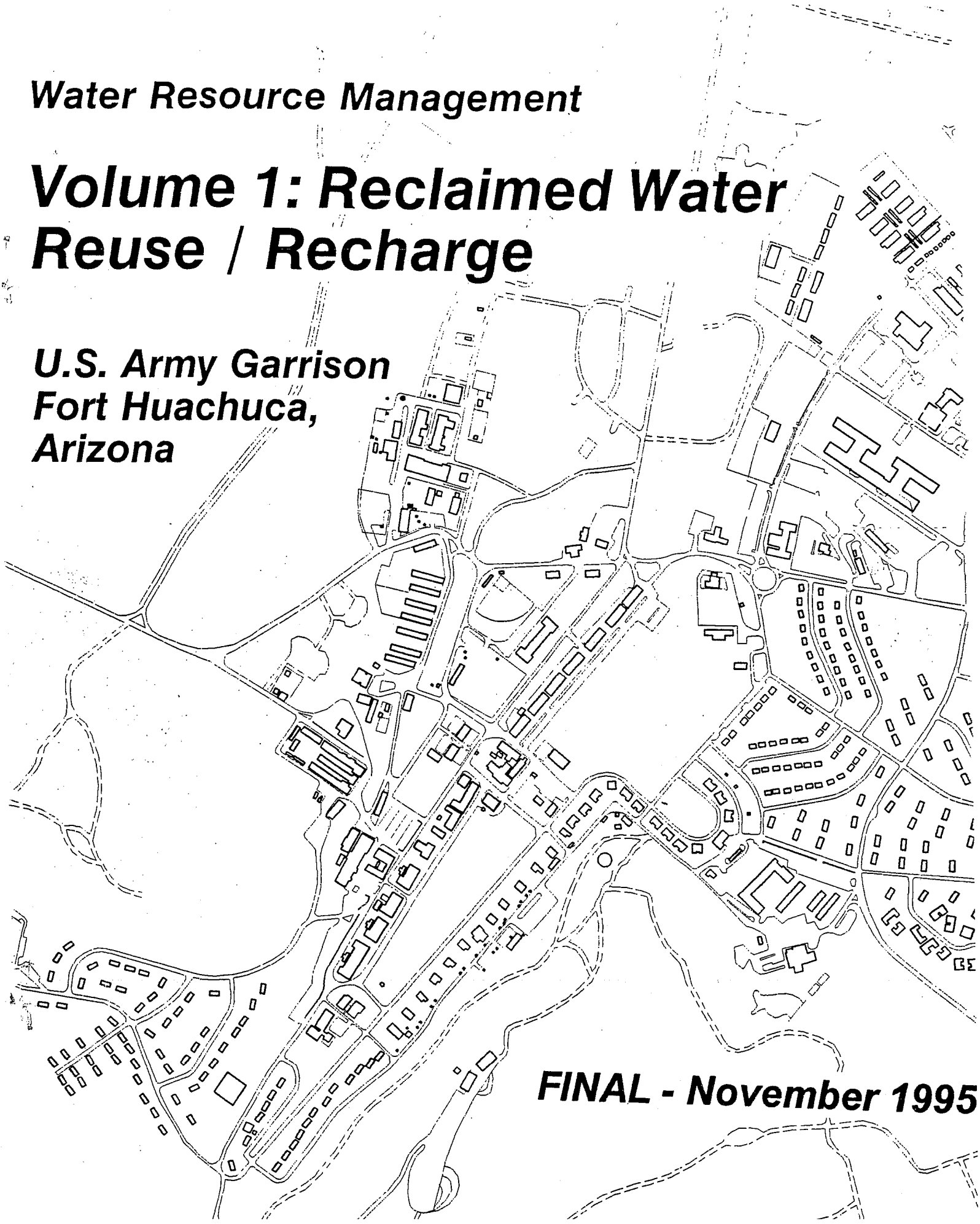
Water Resource Management

Volume 1: Reclaimed Water Reuse / Recharge

U.S. Army Garrison Fort Huachuca, Arizona



FINAL - November 1995

USF200003345

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EXECUTIVE SUMMARY

Proper management of groundwater is a critical component in efficiently managing the Fort's infrastructure needs with those of the riparian environment of this area. This is particularly true given the Fort's location in an arid climate and its proximity to the San Pedro River, a very important environmental resource in southern Arizona which supports a diverse riparian habitat. An important component of the flow in the San Pedro River is the base flow from the regional aquifer. Historical pumping of groundwater from this aquifer by various entities in the region (including Fort Huachuca, Sierra Vista, Huachuca City, and agricultural operations) has contributed to the development of a drawdown cone of depression in the aquifer. Continued expansion of the drawdown cone, if left unchecked, may represent a threat to the unique riparian habitat along the San Pedro River. Additionally, this drawdown will adversely impact the use of groundwater as a potable water source by increasing energy costs and requiring redevelopment (deepening) of existing groundwater well facilities.

Being cognizant of these concerns, the Fort has undertaken a multi-tiered water resource management program in an attempt to efficiently manage and conserve this valuable resource. As a component of this program, the Fort has commissioned this study to evaluate the potential to expand the utilization of reclaimed water (treated wastewater effluent) on the Fort and efficiently recharge the balance of the treated effluent to the aquifer.

Historical records indicate that over the last 31 years Fort Huachuca has withdrawn an average of 949 million gallons (MG) of water per year from the regional aquifer to meet the water demands on the installation. In review of a period between 1978 and 1995, which is reflected of the current missions conducted at the post, a substantial reduction in the water demand was recorded in 1994 with the enactment of water use restrictions. During the period between 1978 and 1993, the average water production on the Post was 934, 558 thousand gallons (Kgal) per year. Of this flow, an average of 623,927 (Kgal) per year entered the sanitary sewer system and was treated at the Fort's Wastewater Treatment Plant (WWTP). The difference between the volume of groundwater pumped and the return flow to the WWTP is the Fort's consumptive use (i.e., irrigation, evaporative cooling, fire protection, etc.). During the years 1994/1995, the average water production dropped to 837,223 Kgal per year, of which 648,689 Kgal per year entered the sanitary sewer system and treated at the WWTP. It should be noted that although the daily flow at the WWTP increased, the per capita flow actually declined during this period, indicating that the other water conservation measures are effective. Based on a review of available records and field observations, irrigation is the largest component of the difference. However, based on a estimate of the existing (1994-1995) water demands, there exists an average of 188,534 Kgal per year of consumptive water uses on the post which could be agumented by the expanded use of reclaimed water (treated effleuent) on the Post.

A portion of the treated effluent (reclaimed water) from WWTP No. 2 is utilized for irrigation. Presently the golf course, Chaffee Parade Field, and the Outdoor Sports Complex use treated effluent for turf - grass irrigation. Based on existing use rates, the average yearly volume of reclaimed water currently being utilized is 260,000 Kgal per year. This rate indicates that the turf is being irrigated at luxury application rates, above the basic consumptive use rate. The balance, of the effluent, 388,689 Kgal per year (94-95), is disposed of in the east range lagoons, a large portion of this effluent is lost through evaporation and evapotranspiration.

Approximately Eighteen percent of the Fort's 1994-1995 groundwater withdrawals are utilized for irrigation and cooling towers demands in addition to the existing reclaimed water usage, and over 40 percent of the reclaimed water produced at the WWTP is not efficiently utilized (evaporation, irrigation

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at luxury rates). Thus, this study evaluated the efficient recharge of all reclaimed water not utilized on the Fort, and the expansion of the reclaimed water system to reduce the demand for groundwater.

A Master Landscape and Irrigation Plan was prepared and is presented in Volume 2 of this study. The results of this plan indicates that, with an expanded reclaimed water distribution system, efficient irrigation application rates, eighty-six percent (86%) of the required irrigation demand on the Fort can be met utilizing reclaimed water. Combining the efficient application rates, with the expanded use of reclaimed water for irrigation, would equate to a 73,043 Kgal reduction, or 8.7 percent decrease in the Fort's total groundwater demands, based on 1994-1995 averages, or a 20.3 percent decrease based on 1978-1993 demands.

In review of other water demands which could be augumented by the expanded use of reclaimed water, various concepts were considered. The use of reclaimed water in cooling towers provided one such alternative. Utilizing reclaimed water in the cooling towers within the vicinity of the irrigation reuse sites can reduce groundwater demands by 26,500 Kgal per year.

With the efficient and practical demand for irrigation and other uses established, the recharge elements of this study were evaluated. As part of this evaluation, non-intrusive, site specific characteristics were reviewed and a technical screening procedure was conducted to identify a suitable recharge area in the site selection process. With the conceptual area identified, various recharge techniques were evaluated. Building on this information a conceptual recharge facility was developed using shallow spreading basins, post-tertiary treatment, and the associated support facilities. Since the daily fluctuation in the demand for irrigation varies from none (rainy days) to the peak daily demand, the recharge facility was designed to accommodate the total plant effluent. The capital cost for the recharge facility has been estimated at $4,841,338 for design and permitting. Further, this study presents an implementation plan for the final development of the facility.

The third aspect evaluated was the expansion of the reclaimed water distribution system to facilitate a reduction in the demand for groundwater pumpage. The existing system was evaluated based on a capacity and reliability standpoint. Various routings were considered, and a conceptual layout presented. The cost of the reclaimed water system has been estimated to be $4,590,163. Due to available funding, various phasing concepts were considered. While several of the components could be constructed within the constraint of a $250,000 to $400,000 construction project, need to provide a functional/productive system will make it necessary to have several major project exceeding $1.0 million.

With the implementation of the recharge and reuse facilities, it has been estimated that based on the 1994 - 1995 period, the Fort can reduce the demand for groundwater by approximately 99,631 Kgal per year (73,043 Kgal irrigation, 26,588 Kgal cooling towers). This, combined with an estimated net increase in recharge of 73,894 Kgal per year, could decrease the Fort's water balance deficit by 29 percent. This percentage would increase to 41 percent when calculated on the 1978 - 1993 period average.

The final aspect of this study is the inclusion of this data into a groundwater simulation model being prepared by the Arizona Department of Water Resources (ADWR). However, this model remains in the development phase. When it becomes available, however, the results of the modeling can be appended to this study. It is noted that similar modeling conducted for the City of Sierra Vista (ASL, 1995) has concluded that mitigation measures and strategies similar to those recommended in this report will allow for continued growth within the Sierra Vista/Fort Huachuca area.

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1.0 INTRODUCTION

1.1 Authorization:

The preparation of this study for Fort Huachuca was authorized by ATZS-EHE Memorandum, dated 19 May 1994, and implemented under contract DACA05-92-C-0117. This study is a component of the Fort Huachuca Water Resource Management Program.

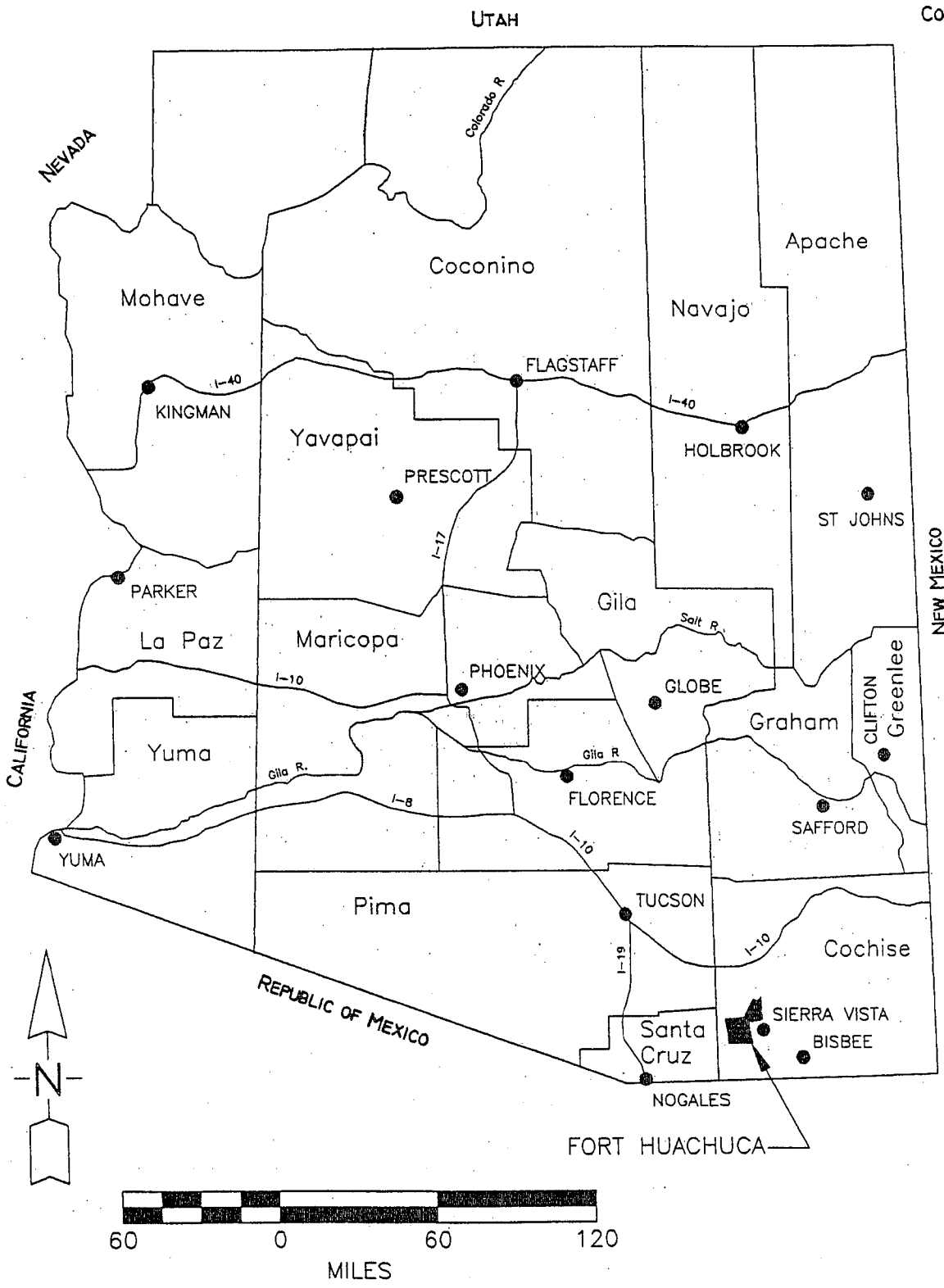
1.2 Water Resource Management Program:

Fort Huachuca is located in southeastern Arizona, in the upper San Pedro River Basin, and adjacent to the City of Sierra Vista, as shown on Figure 1-1. Historically the Fort's water production system relied solely on the harvesting of spring water in the Huachuca Mountains. Beginning in the late 1930's, groundwater wells were developed to augment the Fort's water production system. As drinking water standards were enacted over the years, requiring ever more stringent treatment parameters for surface water sources (spring water), the utilization of spring water was, over time, discontinued at the Fort. Currently the Fort, as well as the adjacent communities of Sierra Vista and Huachuca City, rely solely on groundwater as their potable water source. Additionally, agricultural operations in this rural area are dependent on groundwater for irrigation purposes.

As with any valuable resource, proper management of groundwater is a critical component in efficiently managing the Fort's infrastructure and co-existing with the environment. This is particularly true given the Fort's location in an arid climate. The San Pedro River is a very important environmental resource in southern Arizona which supports a diverse riparian habitat. An important component of the flow in the San Pedro River is the base flow from the regional aquifer. Historical pumping of groundwater from this aquifer by various entities in the region (including Fort Huachuca, Sierra Vista, Huachuca City, and agricultural operations) has contributed to the development of a drawdown cone of depression in the aquifer. Continued expansion of the drawdown cone, if left unchecked, may represent a significant threat to the riparian habitat along the San Pedro River. Additionally, this drawdown will adversely impact the use of groundwater as a potable water source by increasing energy costs and requiring redevelopment (deepening) of existing groundwater well facilities.

Being cognizant of these concerns, the Fort has undertaken a multi-tiered water resource management program in an attempt to efficiently manage and conserve this valuable resource. Some of the major components of this program are identified below:

» Use of Reclaimed Water for Irrigation: In the early 1970's, the Fort constructed secondary treatment facilities at the Wastewater Treatment Plants (WWTP). The Fort also constructed a reclaimed water distribution system to enable the use of reclaimed water (treated wastewater effluent) on the golf course and Chaffee Parade Field. This facility was one of the earliest projects which utilized reclaimed water in southeastern Arizona. Presently the reclaimed water system has been extended to facilitate the use of reclaimed water at the new Outdoor Sports Complex and the relocated Chaffee Parade Field. Improvements to the WWTP No. 2 will be completed in the Fall of 1995 (WWTP No. 1 was taken out of service several years ago and since, only the effluent holding/pumping facilities at WWTP No. 1 have been utilized). These improvements to WWTP No. 2 will enhance the quality of the reclaimed water allowing it to comply with the Arizona Department of Environmental Quality (ADEQ) rules and regulations for "open access" irrigation. As part of this study, the expansion of the reclaimed water system will be evaluated in an attempt to further reduce the demand for groundwater.



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WATER RESOURCE /REUSE STUDY, FORT HUACHUCA

FIGURE 1-1
LOCATION MAP

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» Use of Low Flow Plumbing Fixtures: The Fort has enacted regulations requiring that all plumbing fixtures in new construction and renovations of existing structures utilize a "low-flow" design. In addition to this, the Fort has installed "low-flow" fixtures on many of the existing facilities not scheduled for renovation in the foreseeable future.

» Restriction of Non-Essential Water Use: The Fort has enacted regulations limiting the use of potable water for irrigation. The regulations being enforced restrict the permissible method of irrigating, time and day of irrigating, and duration of irrigation.

» Stormwater Recharge: Concepts for the recharge of stormwater are under investigation by the Fort as part of the Mountain Front Recharge Project. Concepts include peak flow harvesting, augmentation of in-stream infiltration, and other techniques to promote the infiltration of stormwater back to the local aquifer.

» Educational Programs: The Fort has undertaken several programs to educate the population of the Post as to the value of our water resource and methods to reduce consumption.

» Intergovernmental Coordination: The Fort has taken an active roll in intergovernmental coordination to assist in formulating a comprehensive plan which addresses the needs of all of the water interests within the San Pedro Basin.

As part of the Fort's overall water management program, this study will evaluate the potential for recharging reclaimed water to augment the natural recharge of the aquifer. Additionally, this study will evaluate the expanded use of reclaimed water on the Fort to further reduce the demand for groundwater withdrawals.

1.3 Study Organization:

The project team for this study include **GLHN** Architects and Engineers, Inc. and our subconsultants, Ajay Environmental Consultants, Inc. (Ajay), who addressed the recharge aspects of this study; and McGann and Associates, Inc. (McGann), who are responsible for the preparation of the Landscape and Irrigation Master Plan.

In the development of the approach to this project, the following goals were jointly agreed to:

» Develop a master landscape and irrigation plan for the Fort which minimizes water use and is compatible with the function, climate, and other environmental conditions present at the Fort.

» Utilize reclaimed water for irrigation to the maximum extent possible.

» Develop concepts for a recharge facility which will efficiently and safely augment the natural recharge of the aquifer.

» Develop a concept to expand the reclaimed water system to facilitate the use of reclaimed water at the sites identified in the Master Landscape and Irrigation Plan, and other usages such as cooling towers.

In addressing these goals, the Master Landscape and Irrigation Plan was prepared and is presented in Volume 2 of this study. The results of this plan indicates that, with an expanded reclaimed water distribution system, eighty-six percent (86%) of the irrigation demands on the Fort can be met utilizing reclaimed water. As indicated in Volume 2,269.360 Kgal of the total annual irrigation water budget will utilize reclaimed water.

With the efficient and practical demand for irrigation established, other reuse options were evaluated, including cooling towers, and other reuse options.

The recharge element of the study involved a review of existing information to: identify the basic groundwater flow parameters at the Fort Huachuca installation; identify known contaminated or potentially contaminated areas; select appropriate sites for conceptual locations of a recharge facility; and evaluate potential water quality effects of a conceptual recharge facility. Based on this approach, technical and cost requirements of a conceptual recharge facility were developed, regulatory permitting requirements reviewed, and recommendations for further actions developed.

The recharge elements of this study are organized into the following five chapters. Chapter 2 provides a discussion of hydrogeology, ambient groundwater quality, potentially contaminated sites, and effluent water quality. Chapter 3 outlines the process used in selecting the area for the conceptual recharge facility and defines the Primary Potential Recharge Site Zone. Chapter 4 outlines the process used in selecting the conceptual recharge method and describes the selected method. Chapter 5 describes the conceptual recharge facility including hydrogeologic impact, permitting, and cost implications. Chapter 6 provides a discussion of recommended future activities.

The balance of this report will address the elements of the reclaimed water system. Chapter 7 outlines the existing reclaimed water system and it's deficiencies. Chapter 8 describes the expansion of the system and associated costs, and Chapter 9 reviews potential phasing of the reclaimed water system.

1.4 Water Utilization:

Based on historical records, over the past 31 years, Fort Huachuca has withdrawn an average of 949,000 thousand gallons (Kgal) of water per year from the regional aquifer to meet the water demands on the installation. During this period however, the missions carried out on the Post has varied, and subsequently the specific water demands have varied. Thus, for the basis of this study, the period between the years 1978 and 1995 were investigated, since this period is reflective of the existing missions carried out on the Post, and the existing reclaimed water system was in operation.

In review of this data, in 1994, the Post enacted water restrictions which substantially reduced the Post's water demand. During the period from 1978 through 1993, the average water production on the Post was 934,558 Kgal. Of this flow, an average of 623,927 (Kgal) per year enters the sanitary sewer system and is treated at the Fort's Wastewater Treatment Plant (WWTP). The difference between the volume of groundwater pumped and the return flow to the WWTP is the Fort's consumptive use (i.e., irrigation, evaporative cooling, fire protection, etc.). During the years 1994/1995, the average water production dropped to 837,223 Kgal per year, of which, 648,689 Kgal per year entered the sanitary sewer system and treated at the WWTP. It should be noted that although the daily flow at the WWTP increased, the per capita flow actually declined during this period indicating that the other water conservation measures are effective. Based on a review of available records and field observations, irrigation is the largest component of the difference, refer to Table 1-1.

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A summary of the average water production, and wastewater flows, is presented in Table 1-1. Based on these flowrates, the various consumptive water demands, for the various years investigated, were estimated, as well as the distribution of the reuse/disposal of the treated effluent from WWTP No. 2. In review of this table, the following items should be clarified.

In assessing the use of treated effluent from the WWTP, as indicated above, a portion of the treated effluent (reclaimed water) is utilized for irrigation. Currently the golf course, Chaffee Parade Field, and the Outdoor Sports Complex use treated effluent for turf grass irrigation. Based on consumptive use rates, refer to Volume 2, the average yearly volume of reclaimed Water for these facilities have been estimated to be 137,950 Kgal per year. Existing records indicates that approximately 260,000 Kgal per year is being utilized for irrigation. It appears that these facilities are being irrigated at luxury application rates. Studies at the University of Arizona (Kneebone and Pepper 1984) have indicated that the uptake of turfgrass can exceed twice the consumptive use of the grass. Thus to maximize the potential for recharge, the basic consumptive use rates were utilized in this evaluation.

In review of the cooling tower demands, a demand rate of 5,409 gallons, per year, per rated capacity was utilized. This factor include evaporation, drift, and includes a factor for utilization and load profile. For the towers within the vicinity of the irrigation reuse sites, a yearly demand of 26,588 Kgal was estimated. The balance of the cooling towers are remote from the irrigation reuse sites, thus to utilize reclaimed water at these sites would be cost prohibited.

The term "General" consumptive use includes the water for vehicle washing, standard evaporative cooling, and miscellaneous uses around the Post. The large vehicle wash racks on the Post are connected to the sewer system and thus are not consumptive uses, but were considered for reclaimed water use. However, such usage does not conform with current reuse regulations. Use of reclaimed water is standard evaporative cooling systems is also not an appropriate use since the air which enters the building comes in contact with the treated effluent.

Based on the proposed expansion to the reclaimed water system, it is projected that even with an effective population increase of 300 personal, the net demand for groundwater can be reduced to approximately 734,627 Kgal per year. This coupled with the recharge aspects of this study could reduce the volume of the Fort's overdraft of the aquifer to 426,999 Kgal per year, or a 29 percent decrease from the 1994-1995 averages (41 percent based on 1973 - 1993 average).

Table 1–1
Estimate of Water Usage

Annual Demand	1978 – 1993		1994 – 1995		Future (2)	
	1000 Gal	Acre–Foot	1000 Gal	Acre–Foot	1000 Gal	Acre–Foot
Water Well Production	934,558	28,682	837,223	25,695	734,627	22,546
Wastewater Flow	623,927	19,149	648,689	19,909	648,719	19,910
Estimate of Water Usage						
Non–Consumptive Use (3)	623,927	19,149	648,689	19,909	648,719	19,910
Consumptive Use (4)						
– General Use	39,770	1,221	34,143	1,048	34,974	1,073
– Irrigation	233,293	7,160	116,823	3,585	43,780	1,344
– Cooling Towers	37,568	1,153	37,568	1,153	10,980	337
– Total	310,631	9,534	188,534	5,786	89,734	2,754
Estimate of Treated Effluent (Reclaimed Water) Reuse / Disposal						
Reuse	260,000	7,980	260,000	7,980	295,940	9,083
Evapotranspiration	153,955	4,725	153,955	4,725	45,141	1,385
Recharge (Infiltration)	209,972	6,444	234,734	7,204	307,638	9,442
Deficit Water Balance (5)	724,586	22,238	602,489	18,491	426,989	13,105

(1) Acre–Foot = 325,829 Gallons
(2) Includes: Proposed Reuse / Recharge options and a increase in Population of 300 Personal
(3) Usage that flow into the sewer system and into the WWTP
(4) Usage that does not flow into the sewer system and into the WWTP
(5) Water well production less Recharge (infiltration)

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Table 1–1
Estimate of Water Usage

Annual Demand	1978 – 1993		1994 – 1995		Future (2)	
	1000 Gal	Acre–Foot	1000 Gal	Acre–Foot	1000 Gal	Acre–Foot
Water Well Production	934,558	2,868	837,223	2,570	734,627	2,255
Wastewater Flow	623,927	1,915	648,689	1,991	648,719	1,991
Estimate of Water Usage						
Non–Consumptive Use (3)	623,927	1,915	648,689	1,991	648,719	1,991
Consumptive Use (4)						
– General Use	39,770	122	34,143	105	34,974	107
– Irrigation	233,293	716	116,823	359	43,780	134
– Cooling Towers	37,568	115	37,568	115	10,980	34
– Total	310,631	953	188,534	579	89,734	275
Estimate of Treated Effluent (Reclaimed Water) Reuse / Disposal						
Reuse	260,000	798	260,000	798	295,940	908
Evapotranspiration	153,955	473	153,955	473	45,141	139
Recharge (Infiltration)	209,972	644	234,734	720	307,638	944
Deficit Water Balance (5)	724,586	2,224	602,489	1,849	426,989	1,310

(1) Acre–Foot = 325,829 Gallons
(2) Includes: Proposed Reuse / Recharge options and a increase in Population of 300 Personal
(3) Usage that flow into the sewer system and into the WWTP
(4) Usage that does not flow into the sewer system and into the WWTP
(5) Water well production less Recharge (infiltration)

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2.0 HYDROGEOLOGY AND WATER QUALITY

This chapter discusses the general hydrogeology, ambient groundwater conditions, known contaminated or potentially contaminated sites, and effluent water quality conditions. The data presented in this chapter is based on a review of existing records and documentation as no intrusive sampling or other investigations were conducted for this study.

2.1 Hydrogeology

Most of the data used in characterization of the aquifer at Fort Huachuca was taken from various reports generated for specific facilities within the reservation. There have been a number of preliminary assessment/site investigations (PA/SI), remedial investigations (RI), and remedial alternative evaluation studies performed at several facilities on the Post. In addition, quarterly groundwater reports have been generated to document groundwater monitoring efforts at several facilities.

Fort Huachuca is in the San Pedro basin, which is bounded on the west by the Huachuca Mountains. The alluvial sequence in the Fort Huachuca area consists of (from oldest to youngest): the Pantano Formation (a semi-consolidated conglomerate), lower basin fill (interbedded sandy clay, silty sand, and sandy gravel with scattered cobbles and boulders, approximately 235 feet thick in the Fort Huachuca well field, exhibiting variable cementation and sorting), upper basin fill (weakly cemented and compacted clay, silt, sand and gravel, approximately 620 feet thick in the Fort Huachuca area), and floodplain alluvium (Pleistocene and Recent floodplain, channel-fill, and terrace deposits) (Montgomery Watson, 1994a). Cross-sections of the area of Fort Huachuca, as shown in Figure 2-1, are included as Figures 2-2 and 2-3 and primarily include the lower and upper basin fill units.

In general, groundwater enters the Pantano, lower basin fill, and upper basin fill units near the base of the Huachuca Mountains and flows generally northeastward toward the San Pedro River in the center of the basin. Contributions of groundwater to the San Pedro River make up an important component of the flow within the river. The San Pedro River is an important resource within southeastern Arizona. Protection of the river and its associated riparian habitat are important considerations in watershed management throughout the San Pedro River basin. One of the goals for recharge within the San Pedro Basin is to prevent declining water levels from negatively affecting the riparian habitat along the river.

Depths to groundwater in the area of Fort Huachuca and Sierra Vista are up to 500 feet below ground surface (bgs) and decrease gradually toward the Babocomari and San Pedro Rivers. The regional water table lies primarily within the lower fill unit in the vicinity of Fort Huachuca as indicated on the aforementioned cross-sections. Transmissivity varies from 100 ft^2/day near the mountain fronts to 15,000 ft^2/day within the basins. Both the lower and upper fill units have similar hydrologic characteristics and may be considered as one unit for aquifer hydrology purposes (Montgomery Watson, 1994b). The regional hydraulic gradient in the area west of State Route 90 is approximately 1.7 ft/100 ft.

Some perched aquifer zones have been identified in and around Fort Huachuca near the mountain fronts (Montgomery Watson, 1994a; Montgomery Watson, 1994b). These zones have unusually high water levels (up to 4-10 feet bgs). However, perched aquifer zones are generally local features and are discontinuous. Therefore, the presence or absence of perched zones at any given site cannot be confirmed without site-specific intrusive investigations.

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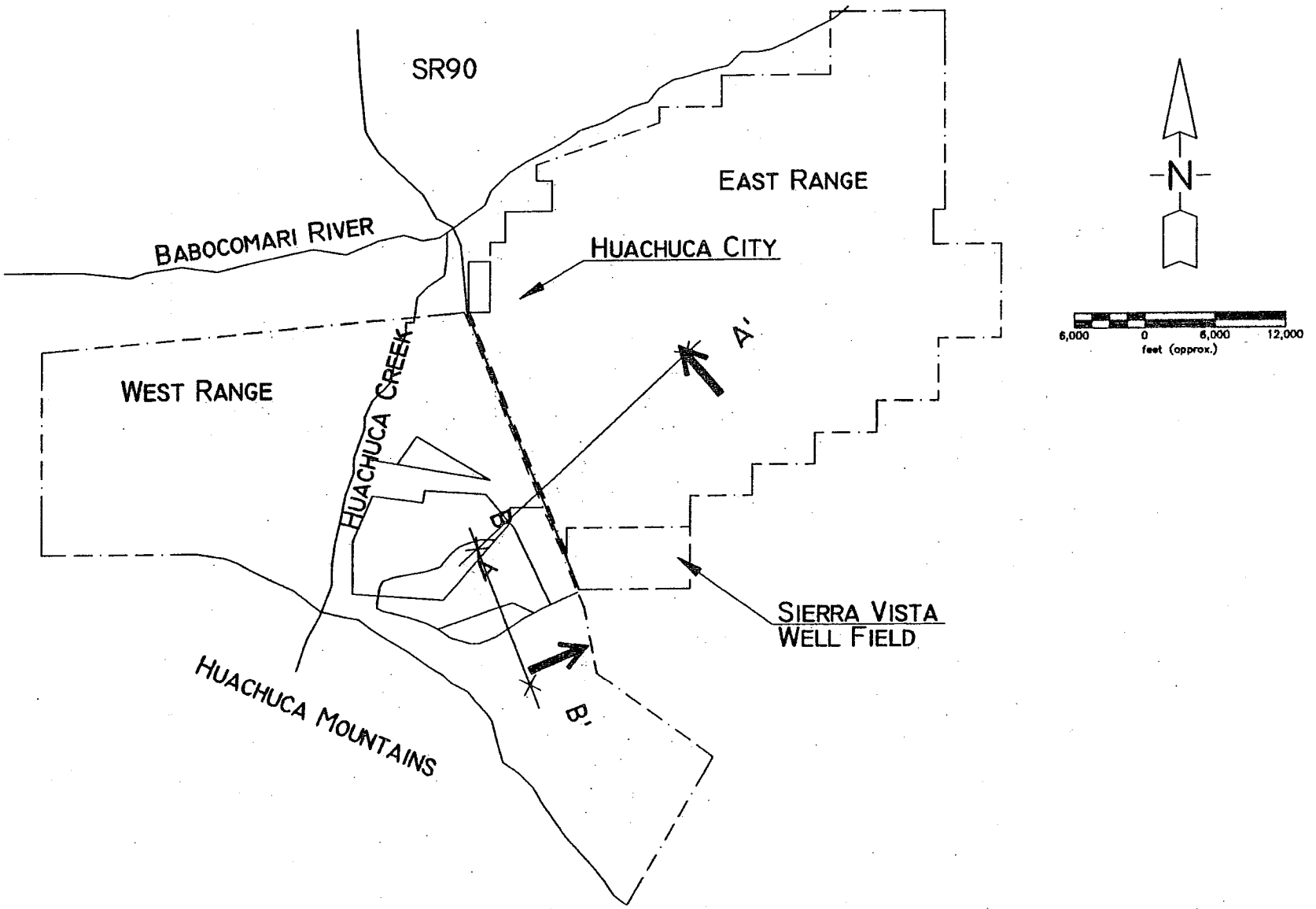

WATER RESOURCE / REUSE STUDY, FORT HUACHUCA

FIGURE 2-1
CROSS-SECTION LOCATIONS

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On Ft. Huachuca:
Upper Basin ~ 620' (sand, silty clay)
Lower Basin ~ 235' (sand, gravel, silt)

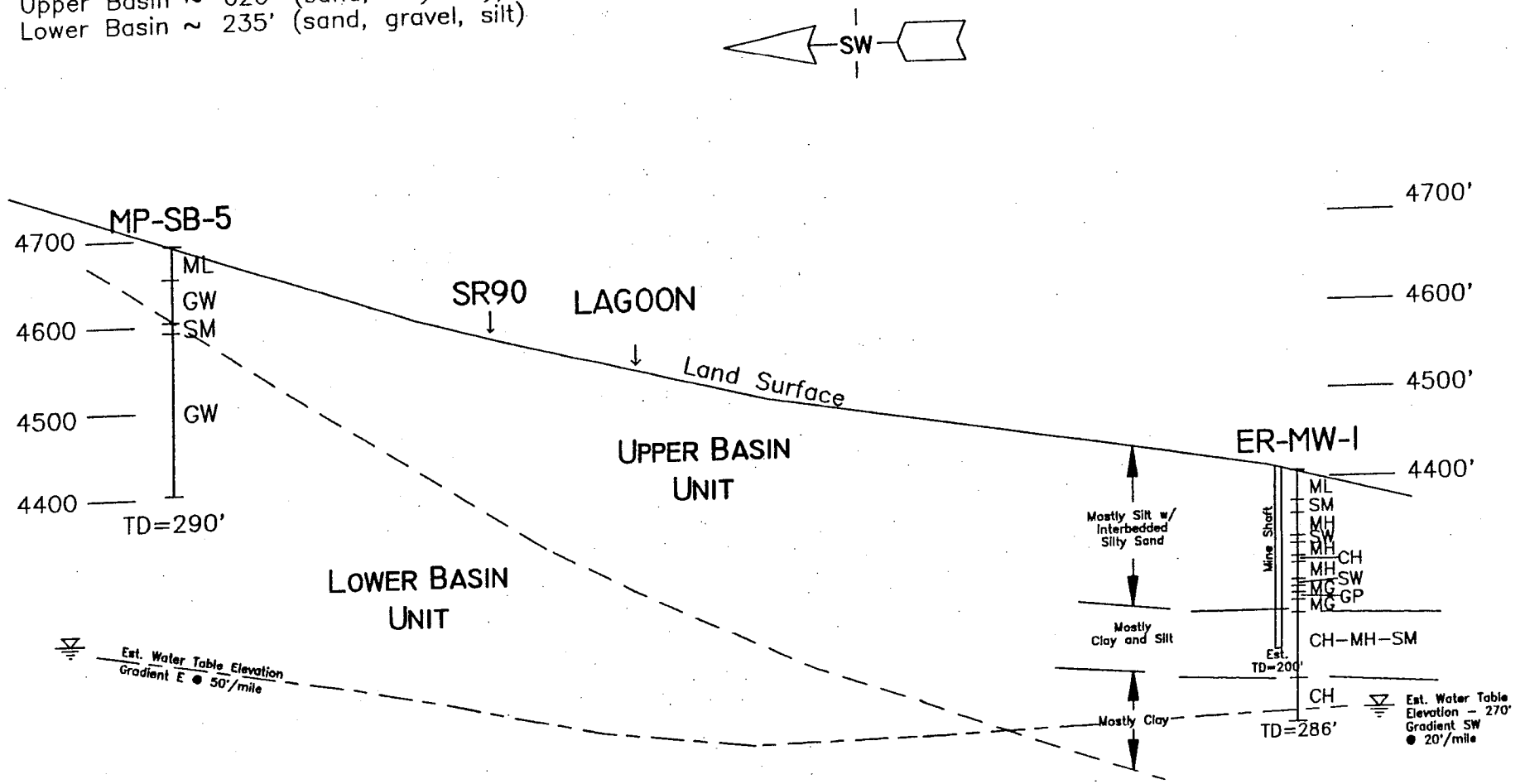

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FIGURE 2-2
CROSS-SECTION A-A'

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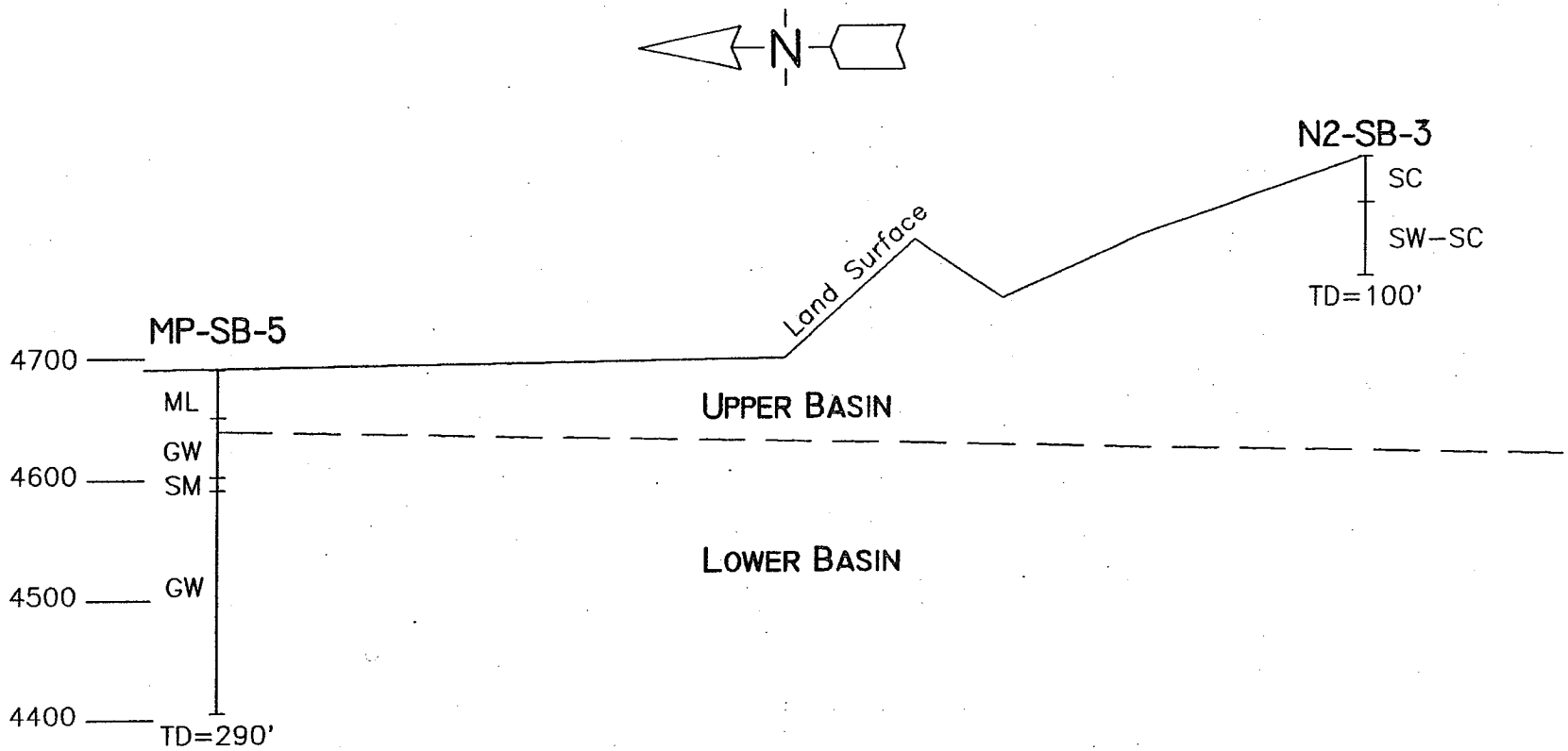

Estimated Water Table Elevation (approx. 475 ft bgs)
Cross-section roughly perpendicular to flow direction

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FIGURE 2-3
CROSS-SECTION B-B'

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Two large cones of depression have been noted in the basin due to groundwater withdrawal for the main population centers. One cone is in the area of the City of Sierra Vista and the Ft. Huachuca well field and the other is in the Huachuca City area. Groundwater level declines in these areas are estimated at 1.4 ft/yr (Montgomery Watson, 1994a).

The surficial soils in the area of Fort Huachuca are primarily of two types: Mineta-Gadwell complex and Gadwell-Kee complex. The Mineta-Gadwell complex occurs on steeper slopes (1 to 30 percent) than the Gadwell-Kee complex (1 to 5 percent)(Montgomery Watson, 1994a). Soil permeability is typically low to moderate and the available water capacity is moderate.

2.2 Ambient Groundwater Quality

Ambient groundwater quality was assessed using the groundwater quality results for major inorganic constituents at several locations on Fort Huachuca. These samples were collected from wells installed to monitor potential impacts of facilities on the groundwater and are reported in Montgomery Watson (1993). The inorganic results reviewed were primarily from sites at which the contaminants of concern were petroleum hydrocarbons (with the exception of samples collected from 2 wells at the South Range Landfill site). Therefore, the concentrations of major inorganic constituents at these sites may reflect ambient groundwater conditions. Table 2-1 indicates the average concentrations of various inorganic constituents reported in Montgomery Watson (1993).

The averages indicated on Table 2-1 were calculated using the following assumptions: Constituents listed as NA (not analyzed) in the Montgomery Watson report were not included in the calculation of the average concentrations. Constituents listed in the Montgomery Watson report as less than the method detection limit were averaged using half of the method detection limit.

General trends in the major inorganic constituent concentrations indicate that the groundwater is relatively hard (≈400 mg/L $CaCO_3$), high in total dissolved solids (≈ 450 mg/L), and slightly alkaline (pH ≈ 7.25). The major cation and anion species in the groundwater are Calcium (Ca^{2+}) and bicarbonate (HCO_3^-), respectively, as shown on Figure 2-4. Nitrate plus nitrite levels (typically predominantly nitrate) were approximately 3 mg/l.

In addition to the general water quality information discussed above, several facilities have been identified within the Fort Huachuca reservation with significant potential for contributing to aquifer contamination. These sites are indicated on Figure 2-5. Due to the great depth to groundwater in the area it is unlikely that many of these sites have already caused a groundwater contamination problem. Based on the previous studies it appears that only the East Range Mine Shaft site, the PX Service Station, the Tank Trails Dump Site #5, the UST Sites #1-4, the South Range Landfill, and the Building #30126 Waste Oil UST site have currently affected groundwater or are being monitored for potential impacts (James M. Montgomery, 1993, Montgomery Watson, 1993). Based on the results of the September 1993 sampling report (Montgomery Watson, 1993) compiling data from the July 1993 and earlier sampling rounds, it appears that the following constituents were the primary concern at these sites:

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Table 2-1
Major Inorganic Groundwater Quality

Constituent	Average Concentration	Average Concentration without South Range Landfill Wells
Total Suspended Solids	529	529
Total Dissolved Solids	453	464
Nitrate plus Nitrite	2.9	3.3
Nitrate - N	1.1	1.2
Nitrite - N	.13	.12
Bicarbonate as HCO_3	401	401
Calcium	108	109
Carbonate as CO_3	1.32	1.34
Chloride	15	16
Fluoride	.52	.56
Hydroxide as OH	.004	.004
Iron	6.6	6.6
Magnesium	28.5	24.2
Potassium	9.0	7.1
Sodium	27.4	26.7
Sulfate	54.7	50.0
Total Phosphate - P	.78	.81
Alkalinity	364	361
Ammonium - N	.17	.17
Biological Oxygen Demand	2.9	2.9
Chemical Oxygen Demand	13.7	13.7
Hardness (as $CaCO_3$)	422	393
Total Kjeldahl Nitrogen	ND	ND
Total Organic Carbon	4.2	4.2
pH	7.2	7.3

Notes: All units, except pH, are in mg/L. Averages calculated using half the detection limit if results were below method detection limit. The average value for Nitrate plus Nitrite may not equal the sum of the average values for Nitrate and Nitrite because most samples were not analyzed for both the total and individual constituents. ND - Not detected in any sample (detection limits varied in different samples).

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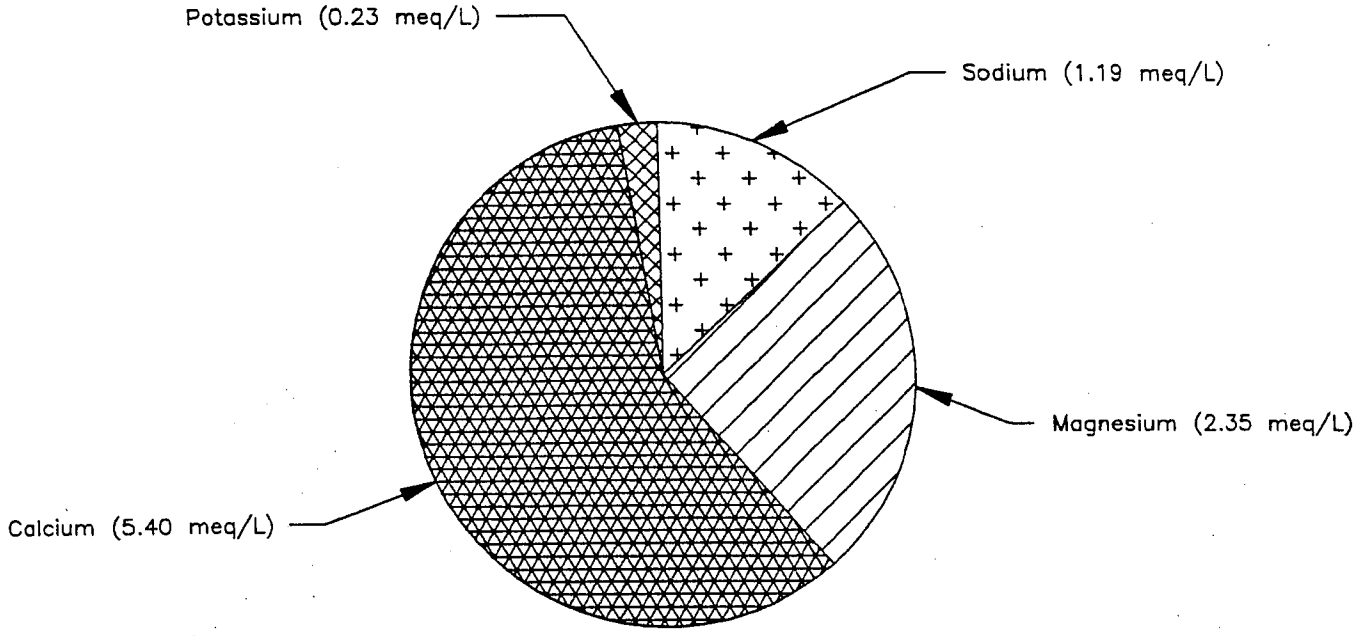
Major Cations



Major Anions

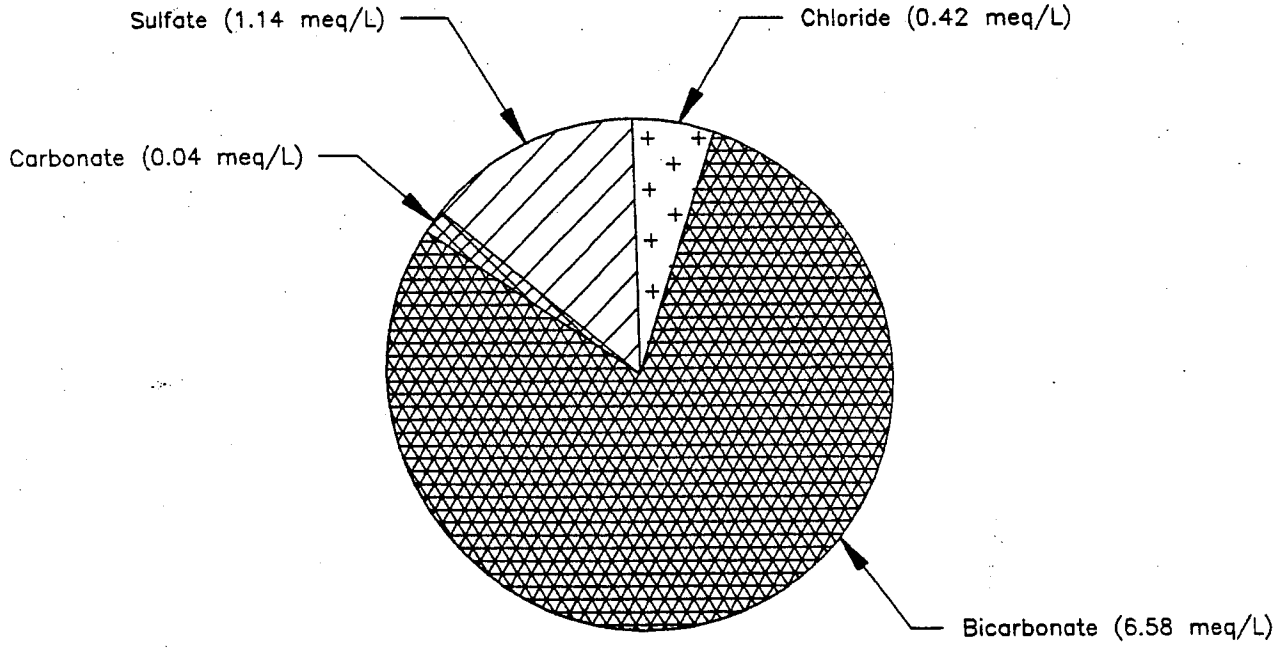


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FIGURE 2-4
AMBIENT GROUNDWATER
GEOCHEMISTRY

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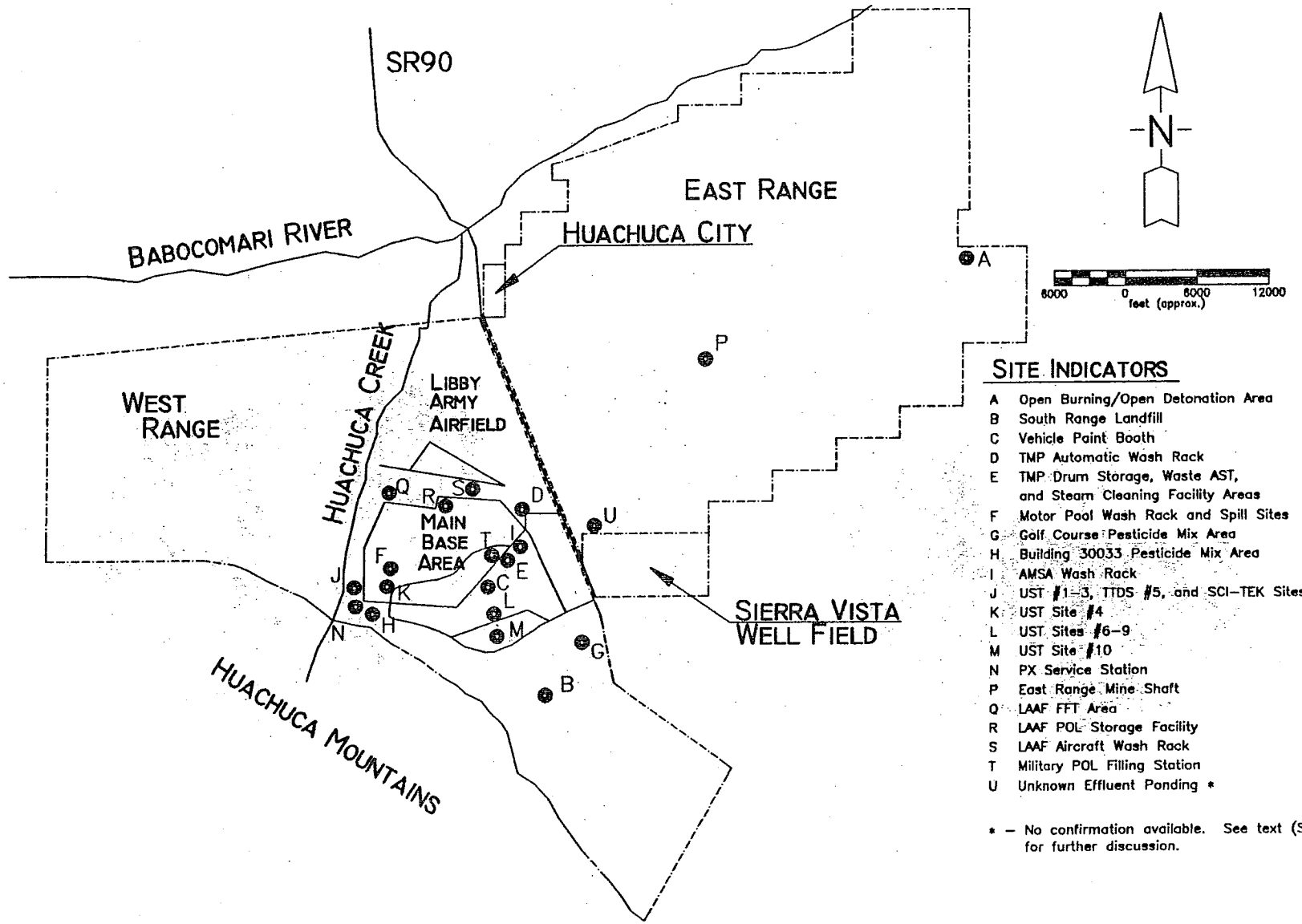

SITE INDICATORS

- A Open Burning/Open Detonation Area
- B South Range Landfill
- C Vehicle Paint Booth
- D TMP Automatic Wash Rack
- E TMP Drum Storage, Waste AST, and Steam Cleaning Facility Areas
- F Motor Pool Wash Rack and Spill Sites
- G Golf Course Pesticide Mix Area
- H Building 30033 Pesticide Mix Area
- I AMSA Wash Rack
- J UST #1–3, TTDS #5, and SCI–TEK Sites
- K UST Site #4
- L UST Sites #6–9
- M UST Site #10
- N PX Service Station
- P East Range Mine Shaft
- Q LAAF FFT Area
- R LAAF POL Storage Facility
- S LAAF Aircraft Wash Rack
- T Military POL Filling Station
- U Unknown Effluent Ponding *

* – No confirmation available. See text (Section 3.3) for further discussion.

SOURCES: Montgomery Watson, 1994c; James M. Montgomery, 1992; Montgomery Watson, 1994b; EPA, 1986

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FIGURE 2–5
POTENTIAL CONTAMINATED SITES

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» East Range Mine Site: Metals (Copper, Lead, and Zinc) detected at relatively low levels (Copper and Zinc below Arizona Health-based Guidance Levels (HBGLs) (ADEQ, 1992), Lead with maximum detection at 0.028 mg/L (HBGL=5.0 µg/L)) and Total Recoverable Petroleum Hydrocarbons (TRPH) detected in one well at 2.7 mg/L. The TRPH detection at this site has been attributed to lubricating oil in this well from the pumping test pump rather than representing conditions in the aquifer (Montgomery Watson, 1994a). This site was not sampled during the July 1993 sampling round but results from the previous sampling in April 1993 were presented in the July 1993 report.

» PX Service Station: Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) compounds (several detections significantly above HBGLs/EPA Maximum Contaminant Levels (MCLs)) and Lead (above HBGLs in some samples with a maximum of 0.035 mg/L). More recent sampling at this site in April 1994 indicates that BTEX concentrations decreased steadily from early 1993 results. For example, benzene concentrations in the most contaminated well declined by a factor of eight between January 1993 and April 1994 (Montgomery Watson, 1994c). This decline was attributed to natural dispersion and/or hydrocarbon degradation.

» Tank Trails Dump Site #5: Metals (detectable concentrations of arsenic, beryllium, chromium, copper, lead, and zinc). However, only lead, with a maximum detection of 0.031 mg/L, and beryllium, with a maximum detection of 0.002 mg/L were above HBGLs.

» UST Site #1: Metals (detectable concentrations of arsenic, beryllium, chromium, copper, lead, mercury, and zinc). However, only lead, beryllium, and mercury exceeded HBGLs with maximum detections of 0.33 mg/L, 0.0033 mg/L, and 3.4 µg/L, respectively.

» UST Site #2: Metals (detectable concentrations of chromium and zinc) and Nitrate plus Nitrite. However, only nitrate plus nitrite (in one sample) exceeded HBGLs.

» UST Site #3: Metals (detectable concentrations of arsenic, chromium, copper, lead, and zinc). However, only lead, with a maximum detection of 0.032 mg/L, exceeded HBGLs.

» UST Site #4: Metals (detectable concentrations of arsenic, beryllium, chromium, copper, lead, and zinc). However, only lead, with a maximum detection of 0.028 mg/L, and beryllium, with a maximum detection of 0.0021 mg/L, exceeded HBGLs.

» South Range Landfill: VOCs (detectable concentrations of 1,4-Dichlorobenzene, acetone, chlorobenzene, ethylbenzene, tetrachloroethene (PCE), and 1,1,1-trichloroethane - none above HBGLs), BNA-Semivolatiles (napthalene detected with a maximum concentration of 32 µg/L while the HBGL for napthalene is 28 µg/L), pesticides (detectable concentrations of DDD, DDE, DDT, and dieldrin above HBGLs with maximum concentrations of 1.57 µg/L, 0.623 µg/L, 0.718 µg/L, and 0.33 µg/L, respectively), and metals (detectable concentrations of antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc - all at or above HBGLs in one or more samples).

» Building #30126 Waste Oil UST site: Metals (detectable concentrations of arsenic, beryllium, chromium, copper, lead, mercury, nickel, and zinc with beryllium (maximum concentration of 0.004 mg/L) and lead (maximum concentration of 0.049 mg/L) exceeding HBGLs) and nitrate plus nitrite with a maximum concentration of 14 mg/L while the HBGL is 7 mg/L.

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Several of these sites have only relatively low levels of metals, which may be indicative of background conditions since UST sites rarely cause groundwater contamination with metals without concurrent BTEX or VOC contamination. However, rising water levels in these areas, as would be expected if artificial recharge were initiated, could contribute to a degradation of groundwater quality if groundwater reached higher concentrations of subsurface contamination in the vadose zone. This may also occur at contaminated sites that are not suspected as contributors to groundwater contamination if infiltrating recharge water passes through the contaminated soils or if rising groundwater levels intercept vadose zone contamination. Screening of potential recharge sites considered these potential concerns as discussed in the next chapter.

2.3 Effluent Quality

Projected effluent quality leaving Wastewater Treatment Plant No. 2 after the treatment plant upgrade is indicated on Table 2-2. The only constituent expected to exceed numeric ADEQ Aquifer Water Quality Standards (AWQS) is nitrate (as N). The projected concentration of nitrate is 22 mg/L, while the AWQS for nitrate is 10 mg/L. Nitrate is a common constituent of sanitary effluent, being a byproduct of protein metabolism. Nitrate can be removed from effluent by a variety of natural and artificial means including wetlands, anoxic biodegradation, ion-exchange (EPA, 1980), and soil-bacterial denitrification.

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Table 2-2
Projected Effluent Quality

Constituent [1]	ADEQ Limit	Projected Quality
Suspended Solids	10	5
Biochemical Oxygen Demand	10	5
Dissolved Oxygen	None Established	2.0
Fecal Coliform (CFU/100 ml)	25	<2
Total Residual Chlorine	None Established	1.0
pH	4.0-9.5	7.5
Turbidity (NTU)	5	1.0
Enteric Virus (MPN/40L)	125	0
Giardia Lamblia (MPN/40L)	None Established	10
Temperature (° F)	None Established	75-80
Arsenic	0.05	<0.01
Barium	1.0	<0.2
Cadmium	0.010	<0.01
Chromium	0.05	<0.05
Lead	0.05	<0.05
Mercury	0.002	<0.002
Nitrate (as N)	10	22 [2]
Selenium	0.01	<0.01
Silver	0.05	<0.05
Fluoride	4.0	<1.0
Endrin	0.0002	ND [3]
Lindane	0.004	ND
Methoxychlor	0.1	ND
Toxaphene	0.005	ND

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Table 2-2
Projected Effluent Quality

2,4-Dichlorophenoxyacetic Acid	0.1	<0.001
2,4,5-Trichlorophenoxypropionic Acid	0.01	<0.0001
Total Trihalomethanes	0.10	ND
Benzene	0.005	ND
Vinyl Chloride	0.002	ND
Carbon Tetrachloride	0.005	ND
1,2-Dichloroethane	0.005	ND
Trichloroethene	0.005	ND
1,1-Dichloroethene	0.007	ND
1,1,1-Trichloroethane	0.20	<0.0004
Gross Alpha Radiation (pCi/L)	15	<2
Radium 226 and 228 (pCi/L)	5	<0.6
Tritium (pCi/L)	20,000	<5
Strontium 90 (pCi/L)	8	<5

Notes:(1) - All units in mg/L, except as noted
(2) - at plant
(3) - ND- Not Detected

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3.0 RECHARGE SITE SELECTION PROCESS

The following discussion describes the methodology used for selection of the appropriate areas of Fort Huachuca for location of the conceptual recharge facility developed under this study. The selected area is a general area that appears appropriate for further investigation based on the data reviewed for this study. Further refinement of the recharge location, should be developed during future studies based on site-specific data, as discussed in Chapter 6.

3.1 Technical Screening Factors

Screening of potential recharge locations involved consideration of a number of factors. The initial screening was based on technical factors including topography, presence of known contaminated or potentially contaminated sites, proximity to the treatment plant, and presence of significant fixed facilities. This initial screening did not consider the method of recharge or land use considerations. These elements were considered elsewhere in the conceptual recharge facility development. The considerations included in each of the factors of the initial screening were the following:

» Topography: The elevation of the recharge facility is a significant potential constraint on the feasibility of the facility. Pumping of effluent to sites located at elevations significantly higher than the treatment plant would require large capital and ongoing O&M expenditures. Therefore, locations significantly higher than the treatment plant (i.e., above the 4700-foot contour) were eliminated from further consideration as a conceptual recharge site.

  In addition, topographic constraints such as large watercourse crossings or rough terrain were considered due to the difficulty in constructing the conveyance system to the conceptual recharge site. Therefore, locations west of Huachuca Creek were eliminated from further consideration as a conceptual recharge site.

» Presence of Known Contaminated or Potentially Contaminated Sites: Several of these sites on the Fort Huachuca installation have been identified from previous investigations. These sites are illustrated on Figure 2-5. Although many of these facilities have not been implicated in a degradation of groundwater quality at the site, the vicinity of these sites was removed from further consideration because of potential contamination problems. These could be due to infiltrating recharge water moving contaminants deeper into the subsurface, rising water levels intercepting contaminated soils in the vadose zone, or a combination of the two. Sites within 0.5 miles of identified contaminated or potentially contaminated sites were removed from further consideration as a conceptual recharge site.

» Proximity to the Treatment Plant: Recharge locations closer to the treatment plant are preferable from the standpoint of reduced cost of effluent transportation. This factor was not considered a primary factor in the screening process (i.e., this criterion was not used to screen out potential locations). However, this factor was used to differentiate between locations that were similar with respect to the other factors.

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» Presence of Significant Fixed Facilities: This screening factor considered the locations of fixed facilities (e.g., buildings, roads, airstrips, etc.) on the Fort Huachuca installation that were easily identifiable from the provided maps and aerial photographs. Fixed facilities limit the flexibility of the recharge facility configuration and potentially impact active operations. Because of this factor, sites near the Libby Army Air Field and the Main Post Area were removed from further consideration as a conceptual recharge location.

3.2 Fort-Provided Constraints

After the initial screening of potential conceptual recharge sites based on the technical factors described above, discussions were held with Fort personnel to identify other constraints. These constraints included current locations of Army activities incompatible with recharge facilities, potential future locations of Army or other facilities, and exclusion zones required for the flight operations at the Libby Army Airfield. Based on these discussions (Fort Huachuca, 1995), the following areas were removed from further consideration as a conceptual recharge location: West Range north of the Libby Army Airfield and east of Huachuca Creek; and East Range more than one mile east of SR90 and more than 1 mile north of the City of Sierra Vista.

3.3 Selected Location

Figure 3-1 indicates the results of the preceding analysis. All areas of the West Range were screened out on the basis of topography, presence of known contaminated or potentially contaminated sites, presence of significant fixed facilities, or Fort-provided constraints. Many areas of the East Range were screened out on the basis of presence of known contaminated or potentially contaminated sites or Fort-provided constraints. The remaining areas, referred to as potential areas, are located within one mile of SR90 and/or the City of Sierra Vista. Based on the proximity to the treatment plant, the potential area south of the exclusion zone from Libby Army Airfield (Primary Potential Recharge Site Zone) is recommended for further investigations as a conceptual recharge location. If information collected in further studies indicate that this area is incompatible with an efficient recharge facility, the potential area north of the exclusion zone from Libby Army Airfield should be considered.

The Primary Potential Recharge Site Zone contains one area (Site U on Figure 2-5) that may present a problem with respect to site contamination. This area is located along Soldiers Trail Wash within 0.5 miles of the Fort Huachuca/City of Sierra Vista boundary. It was noted on a set of maps prepared by EPA as a location of ponded "turbid effluent" in 1978 (EPA, 1986). Communications with Fort Huachuca and City of Sierra Vista personnel did not indicate significant concern with respect to this site (Fort Huachuca, 1995 and Sierra Vista, 1995). It is possible that this water was due to washing activities at gravel extraction facilities in the area. It is not expected that this site represents a significant constraint on the location of the conceptual recharge facility, but it should be investigated further in the Feasibility Study if the proposed facility site is near this area.

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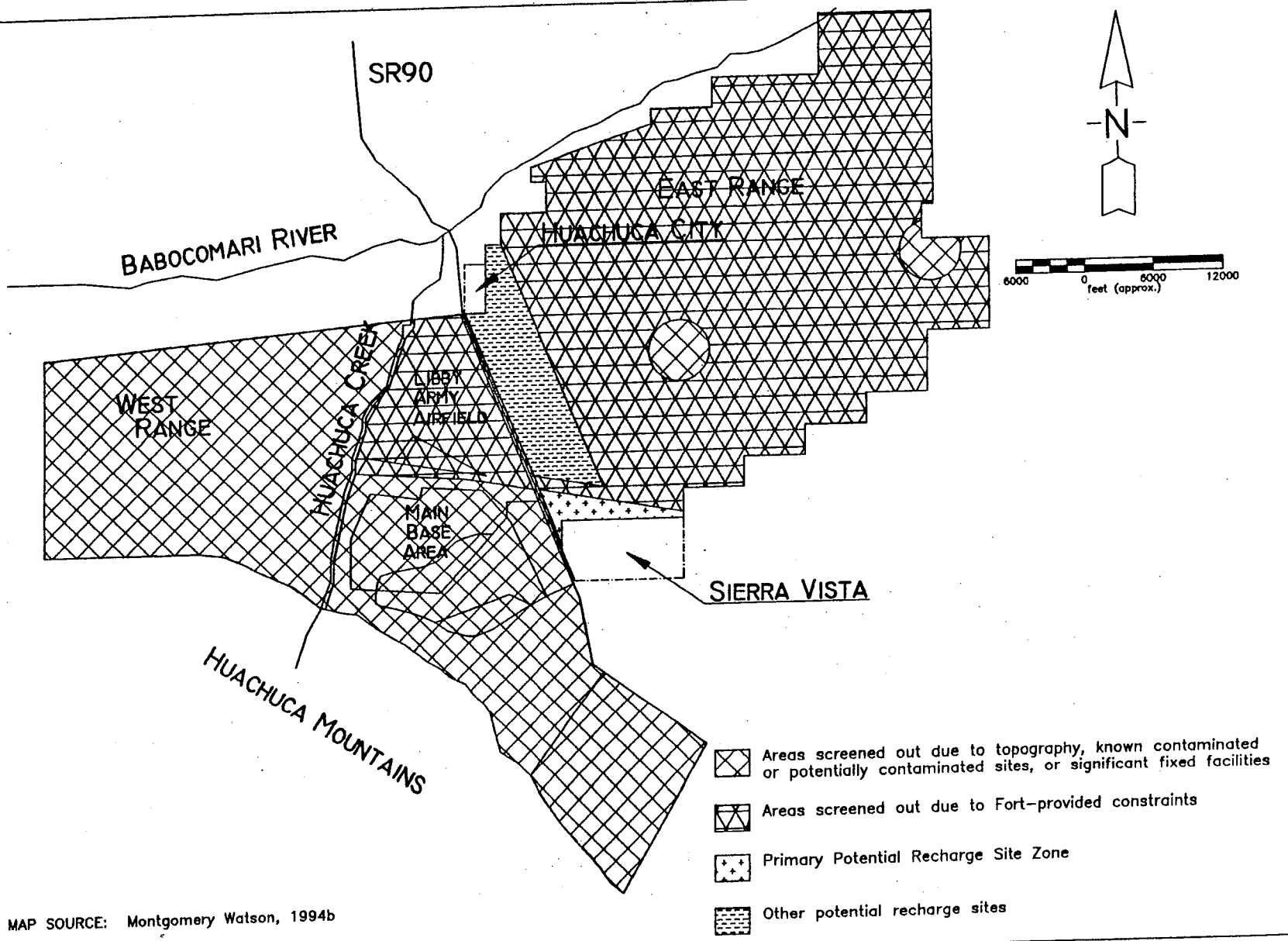

MAP SOURCE: Montgomery Watson, 1994b

WATER RESOURCE / REUSE STUDY, FORT HUACHUCA

FIGURE 3-1
CONCEPTUAL RECHARGE SITE SCREENING

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4.0 RECHARGE METHOD SELECTION PROCESS

The following discussion describes some of the methods available for recharging water from the surface into the aquifer; screening criteria appropriate to Fort Huachuca; and the selection of the recharge method considered most feasible given site conditions known at this time. Site-specific hydrogeologic information is required to refine the selected recharge method.

4.1 Available Recharge Methods

A number of different methods are available to recharge water into an aquifer. Each method has advantages and disadvantages and the selection of the appropriate method is dependent on site-specific conditions. The following is a list of some of the more commonly used recharge methods:

» Shallow Spreading Basins: This method involves construction of one or more diked basins designed to be filled with water to a depth of less than five feet. The water is allowed to infiltrate into the soils beneath the basins and the basins are typically operated on a "wet-dry" cycle to maintain infiltration rates. Advantages of this method include low O&M costs, efficient operation, and ease of control. Disadvantages include large land area requirements and decreases in infiltration rates over time unless "wet-dry" cycling and periodic disking of the basin bottom is conducted.

» Deep Spreading Basins: This method involves the use of basins designed to hold water at depths in excess of five feet. Because of the deep basins required, this method is usually used where another operation (gravel pit, etc.) has already excavated the basin. These basins are usually operated continuously because of the difficulty in draining the basin. Advantages of this method include multi-use potential and a beneficial use of abandoned gravel pits. Disadvantages include low infiltration rates over time and difficult maintenance.

» In-Channel Techniques: This method is actually a group of similar methods that provide for recharge within the channel of an ephemeral stream or flood-control channel. Differences between the methods primarily relate to the means used to prevent or reduce the downstream flow of the water in order to allow the slower process of infiltration to occur. Methods include inflatable dams, gated structures, and channel earthwork. Advantages of these methods include higher infiltration rates typically associated with in-channel alluvium, interception of stormwater flows, and some degree of flood control. Disadvantages include high construction and/or O&M costs, potential flooding problems during flood events if the facility's bypass mechanism does not operate properly, and federal NPDES permitting requirements.

» Induced Infiltration: This method uses a groundwater discharge facility (typically a well) to develop a hydraulic gradient from a surface water source to the point of discharge (CH2M Hill, 1992). Advantages of this method include increased infiltration rate due to the artificially-induced gradient. Disadvantages include the requirement for direct hydraulic contact between the recharge source and the wells in the aquifer, high cost, and the need for a beneficial use of the extracted water.

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» Injection Wells: This method involves use of a well to inject recharge water into the aquifer or the vadose zone immediately above the water table. Injection wells can be operated under pressure or by gravity flow. Advantages of this method include the ability to bypass low permeability layers in the vadose zone, low evaporation losses, and low land area requirements. Disadvantages include high O&M costs, high construction costs, and more stringent quality requirements of the recharge water source since no vadose zone treatment is provided. Some studies also indicate that the injection wells method may be incompatible with treated effluent as the source of recharge water (CH2M Hill, 1989). This is due to the presence of biological matter and the development of biological films that reduce long-term recharge efficiency and require eventual replacement of the wells.

» Infiltration Galleries: This method involves construction of a network of pipes to distribute the recharge water to a field in a higher permeability layer in the shallow vadose zone. It is analogous to the injection well method except that the "well" is oriented horizontally. Advantages of this method include the possibility of bypassing low permeability zones near the surface and low evaporation losses. Disadvantages include high O&M costs, high construction costs, and high land area requirements. A clogging effect due to biological matter/films similar to that noted above for injection wells may reduce the long-term efficiency of the infiltration gallery. However, the near-surface location of the gallery may ease redevelopment of the gallery.

4.2 Selection Criteria

Selection of the appropriate method for the conceptual recharge facility in this study requires consideration of site-specific conditions at Fort Huachuca. In general, the recharge operation at the Fort would involve conveyance of recharge water from an artificial source (treated effluent), through a thick vadose zone to the aquifer (≈ 400 feet below ground surface). Since the Fort has a relatively large area available, land area considerations are not as significant as they might be at other sites. Since one of the goals of the recharge program is to maximize the fraction of effluent returned to the aquifer, evaporation losses should be minimized. The facility is proposed to be operated for a considerable length of time; therefore, O&M costs are a significant consideration. The recharge source under consideration in this study is treated effluent. Quality concerns associated with permitting may require additional treatment processes if discharge to "waters of the United States" or near the water table is involved in the selected recharge method. In addition, the method selected should allow efficient infiltration of the recharge water to the aquifer over the long-term.

The primary criteria for selection of the conceptual recharge method, in no particular order, are:

» Applicability to General Site Conditions
» Minimal Evaporation Losses
» Construction and O&M Cost
» Treatment Requirements
» Long-Term Efficient Operation

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No intrusive studies have been conducted under this project. Therefore, detailed site-specific hydrogeologic information is not available for the selected recharge site area. Selection criteria based on hydrogeology (i.e., presence of low permeability layers at the recharge site) cannot be applied at this time. Therefore, the selection of recharge method for further investigation should be considered as conceptual. Detailed, site-specific information developed by further investigations may require the selected site and/or recharge method to be modified.

4.3 Selected Method

Based on the above-described criteria, the following logic was used in selection of the conceptual recharge method for further analysis. This analysis is summarized on Table 4-1. Land costs were not used as a selection criterion because of the available land area at Fort Huachuca. Flooding potential was not used as a selection criterion because of the lack of structures subject to flood damage in the east range areas considered. (Flooding potential with respect to off-Post structures should be considered in final site selection if in-channel methods are selected, however.)

All of the methods were unfavorable with respect to at least one criterion. However, the shallow spreading basins and infiltration galleries methods were only unfavorable with respect to one criterion (evaporation losses and cost, respectively). The following discussion summarizes the screening for each method.

Deep spreading basins were screened out because of high evaporation losses, cost, and efficiency considerations. Since no deep pits are available within the available area for recharge facilities, large basins would have to be excavated for this method, at a high construction cost. Because deep spreading basins are designed to be operated continuously, long-term infiltration rates would be low and the evaporation losses would be high relative to the long-term infiltration rate.

In-channel methods were screened out due to high evaporation losses, high construction and/or O&M costs, and additional treatment requirements that may be necessary to comply with an NPDES discharge permit.

The induced recharge method requires a direct hydraulic connection between a surface water source and the groundwater and is, therefore, not applicable to general site hydrogeologic conditions.

Injection wells were screened out due to high construction and O&M costs, as well as additional treatment requirements necessary to comply with an aquifer protection permit since vadose zone treatment cannot be considered with this method. In addition, studies have indicated that this method may be incompatible with treated effluent as a recharge water source due to concerns over long-term recharge efficiency (CH2M Hill, 1989).

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Table 4-1
Screening of Available Recharge Methods

Method	Criteria						
	Applicable to Hydrogeologic Conditions?	Land Costs	Flooding Potential	Evaporation Losses	Cost	Treatment Requirements	Long-Term Efficiency
Significant Concern at Fort Huachuca?	Yes	No	No	Yes	Yes	Yes	Yes
Shallow Basins	Yes	U	F	U	F	F	F
Deep Basins	Yes	U	F	U	U	F	U
In-Channel Methods	Yes	N	U	U	U	U	F
Induced Infiltration	No	Since this method is not applicable to the hydrogeologic conditions at the site, no further analysis is necessary					
Injection Wells	Yes	F	F	F	U	U	U
Infiltration Galleries	Yes	U	F	F	U	F	N

Notes: F - Method is favorable with respect to that criterion
N - Method is neutral with respect to that criterion
U - Method is unfavorable with respect to that criterion
Shaded columns represent criteria not used in the selection process

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On the basis of information available at this time, shallow spreading basins and infiltration galleries appear to be the most favorable methods of recharging treated effluent to the aquifer. Both are considered unfavorable with respect to only one criterion. Of the two methods, shallow spreading basins were selected because the inherent evaporation losses of that method can be minimized by proper design and operation. In addition, infiltration galleries are a relatively untested method of long-term, large scale recharge in Arizona, although the method is analogous to septic tank leach fields and dry wells, both of which are commonly used in Arizona. The infiltration gallery method was considered neutral with respect to long-term efficiency because, although clogging may occur from biological matter/films associated with treated effluent recharge, the near-surface location of the galleries may allow easier redevelopment/replacement than other methods (e.g., injection wells).

The shallow spreading basins method will require a relatively large surface area (≈40-60 acres, depending on site-specific conditions) to allow recharge of the available effluent volume at potential infiltration rates. Some evaporation losses can be expected from a shallow spreading basin facility, especially during the hot, dry months of the early summer. Using conceptual infiltration and net evaporation rates of 0.1 in/hour and 52.07 in/yr respectively (as discussed later in Chapter 5), it is estimated that approximately 6% of the effluent volume would be lost to evaporation over an annual average. The fraction of the effluent stream lost to evaporation can be minimized by maintaining relatively high infiltration rates by "wet-dry" cycling and periodic basin bottom disking. However, shallow spreading basins provide a relatively low-cost, low maintenance means of recharging the aquifer and the thick vadose zone through which the recharged water will percolate provides significant potential additional treatment before reaching the aquifer.

If information gathered in subsequent phases of the recharge investigations indicate site-specific conditions incompatible with shallow spreading basins, another recharge method, such as infiltration galleries, may be considered.

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5.0 CONCEPTUAL RECHARGE FACILITY

This chapter outlines the conceptual layout of the selected recharge facility to be constructed at the selected location. It also provides an assessment of the hydrogeological effects of the facility; major permitting requirements of a recharge facility at Fort Huachuca; and an "order of magnitude" opinion of probable construction cost for the recharge facility. It should be noted that this discussion is at a conceptual level only and further refinements to the facility layout, hydrogeologic assessment, permitting analysis, and opinions of probable construction cost should be made as more detailed, site-specific information becomes available during future investigations.

5.1 Conceptual Layout

The conceptual layout of a shallow spreading basin recharge facility is illustrated in Figure 5-1. The major components of the facility are: a conveyance pipe from the treatment plant; a post-secondary treatment system (if required to meet permit conditions); an operations building; a series of earthen-diked basins (≈ 1-5 acres each); and a means of distributing recharge water into one or more recharge basins.

For purposes of further analysis of this conceptual layout, the following sizing estimates were derived. These estimates are based on rough estimates of the effluent flowrate (assumed constant), infiltration capacity of the soils beneath the conceptual recharge facility, and contingency allowances (storage volume and basin drying considerations). Further site-specific and operational data is needed to develop the design of the recharge facility to a greater level of detail.

Based on general soil types in the Fort Huachuca/Sierra Vista region (ASL, 1995), soil classification data (SCS, 1974), and an assumed 50% reduction in long-term infiltration rates, an effective infiltration rate of 0.10 in/hr (0.20 ft/day) was used in the conceptual layout. Given an average effluent generation of 2.0 MGD, effluent reuse of 178 MG/yr (existing), and net evaporation of 52.07 in/yr (66.61 in evaporation minus 14.54 in precipitation), it is assumed that approximately 22 acres would be required to recharge the effluent. To allow for "wet-dry" cycling, it is assumed that 45 acres of total basin area would be required. This would allow half of the basins to be drying while the other half are actively recharging effluent. To provide flexibility in basin operation, it is assumed that 10 basins of 4.5 acres each would be used in the conceptual facility.

Individual basins in the conceptual layout are long and narrow (length:width ratio approximately 5:1), and aligned such that the longitudinal axis of the basin is roughly parallel to the surface contours. This arrangement minimizes earthwork necessary to grade the basin bottoms. Access roadways are included between the basins to allow maintenance activities. For purposes of determining opinions of probable construction cost, it was assumed that the dike height of the basins would be 3 feet (2 feet maximum depth plus 1 foot of freeboard).

The conceptual size of the basins (4.5 acres each @ 2 foot maximum depth) would provide significant equalization storage in the system. For example, given a Peak Day Wastewater Flow (PDWF) of 3.1 MGD with no reuse or evaporation, along with infiltration of 0.1 in/hr, the available storage time in one-half (5) of the basins would be approximately 9 days. However, in the event that the recharge basins would have to be taken off-line for an extended period, an alternate disposal mechanism may be needed. Consideration should be given to retaining the existing lagoon areas for emergency disposal.

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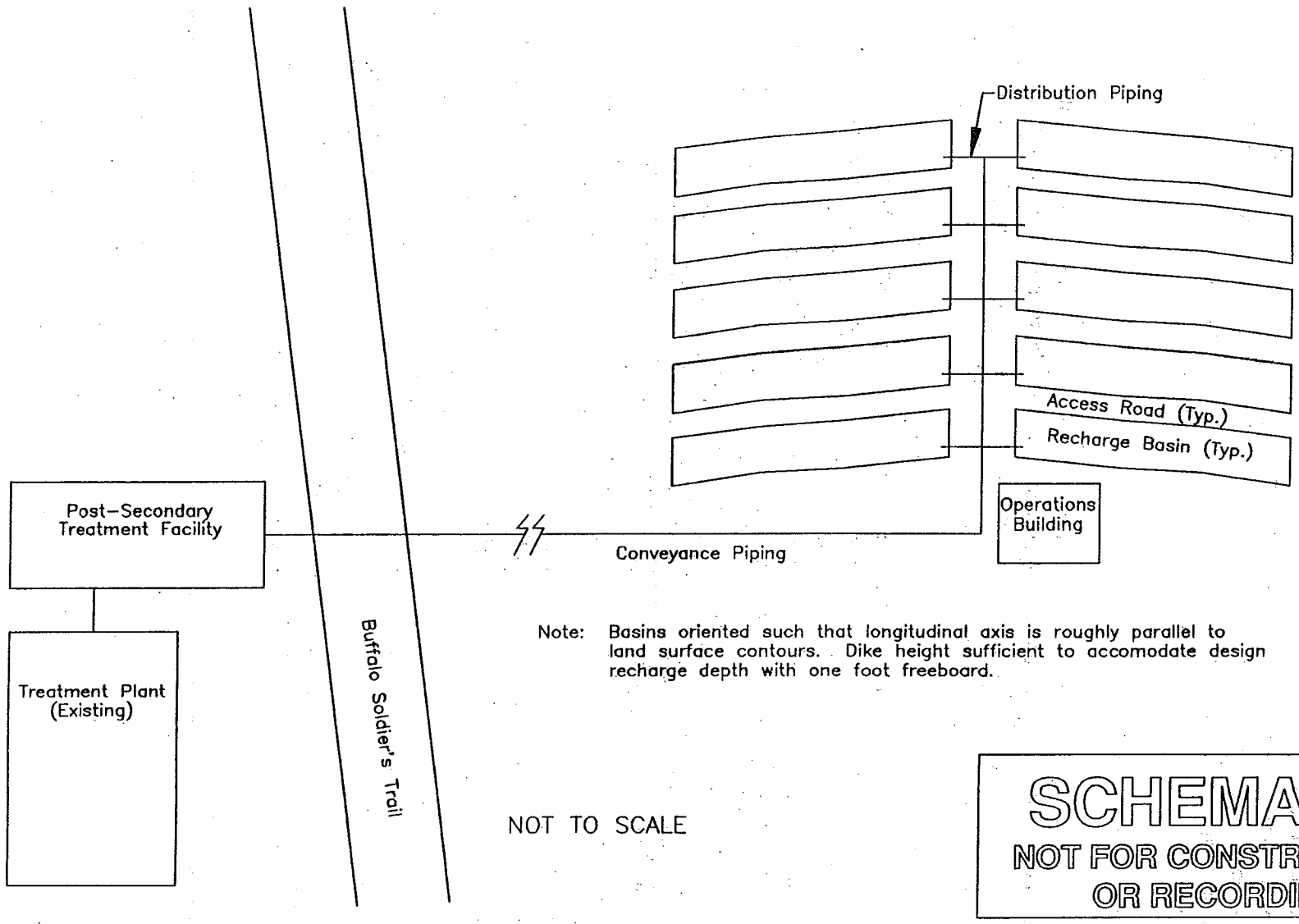

Note: Basins oriented such that longitudinal axis is roughly parallel to land surface contours. Dike height sufficient to accomodate design recharge depth with one foot freeboard.

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FIGURE 5-1
CONCEPTUAL RECHARGE FACILITY LAYOUT

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Effluent is conveyed to the conceptual recharge facility via a buried transmission main. Depending on the relative elevation of the facility to the treatment plant and topography of the transmission main alignment, the main may require a pump station or may operate by gravity flow. At the conceptual facility, smaller laterals branch out from the main distribution pipe to each of the basins. Flows from the distribution laterals can be controlled with manual- or solenoid-operated valves. An erosion control system (such as a rip-rap pad) should be included where the distribution lateral discharges into each basin. This will minimize local erosion and reduce resultant basin clogging.

Monitoring wells will also be required at the recharge facility to monitor the effects (water level and water quality) of the facility on the aquifer. Location and design of these wells will depend on hydrogeologic analysis based on site-specific conditions.

5.2 Hydrogeological Assessment

To evaluate the potential impact of effluent recharge on the underlying groundwater, a computer model simulation was performed for vadose zone flow and contaminant transport. Since nitrate appears to be the effluent constituent of greatest concern regarding groundwater quality, the modeling was used to predict nitrate concentrations over time immediately above the water table elevation. The following sections describe the methodology, input parameters, and results of the computer modeling:

5.2.1 Methodology

The following time-dependent one-dimensional convective-dispersive solute transport equation was solved for transport in the vadose zone:

$$R\left(\frac{\partial C}{\partial t}\right)=D\left(\frac{\partial^2 C}{\partial x^2}\right)-V\left(\frac{\partial C}{\partial x}\right)$$

Where:

- R = Retardation Factor
- x = Distance
- C = Concentration
- D = Dispersion
- V = Seepage Velocity
- t = Time

For unsaturated flow conditions, the retardation factor is determined as follows:

$$R=1+\frac{BK_d}{\theta_v}$$

Where:

- K_d = Linear partition coefficient (ratio of concentration in soil to concentration in water)
- B = Soil bulk density
- θ_v = Volumetric moisture content.

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However, this calculation requires knowledge of the K_d, B, and θ_V at the conceptual recharge site. While the values of B and θ_V could be estimated from available geotechnical data from other sites on the Fort (e.g., East Range Mine Shaft site), the value of K_d is highly dependent on site-specific soil conditions and contaminant characteristics and usually requires laboratory column testing. Therefore, for purposes of this conceptual analysis, an R of 1.5 was assumed to provide for minimum adsorption capacity of the soils.

An analytical solution to this equation for a uniform seepage velocity in the vadose zone for a semi-infinite column is provided by Lapidus and Amundson (1952) and by Ogata and Banks (1961) as follows:

$$C(x,t) = \begin{cases} C_i + (C_o - C_i)A(x,t) & \text{for } 0<t<t_o \\ C_i + (C_o - C_i)A(x,t) - C_o A(x,t-t_o) & \text{for } t>t_o \end{cases}$$

Where:

$$A(x,t) = 0.5\,\mathrm{erfc}\left(\frac{Rx - Vt}{2(DRt)^{0.5}}\right) + 0.5\exp\left(\frac{Vx}{D}\right)\mathrm{erfc}\left(\frac{Rx - Vt}{2(DRt)^{0.5}}\right)$$

The corresponding boundary conditions to this solution are: (1) a uniform input source at the top of the vertical soil column and (2) the rate of change of the concentration gradient at an infinite distance vertically is zero. A computer-coded solution to the above equation provided by van Genuchten and Alves (1982) was used to simulate nitrate transport in the unsaturated zone.

5.2.2 Input Data and Assumptions

To develop a worst-case estimate of the nitrate transport to the aquifer, the following assumptions were used:

Nitrate Concentration:	22 mg/L
Seepage Velocity:	0.63 in/hr = 1.26 feet/day
Seepage Duration:	Continuous
Retardation:	1.5
Dispersion:	Minimal (assumed 0.1)
Depth to Water:	400 feet

Because this solution only considers soil sorption as the retardation mechanism, it represents a worst-case estimate of the nitrate transport to the aquifer. In the natural environment, soil bacteria may be very effective in converting nitrate (NO_3) to N_2 and O_2 (Freeze and Cherry, 1979). This mechanism occurs in reducing environments and may be limited by the availability of a carbon source. The nature of the vadose zone beneath the conceptual recharge facility is unknown at this time; therefore, the degree of natural denitrification during vadose zone transport is not known. However, it can be expected that some denitrification would occur.

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5.2.3 Results

The results of this analysis are shown in the plots on Figures 5-2 and 5-3. Detailed print-outs of the computer runs are included in Appendix 1. The baseline case of the analysis, using the parameters listed in Section 5.2.2, indicates that some nitrate would reach the water table elevation within 450 days and would quickly reach an equilibrium in the vadose zone at the loading concentration. However, it should be noted that the results of this analysis are based on limited data available at this time and should be so considered in light of the assumptions inherent in the solution.

Several conclusions can be drawn from the results of this analysis:

» The analytical solution is highly sensitive to a number of hydrogeologic factors that are site-specific and not quantified at the conceptual recharge location. These factors include infiltration rates, variation in vadose zone permeability with depth, retardation factors, dispersion, etc. More detailed, site-specific investigations should be conducted to determine these factors in order to refine estimates of the effect of nitrate loading on the aquifer.

» The analytical solution presented considers retardation as the primary mechanism of the variation of the contaminant transport from pure convective flow. However, nitrate migration in the vadose zone is probably affected by transformation mechanisms to a much greater degree. Nitrate is one element of the nitrogen cycle and understanding of the mechanisms of this cycle relevant to effluent treatment and disposal is necessary to evaluate the potential impacts on the aquifer. Raw sewage is typically high in nitrogen-containing compounds, primarily organic nitrogen and ammonia, which are byproducts of protein metabolism. In typical treatment processes, these compounds are oxidized to nitrite (NO_2) and then to nitrate (NO_3).

  Nitrate is typically very stable in well oxygenated environments. Facultative, heterotrophic microbial action in anoxic conditions, however, converts the nitrate to N_2O and then to N_2 and O_2 (Freeze and Cherry, 1979; EPA, 1980). These compounds are gasses and, therefore, are removed from the vadose zone by off-gassing. Thus, the nitrate transformation processes remove nitrogen from the vadose zone and would, therefore, result in steady-state nitrate concentrations near the water table lower than the loading concentrations. It is possible that this mechanism within the 400 feet of the vadose zone above the water table would be sufficient to reduce nitrate concentrations to below Aquifer Water Quality Standards (AWQS) without additional treatment trains at the treatment plant. Provision of a carbon source may or may not be necessary to stimulate biochemical transformation of the nitrate.

  The transformation of nitrate would best be modeled using a decay term in the analytical solution; however, the appropriate decay rate is not known at this time. More detailed investigation into the potential for nitrate transformation to reduce nitrate concentrations in the percolating recharged water should be considered as part of the feasibility study discussed in Chapter 6.

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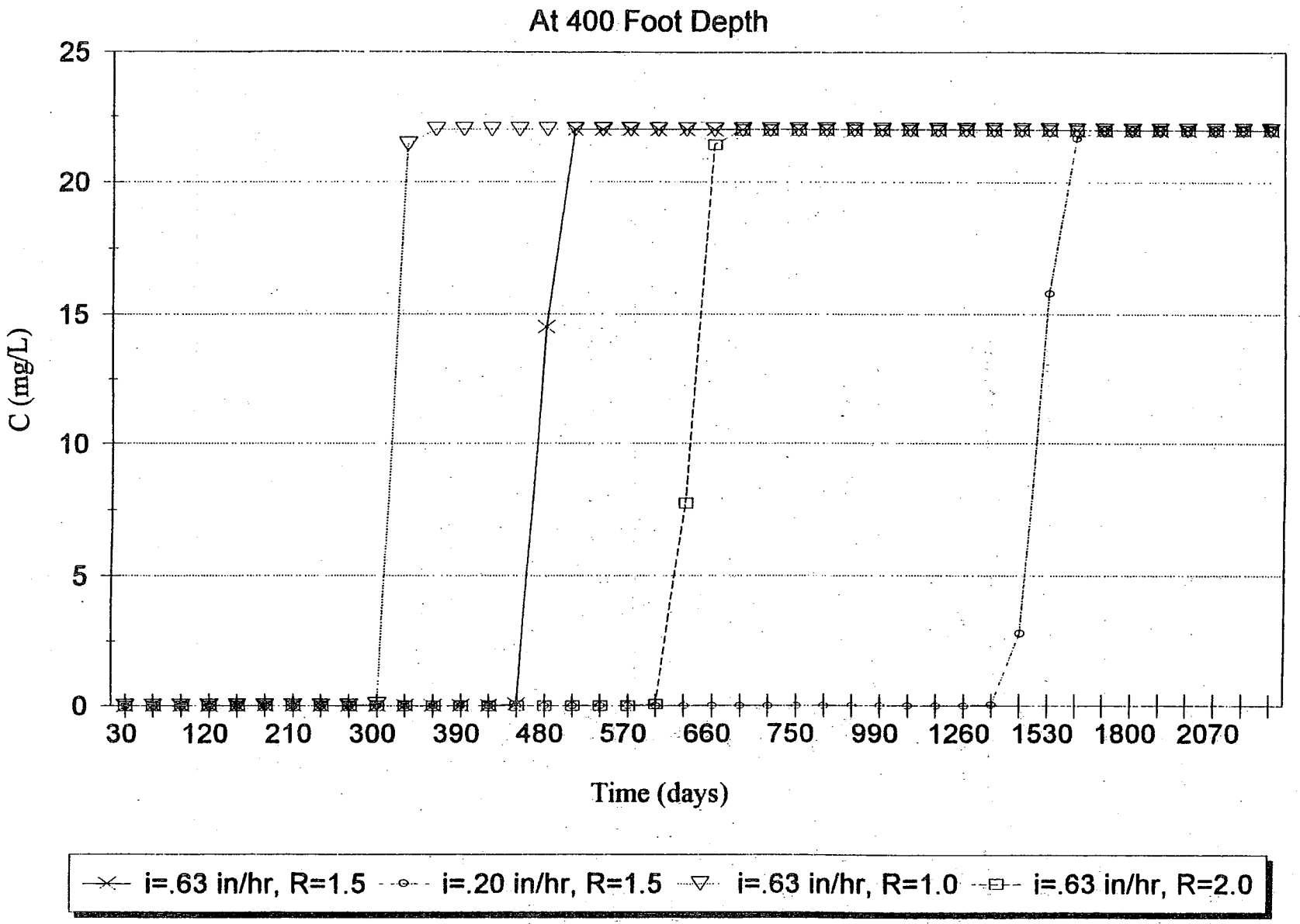

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FIGURE 5-2
NITRATE CONCENTRATION VS TIME FOR VARIOUS INPUT PARAMETERS (i AND R)

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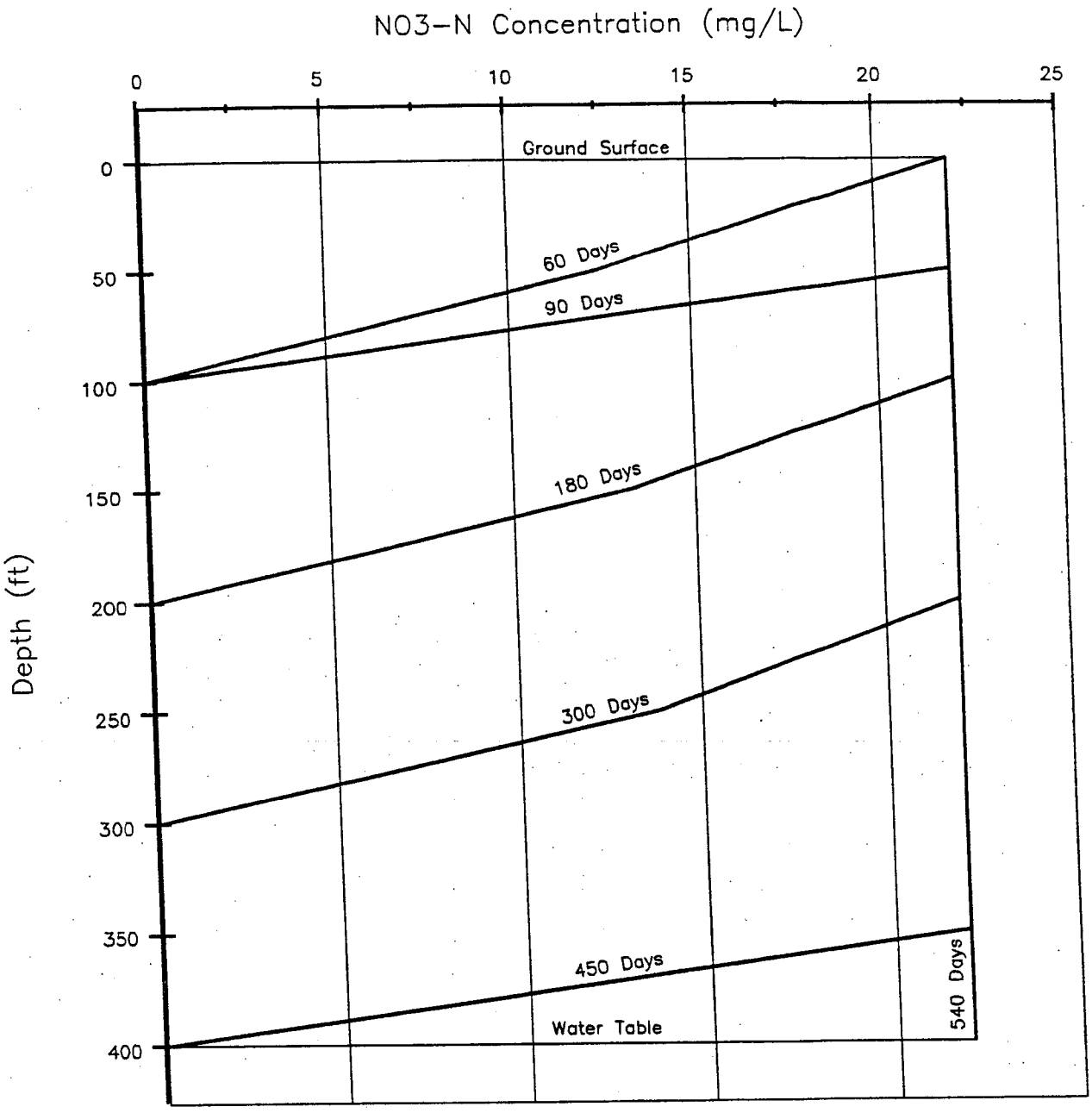

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FIGURE 5-3
NITRATE CONCENTRATION VS DEPTH
(i=1.26 FT/DAY, R=1.5)

» Assumption of retardation and dispersion as the mechanisms of variation of the contaminant transport from pure convective flow will always result in a steady-state concentration at the loading concentration. Varying the values for these parameters will increase or decrease the time required to reach steady-state, but will not change the steady-state concentration. This is because no contaminant mass is removed from the system and all of the influent water has the same concentration of contaminant (i.e., there is no "clean" water to dilute the contaminant mass). As discussed above, it is likely that the primary mechanism affecting nitrate fate and transport would be transformation of the nitrate to other nitrogen compounds or nitrogen gas. This would remove most of the nitrate from the system and result in steady-state nitrate concentrations lower than the loading concentration.

» Concentrations of nitrate in the native groundwater at the site are not known. Comparison to the groundwater nitrate concentrations at other sites at Fort Huachuca indicate that nitrate concentrations may be in the range of 1-3 mg/L. Knowledge of the background nitrate concentrations at the site are necessary to evaluate the potential impact of nitrate loading at potential points of compliance, since mixing of recharge water and native groundwater is likely to occur.

» Locations of points of compliance should be determined after acquisition of site-specific data. This will allow better determination of the hydrologic effects of the proposed facility (i.e., horizontal and vertical extent of groundwater mounding). Several downgradient monitoring wells will likely be required to allow sufficient monitoring of groundwater quality at the point(s) of compliance. Since the discharge is not defined as a hazardous substance at ARS 49-201.16, more flexibility is allowed in the location of the points of compliance. Typically points of compliance are proposed at the property boundaries, but, given the large extent of the boundaries of Fort Huachuca, alternate locations may be appropriate to isolate the effects of the recharge facility from the effects of other facilities/sites.

» In general, because of the uncertainty associated with most of the hydrogeological and regulatory (location of points of compliance) parameters, it is not possible to evaluate the level of treatment that would be required to prevent violation of AWQS and/or degradation of existing ambient groundwater quality. However, the assumptions used in the analysis performed were highly conservative. The assumptions included infiltration rates at the high end of the range associated with general soil types in the Sierra Vista/Fort Huachuca area; included minimal dispersivity/diffusion; and discounted layers of decreased permeability in the vadose zone, microbial transformations of nitrate to N_2O/N_2, and mixing with native groundwater upgradient of the points of compliance.

Therefore, the breakthrough times indicated by the analysis are considered to represent a worst case estimate of the time required to note an effect at the point(s) of compliance. The estimates should be refined using site-specific data collected through intrusive studies/laboratory analysis to better represent the actual conditions before a final decision is made on additional treatment requirements/methods.

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5.3 Permitting Requirements

Note: This section describes technical permitting requirements and is not offered as legal advice

Several federal and state statutes and regulations apply to the development of a facility intended to recharge the aquifer with treated effluent. The primary permitting considerations for a recharge facility utilizing shallow basins to recharge treated effluent outside the floodplain of "waters of the United States" are the Aquifer Protection Permit (APP) issued by the Arizona Department of Environmental Quality (ADEQ) and the appropriate type of recharge permit issued by the Arizona Department of Water Resources (ADWR). Other permits/regulatory restrictions may be required depending on site-specific conditions (proximity to "waters of the United States", presence of endangered species/archaeological sites, etc.). These permitting issues are discussed in the following sections.

5.3.1 ADEQ APP

The APP requirements for recharge projects are based on the source water used. Certain source waters are exempt from APP requirements, including CAP water. However, the use of treated effluent as the source of recharge water will trigger the APP requirement. The general process for obtaining an APP is illustrated on Figure 5-4. The requirements of the APP include preparation of a hydrogeologic study to define surface and subsurface geology and hydrology, assess the impact area of the discharge, and develop a monitoring plan.

In general, the applicant is required to make two demonstrations in order to obtain an APP:

» The facility will be so designed, constructed, and operated so as to ensure the greatest degree of discharge reduction achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives" (ARS 49-243.B).

» The discharge will not cause or contribute to a violation of an aquifer water quality standard (AWQS) at the designated point of compliance or will not further degrade an aquifer that already exceeds AWQS.

For recharge projects, the first requirement, commonly referred to as "BADCT" (Best Available Demonstrated Control Technology) is waived, so the applicant must only demonstrate that the facility/project will be designed, constructed, and operated such that it will not cause or contribute to a violation of AWQS (ADEQ, 1991).

The initial steps in the APP process, the pre-application meeting and application proposal, are optional, but are recommended to obtain agency guidance regarding the format, appropriateness, and content of the proposed application as well as guidance on the scope of the hydrogeologic study. These elements add approximately one month to the APP schedule for agency review time. Assuming best conditions (i.e., the application is not returned as incomplete/inaccurate and no public hearing is required), the APP process would require approximately 9 months. Six months or more could be added to the schedule if the application is returned and/or a public hearing required. The times listed above do not include preparation or review time by the applicant.

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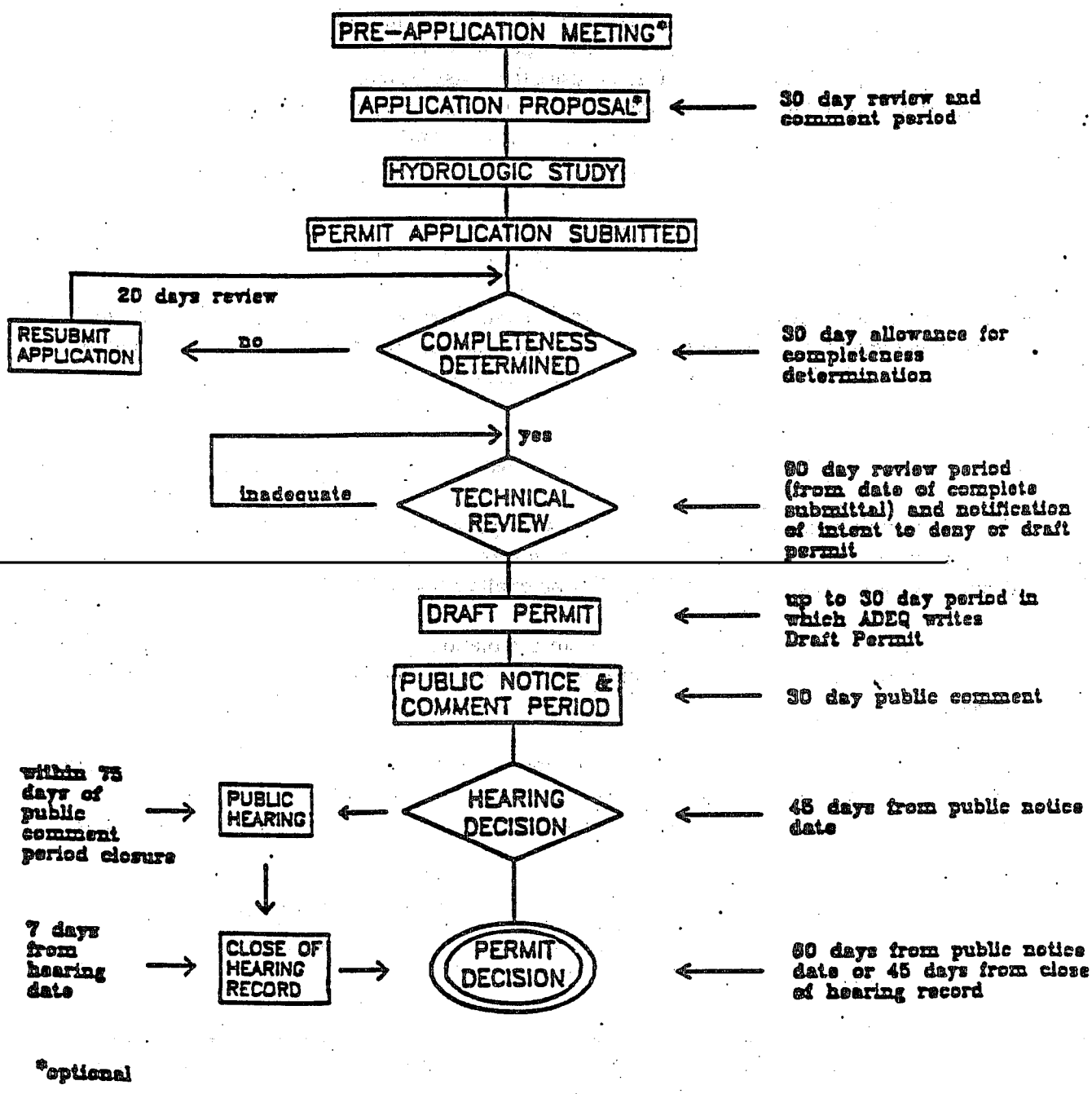

Note: Source ADEQ, 1991

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FIGURE 5-4
ADEQ AQUIFER PROTECTION

5.3.2 ADWR Recharge Permit

In addition to the APP permit issued by ADEQ, a recharge permit will be required from ADWR. There are several types of recharge permits that may be issued, depending on the proposed operation with respect to water budget accounting and the legal constraints imposed by the location of the facility. Specific types of recharge permits include Underground Water Storage and Recovery (US&R) Permits (ARS §45-801 et seq.), Parks/Instream Storage and Recovery Permits (amendment to US&R statutes), Annual Storage and Recovery (AS&R) Permits (ARS §45-881 et seq.), Artificial Groundwater Recharge Permits (ARS §45-651 et seq.), Aquifer Replenishment Projects (ARS §45-671 et seq.), Indirect Groundwater Storage and Recovery Permits (ARS §45-851 et seq.), and State Demonstration Projects for CAP Water Permit (ARS §45-831 et seq.) (SAWARA, 1993). The Parks/Instream Storage & Recovery Permit requires the project to provide an added value to a national park or monument and is, therefore, not appropriate. The State Demonstration Projects for CAP Water Permit requires the use of CAP water and the involvement of the Central Arizona Water Conservation District (CAWCD) and is, therefore, also not appropriate.

Fort Huachuca is located in the San Pedro River basin. This basin has not been designated as an Active Management Area (AMA) by the Arizona Department of Water Resources. Thus, groundwater production and the generation of groundwater recharge credits are not regulated (ASL, 1995). Therefore, the recharge permits containing storage and recovery provisions (US&R, Parks/Instream Storage & Recovery, AS&R, and Indirect US&R) are probably not appropriate. The Aquifer Replenishment Projects Permit requires the formation of a replenishment district, and is therefore probably not appropriate. However, if legal conditions change (such as designation of the San Pedro Basin as an AMA or formation of a replenishment district in the area), these permits may become appropriate.

Under present conditions, the Artificial Groundwater Recharge Permit is probably most appropriate to the Fort Huachuca conceptual recharge project. The general procedure for obtaining the recharge permit is illustrated on Figure 5-5. Because of the similarity of permit application requirements, many sections of the APP and recharge permits (including the hydrogeologic study) can be prepared for submission in both permits (CH2M Hill, 1992). The recharge permit application must demonstrate that:

- The applicant is technically and financially capable of constructing and operating the facility
- The applicant has the right to use the proposed water source(s) for recharge purposes
- The project is hydrologically feasible
- The project will not cause unreasonable harm to land or other water users
- The applicant has applied for water quality permits required by ADEQ

The time required for the permit review/issuance is dependent on the simplicity of the hydrologic system. In simple systems, the process may require 4-5 months. At more complicated sites, or sites at which objections are filed during the public review, the process could require an additional year (SAWARA, 1995).

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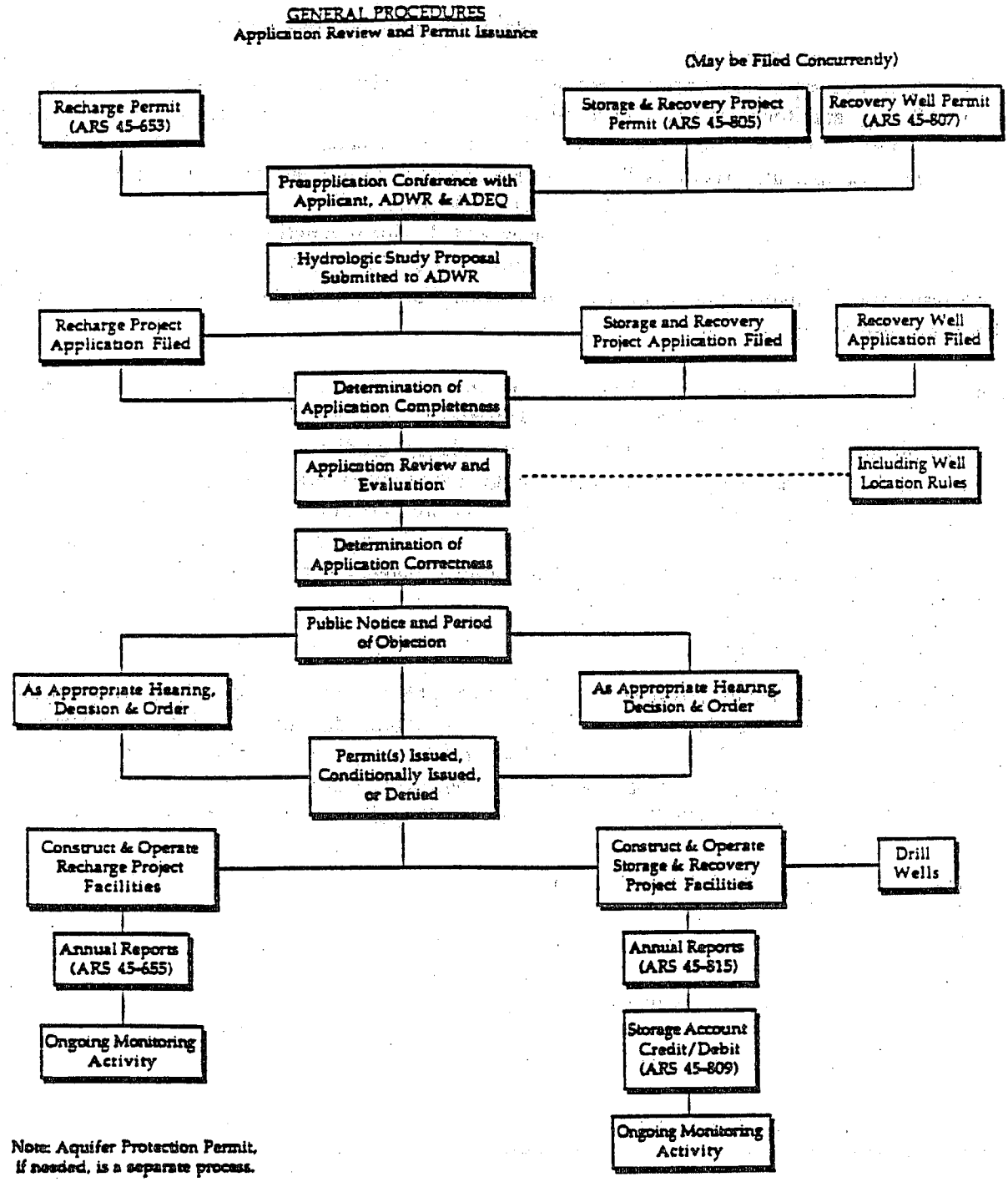

Note: Source CH2M Hill, 1992

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FIGURE 5-5
ADWR RECHARGE PERMIT PROCESS

5.3.3 Other Permits/Regulations

Depending on site-specific conditions, additional permits may be required. The following list indicates some of the permits that may be required or regulations that must be followed as well as some of the site-specific conditions that may trigger them:

» NPDES Permit: An NPDES permit may be required if there is a potential for discharge to "waters of the United States" which include "navigable waters" and their tributaries

» Endangered Species Act (ESA): The requirements of the ESA may apply if the facility may affect endangered/threatened species or critical habitat of an endangered/threatened species

» Section 404 Permit: A section 404 permit may be required if the project involves dredge or fill of a navigable water

» National Historic Preservation Act, Archaeological and Historic Protection Act, and Historic Sites, Buildings, and Antiquities Act: Requirements of one or more of these acts may apply if archeological/historical sites/objects may be affected by the facility

5.4 Conceptual-Level Opinion of Probable Construction Cost

A conceptual-level opinion of probable construction cost for the conceptual recharge facility, exclusive of any additional treatment that may be required, was developed as indicated on Table 5-1. This opinion should be considered an "order-of-magnitude" estimate of the probable construction cost. It can be used in comparison with other alternatives and general planning. However, no design (including preliminary design) activities have been conducted on the conceptual facility and key elements that significantly affect cost have not been determined (i.e., final site location, site-specific hydrogeologic conditions, etc.). Therefore, these probable construction costs should not be used for activities/decision-making requiring a higher degree of detail and/or precision than is included in this report.

The total probable project construction cost for the conceptual recharge facility is $4,841,338. This includes the cost of elements specified in Table 5-1, design fees, overhead & profit, and contingency factors. Annual operation and maintenance costs, estimated at $68,500/yr based on CH2M Hill (1992) result in a net present worth (NPW) of $854,000, assuming a 20-year design life and 5% rate of return.

In addition, "ballpark" opinion of probable cost for feasibility studies, pilot project and permitting are presented in Table 5-1. The probable cost for these studies/permitting is approximate since the scope of these studies is not defined at this time. Tasks that should be considered for inclusion in these studies are discussed in Chapter 6. The probable cost for the pilot project does not include capital elements which are already included in the estimate.

The total opinion of cost of the conceptual recharge facility is $5,695,338.

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Table 5–1
Conceptual Level – Opinion of Probable Cost
Shallow Spreading Basins

System	Item	Unit of Measure	Unit Cost (Dollars)	Quanity	Estimated Cost
Survey	Aerial Mapping	ls	$18,000.00	1	$18,000
	Field Survey	ls	$9,500.00	1	$9,500
Conveyance	Piping	lf	$42.00	5300	$222,600
	Trenching	cy	$3.18	3520	$11,194
	Bedding	cy	$14.00	981	$13,734
	Backfill	cy	$1.20	3520	$4,224
	Road Crossing	ea	$54,000.00	1	$54,000
	Pump Station	ea	$113,400.00	2	$226,800
Operations	Building	ea	$100,000.00	1	$100,000
	Controls	ls	$300,000.00	1	$300,000
	Gravel Access Road	sy	$12.00	5560	$66,720
	Monitor Wells	ea	$15,000.00	3	$45,000
Basins	Berms	cy	$11.24	15750	$177,030
	Clear and Grub	ac	$2,200.00	50	$110,000
	Rough Grading	sy	$1.90	217800	$413,820
	Finish Grading	sy	$0.65	217800	$141,570
Distribution	Piping	lf	$35.00	1280	$44,800
	Trenching	cy	$3.18	450	$1,431
	Bedding	cy	$14.00	200	$2,800
	Backfill	cy	$1.20	450	$540
	Control Valves	ea	$1,650.00	10	$16,500
	Erosion Control	ls	$15,000.00	1	$15,000
Post Tertiary Treatment	Structures	ls	$495,000.00	1	$495,000
	Process equipment	ls	$650,000.00	1	$650,000
	Electrical	ls	$265,000.00	1	$265,000
	Controls	ls	$105,000.00	1	$105,000
Project Construction		Subtotal			$3,510,263
		SIOH (6%)			$210,616
		COE Contingency (5%)			$186,044
		Subtotal Construction Cost			$3,906,922
		Design (6%)			$234,415
		Subtotal Project Construction Cost			$4,141,338
Study / Permitting		Feasibility Study			$300,000
		Pilot Project			$200,000
		Recharge Permit			$45,000
		Aquifer Protection Permit			$155,000
		Subtotal Study / Permits			$700,000
Total Probable Project Construction Cost					$4,841,338
Operation and Maintance		Annual O & M			$68,500
		20 Year P/A Factor			12.4622
		Estimated Net Present Worth O & M Cost			$854,000
Total Probable Construction Cost and Present Worth O & M					$5,695,338

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5.4.1 Alternative Recharge Method

In addition to the opinions of probable cost presented above, a cost comparison was developed for an alternate recharge method. The alternate method selected for this evaluation was the infiltration gallery method. This method was selected because it ranked high on the screening of recharge methods (Chapter 4) and because of its similarity to the shallow spreading basins method with respect to treatment/permitting conditions, since the degree of additional treatment that may be required by the APP/recharge permit is not known at this time. The opinion of cost for the conceptual infiltration gallery system, exclusive of any additional treatment that may be required, is indicated on Table 5-2. The infiltration gallery system does have the advantage of reduced evaporation losses. The shallow spreading basins method may have an evaporation loss of approximately 6% based on assumed rates of infiltration (0.1 in/hr on long-term basis) and net evaporation (52.07 in/yr). However, as shown on Table 5-2, the infiltration galleries method has significantly higher capital and O&M costs.

One major disadvantage of the infiltration galleries method (as well as the injection wells method) is the high cost of replacement that may be required to sustain infiltration rates over decades. Use of recharge water sources such as treated effluent or stormwater lead to decreases in recharge efficiency over time as the gravel bed/well pack and become clogged with biological matter/films and/or inorganic suspended solids. This requires redevelopment and eventual replacement of the gallery/wells. Although a similar effect occurs in basin recharge methods, relatively low-cost maintenance of the basins (i.e., "wet-dry" cycling and periodic disking of basin floors) is able to overcome the reduction in recharge efficiency.

For purposes of this cost estimate, it was assumed that the entire infiltration gallery would need to be replaced once in the design life of the facility. Only the gallery itself was considered to require replacement (i.e., replacement of the conveyance and operations systems was not included in the cost estimate).

The total estimated capital cost for the alternative conceptual recharge facility (infiltration galleries) is $7,666,044. This includes the cost of elements specified in Table 5-2, appurtenant facilities, design fees, overhead & profit, and contingency factors. Annual operation and maintenance costs, estimated at $10,000/yr, result in a net present worth (NPW) of $125,000, assuming a 20-year design life and 5% rate of return. In addition, as described above, the cost of replacing the infiltration gallery after half of the design life of the facility (i.e., 10 years) was included. The estimated NPW of the replacement cost is $2,759,000.

Similarly to the presentation of estimated costs presented in the previous section, "ballpark" estimates of the cost for feasibility studies, pilot projects and permitting are presented in Table 5-2. The estimated cost for the pilot project does not include capital elements which are already included in the estimate.

The total estimated cost for the alternative conceptual recharge facility is $10,550,044.

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Table 5–2
Conceptual Level – Opinion of Probable Cost
Infilteration Galleries

System	Item	Unit of Measure	Unit Cost (Dollars)	Quanity	Estimated Cost
Survey	Aerial Mapping	ls	$12,000.00	1	$12,000
	Field Survey	ls	$8,500.00	1	$8,500
Conveyance	Piping	lf	$42.00	5300	$222,600
	Trenching	cy	$3.18	3520	$11,194
	Bedding	cy	$14.00	981	$13,734
	Backfill	cy	$1.20	3520	$4,224
	Road Crossing	ea	$54,000.00	1	$54,000
	Pump Station	ea	$113,400.00	2	$226,800
Operations	Building	ea	$100,000.00	1	$100,000
	Controls	ls	$300,000.00	1	$300,000
	Gravel Access Road	sy	$12.00	5560	$66,720
	Monitor Wells	ea	$15,000.00	3	$45,000
Infiltration Galleries	Clear and Grub	ac	$2,200.00	25	$55,000
	Perforated Piping	lf	$8.50	48020	$408,170
	Trenching	cy	$3.18	14200	$45,156
	Filter Fabric	sf	$0.75	958320	$718,740
	Gravel	cy	$18.90	106500	$2,012,850
	Control Valves	ea	$1,650.00	6	$9,900
	Native Backfill	cy	$1.20	35500	$42,600
	Distribution Piping	lf	$33.00	980	$32,340
Post Tertiary Treatment	Structures	ls	$495,000.00	1	$495,000
	Process equipment	ls	$650,000.00	1	$650,000
	Electrical	ls	$265,000.00	1	$265,000
	Controls	ls	$105,000.00	1	$105,000
Project Construction		Subtotal			$5,904,528
		SIOH (6%)			$354,272
		COE Contingency (5%)			$312,940
		Subtotal Construction Cost			$6,571,739
		Design (6%)			$394,304
		Subtotal Project Construction Cost			$6,966,044
Study / Permitting		Feasibility Study			$300,000
		Pilot Project			$200,000
		Recharge Permit			$45,000
		Aquifer Protection Permit			$155,000
		Subtotal Study / Permits			$700,000
Total Probable Project Construction Cost					$7,666,044
Operation and Maintance		Annual O & M			$10,000
		20 Year P/A Factor			12.4622
		Estimated Net Present Worth O & M Cost			$125,000
		Replacement Cost (Infil. Galleries)			$4,493,500
		10 Year P/F Factor			0.6139
		Net Present Worth Replacement Cost			$2,759,000
		Total Estimated NPW Replacement and O&M Cost			$2,884,000
Total Probable Construction Cost and Present Worth O & M					$10,550,044

USF200003396

6.0 RECOMMENDED ACTIONS FOR RECHARGE

This chapter outlines the types of investigations, studies, and pilot-scale recharge facility implementation programs that are recommended to address data deficiencies discussed in this report. These investigations will develop the data necessary to make final decisions regarding the feasibility of recharging treated effluent in the areas selected in Chapter 3; prepare required permit applications; design and implement additional treatment trains at the treatment plant (if necessary); design the recharge facility; and develop operational parameters for the recharge facility. If, at any time during the conduct of these investigations, recharge, as configured at that time, is determined not to be feasible, the process should be halted. Recharge as a concept may still be feasible at Fort Huachuca but reconfiguration (i.e., change in selected site, selected method, treatment criteria, etc.) may be needed to result in a practical final facility.

The recommended investigations are divided into three phases. The first involves a feasibility study to select an appropriate recharge site within the area selected in Chapter 4, collect site-specific hydrogeologic information, and refine estimates of the impact of the facility on the groundwater (and associated treatment requirements). The second phase involves construction and operation of a pilot scale recharge facility at the selected site to determine long-term recharge rates, vadose zone travel times of groundwater and contaminants, and treatment capacity of the vadose zone. This phase will also allow determination of appropriate operational parameters (optimal ponding depth, "wet-dry" cycle frequency, basin bottom scarification intervals, etc.). The third phase involves construction and operation of the full-scale facility with all required control, treatment, and contingency provisions. The following sections describe these phases.

6.1 Feasibility Study

The first phase of the additional investigations recommended is the feasibility study. The purpose of this study is to identify the actual final recharge site, collect site-specific hydrogeologic information necessary to identify impediments to recharge at the site, and prepare the hydrogeologic study portions of the APP and recharge permits, refine estimates of the impact of the facility on the groundwater, and identify additional treatment requirements, if necessary. Recommended elements of this study and anticipated products are discussed in the following sections. Scheduling of a pre-application meeting with participation by both ADEQ and ADWR should be considered as early as possible in the Feasibility Study (probably immediately after the site selection). This will allow input from the agencies regarding the scope of the hydrogeologic investigations and will ease the process of obtaining permits for the pilot-scale recharge facility.

6.1.1 Elements of Study

The following elements should be considered in this phase of the additional investigations:

» Final Site Selection: One element of this phase should be the selection of the proposed recharge site location. Site selection should consider sites within the area identified in Chapter 3 as the Primary Potential Recharge Site Zone. This area is defined as the portion of the East Range within one mile of either SR90 or the City of Sierra Vista boundary and south of the alignment of the main runway at Libby Army Airfield. Final site selection should consider topography at a greater level of detail (1-2 foot contour interval mapping, if available), land use considerations, discussions with operational personnel at Libby Army Airfield/Federal Aviation Administration, site reconnaissance information, and discussions with nearby property owners.

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The site location used in preparation of the opinions of probable construction cost in Chapter 5 was along the Fort Huachuca/City of Sierra Vista boundary east of the flowline of Soldiers Trail Wash. This location was used since it appears to be relatively flat based on the 25 foot contours found on the USGS 7.5' topo quad. It is also relatively distant from the Libby Army Airfield runway alignments. Final site selection should consider all areas of the Primary Potential Recharge Site Zone to identify a site that minimizes earthwork, conveyance costs, disruption of Fort activities, and impacts on nearby properties.

» Site Hydrogeologic Data Collection: This element of the Feasibility Study should include various intrusive sampling/investigative methods to collect data on the site hydrogeology. Potential sampling/investigative methods include deep vadose zone borings with ring samples collected, backhoe pit investigations to characterize shallow site lithology, infiltrometer tests, and monitoring well installation to determine ambient groundwater quality.

» Column Testing: Selected ring samples should be used in column testing to identify permeability of the formation at these intervals and estimate the absorption of effluent contaminants by these soils. Influent water for these tests should be the source proposed for recharge - treated effluent. Changes in the chemical composition of the effluent before and after the column testing can be used in determining absorption capacities of site soils.

» Refinement of Contaminant Transport Estimates and Points of Compliance: Based on the data collected for the Feasibility Study, the estimates of contaminant transport through the vadose zone should be refined. These refined estimates should consider site-specific infiltration/percolation rates, retardation estimated from column tests, and estimates of potential biological transformation of the nitrates. Based on this analysis, appropriate points of compliance should be identified.

» Identification of Design Criteria/Parameters: This element of the Feasibility Study should involve identification of the infiltration rates, basin excavation requirements, sizing, etc. needed for design of the pilot scale system.

» Preparation of Permit Applications: Based on the information developed during the Feasibility Study, the applications for the permits (APP and recharge) required for the pilot study should be prepared and the permitting process initiated.

6.1.2 Anticipated Products

The primary product of the Feasibility Study will be a determination of whether or not it is reasonable to proceed with further investigations into recharge at the selected site. The Feasibility Study will also develop permit applications and design criteria/parameters for the next phase of the investigations, the pilot study.

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6.2 Pilot Project

The second phase of the recommended investigations is a pilot project involving a pilot-scale recharge facility. The purpose of this study is to better define the long-term infiltration rates and vadose zone treatment that may be expected at the recharge site. Pilot-scale implementation simplifies the permitting process, since less-detailed information is expected in the hydrogeologic studies, with the expectation that more detailed information collected during the pilot study will be provided in the final, full-scale permit application.

The following sections describe a conceptual layout of the pilot scale facility (as compared to the full-scale facility described in Chapter 5), a potential operational strategy to assist in data collection, requirements for monitoring during the pilot study, and pilot-scale facility permit requirements.

6.2.1 Conceptual Layout

Much of the full-scale facility does not need to be constructed in order to operate the pilot-scale facility. However, where appropriate, the pilot-scale facility should be designed and constructed to allow efficient expansion to the full-scale facility. For purposes of the pilot test, at a minimum the following items of the full-scale facility should be constructed:

» Conveyance System: To simplify eventual expansion to the full-scale system, the transmission main, pump station, etc. should be sized to convey the flowrate projected for the ultimate effluent system. However, it may be possible to design the pump station with a portion of the pumps block-out, to allow for their installation in the future rather than providing the full number of pumps during the construction of the pilot-scale facility. However, at the time of the design, an assessment should be made to determine if the initial cost will be offset by inflation. Additionally, the pump station should be sited to accommodate the potential Post Tertiary Treatment Facility.

» Operations System: The operations building probably would not be required for the pilot study. The gravel access road and monitoring wells will need to be constructed for the pilot test. The road can probably be constructed to a utility level-of-service design, with an aggregate base course, and gravel or chip seal surface.

» Basin System: For purposes of the pilot study, only a portion of the site must be cleared/grubbed and a portion of the basin earthwork constructed. At least two basins should be constructed to allow the pilot study to evaluate "wet-dry" cycling durations and scarification frequencies.

» Distribution System: Only the portions of the distribution system necessary to supply the basins used in the pilot study need to be constructed for the pilot-scale system. In addition, the valves used in the pilot-scale system could be manually-operated with provision to convert to solenoid-operation in the full-scale system.

Many of the appurtenant facilities would also not be required for the pilot-scale system. Figure 6-1 indicates a conceptual layout of the pilot-scale system.

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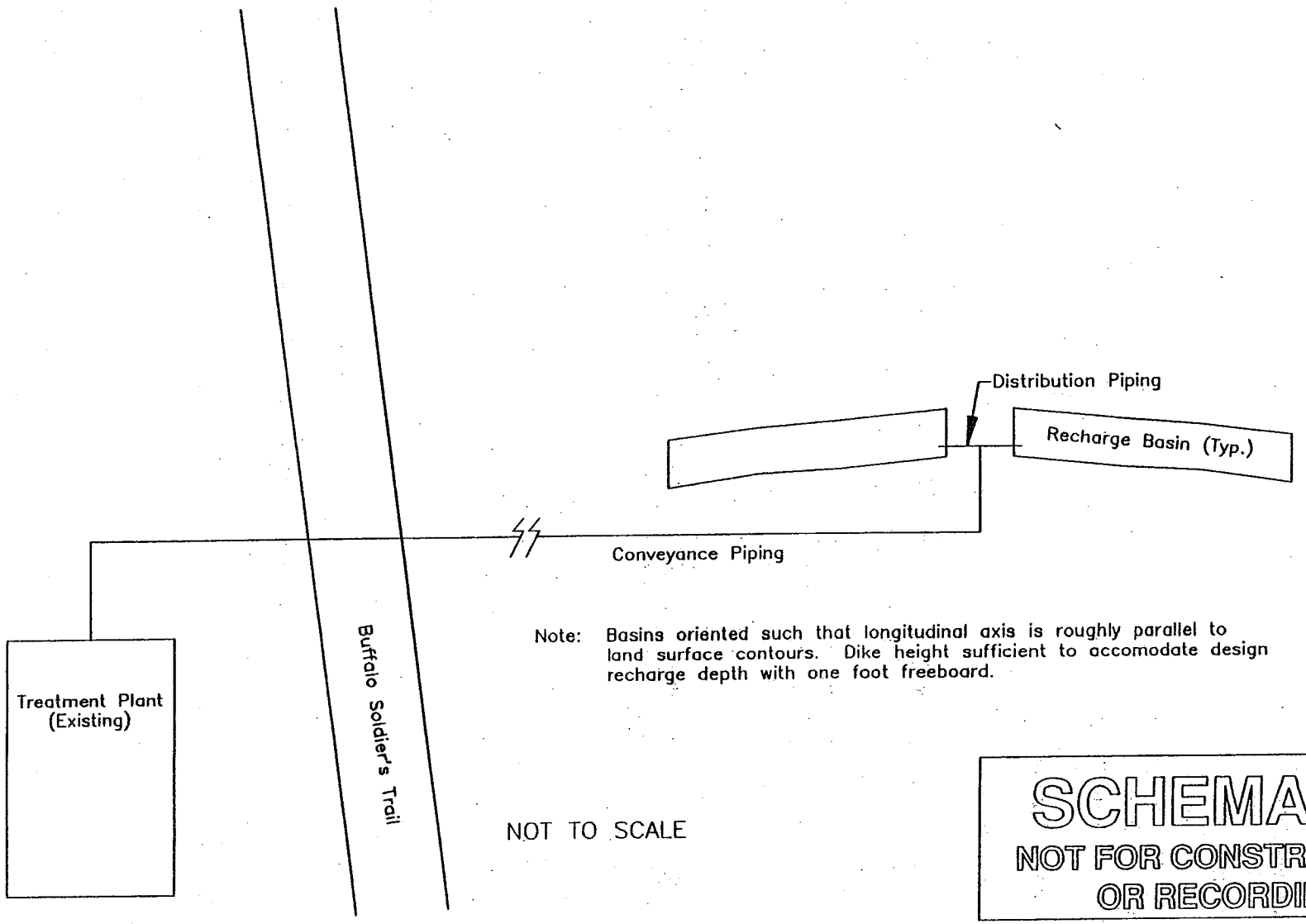

Note: Basins oriented such that longitudinal axis is roughly parallel to land surface contours. Dike height sufficient to accomodate design recharge depth with one foot freeboard.

NOT TO SCALE

SCHEMATIC
NOT FOR CONSTRUCTION OR RECORDING

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FIGURE 6-1
CONCEPTUAL PILOT RECHARGE FACILITY LAYOUT

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6.2.2 Operational Strategy

The operational strategy should be developed to allow collection of data required to determine the feasibility of long-term recharge at the facility location, design the full-scale system, develop operational parameters for the full-scale system, and meet permitting requirements for the full-scale system. In general, the operation of the system should consist of discharges alternating between the two recharge basins. "Wet-dry" cycles should be varied to determine optimal durations of recharge and drying to minimize loss in infiltration rates. Various flowrates and ponding depths can be tried but ponding depths should not exceed 2 feet. Ponding depths greater than 2 feet have been shown to reduce infiltration rates due to compaction of surface sediments or algal growth (CH2M Hill, 1992).

One of the key considerations in the operation of the recharge facility is the rate of development of clogging materials in the basins. Since treated effluent will be used as the recharge water source, clogging materials, especially algal films, may develop more rapidly than if other recharge waters were used. While the drying cycle will tend to break up these materials as they dry, crack, and curl up, periodic scarification of the basin bottoms is necessary to retain high recharge rates. Therefore, the recharge rate should be closely monitored during the conduct of the pilot study and scarification initiated when recharge rates drop significantly from the initial rate. If large quantities of clogging materials build up during basin operation, it may be necessary to remove the top 1"-2" of the basin floor prior to scarification.

Careful notation of basin conditions throughout the "wet-dry" cycle should be made during the pilot study. This may require daily visits to the facility to observe ponding depth, effluent flow rate, development of clogging layer, drying time, breakdown of algal films or other clogging materials during the drying cycle, condition of basin floor and berms, etc. Records of air temperature, wind speed, relative humidity and other weather conditions should be kept, either at the facility or at a nearby weather station. This will allow an estimation of the net evaporation at the facility and calculation of the infiltration rate corrected for evaporation loss. The design should consider utilizing the weather station located at the east end of Libby Field. Initial indications suggest that the data from this weather station would be representative for the recharge site.

6.2.3 Monitoring Requirements

In addition to the daily records described above, periodic monitoring of the recharge facility is necessary to determine the effectiveness of the facility and optimal facility operational parameters and/or meet permit conditions. General categories of required monitoring include:

» Discharge Monitoring: In addition to daily records of the flow to the recharge facility, periodic monitoring of water quality parameters should be conducted. The primary location for collecting these water quality samples should probably remain at the treatment plant; however, occasional samples should also be collected from the recharge basin to note any changes in water quality that occur in the conveyance system or during discharge into the basins.

» Vadose Zone Monitoring: Because of the thick vadose zone at Fort Huachuca, monitoring of the vadose zone will be important, especially in the first year of the pilot study, to monitor the percolation rate. Based on an estimated percolation velocity of 1.26 ft/day (infiltration rate estimated for analysis in Chapter 5) and depth to water of 400 ft, it is estimated that it will take approximately 320 days for the recharge water to reach groundwater. Since the pilot study permit from ADWR is limited to 2 year duration (with no renewals allowed), only vadose zone impacts will be noted during nearly half of the pilot study duration.

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» Groundwater Monitoring: Groundwater monitoring from one or more points downgradient of the facility will be a requirement of the APP for the pilot-scale facility. In addition, monitoring of groundwater levels will be necessary to comply with the recharge permit and to gauge the mounding effects of the recharge facility.

6.2.4 Permitting Requirements

Permitting requirements for the pilot-scale facility are somewhat relaxed compared with those required for the full-scale facility. The following indicates the ADWR and ADEQ permitting requirements for pilot-scale facilities.

» ADWR Recharge Permit: ADWR provides for permitting a pilot-scale facility to discharge 10,000 ac-ft or less over the 2-year duration of the permit (ADWR, 1995a). The hydrogeological requirements for this permit are less than for the full-scale facility permit to allow for data collection during the pilot study (ADWR, 1995b). Since the effluent production from the upgraded treatment plant is 807 MG/yr (2,480 ac-ft/yr), the recharge rate for the pilot study will be within the recharge volume limitations of this permit.

» ADEQ Aquifer Protection Permit (APP): ADEQ regulations contain provision for a general APP for pilot-scale recharge facilities, although this provision excludes facilities using effluent as the recharge water (ADEQ, 1995). The general permit could provide coverage for the Fort Huachuca facility if an alternate source of recharge water were used for the pilot study. However, one of the purposes of the pilot study is to evaluate interactions between the effluent recharged and the vadose zone (i.e., the transformation of effluent as it passes through the vadose zone and vadose zone changes due to effluent interactions that may affect percolation rate). Therefore, an alternate water supply is not appropriate for the pilot study.

However, permitting for an individual APP for a pilot-scale recharge facility using effluent as the source water may be expedited by ADEQ if it is noted that the facility meets all the conditions of the general permit except for the use of effluent as the source water (ADEQ, 1995).

6.3 Full-Scale Implementation

After completion of the pilot project, design and construction of the expansion to the full-scale facility should be initiated (assuming full-scale recharge is deemed feasible). Since permitting of the facility may require approximately 1 year, permit application writing should begin in the second year of the pilot study. Full-scale implementation should involve expansion of the pilot-scale facility by addition of additional basins, distribution piping, and pumps, upgrading of control systems and access roadways, and construction of an operations building. Appurtenant facilities necessary for the smooth functioning of the full scale facility at Fort Huachuca should also be constructed at this time.

Full-scale implementation of the recharge facility should utilize design and operational data developed during previous investigation phases. Monitoring will continue to be required to comply with the requirements of the APP and recharge permits. In addition, detailed records should be kept of the volume of effluent recharged to support negotiations, settlements, conditions, etc. that may be necessary.

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7.0 EXISTING RECLAIMED WATER SYSTEM

7.1 General Description:

The existing reclaimed water distribution system is supplied with tertiary treated effluent from Wastewater Treatment Plant (WWTP) No. 2. The WWTP is currently being upgraded and when the plant is fully functional the quality of the treated effluent will comply with all of the parameters for "open access" reuse of treated wastewater as defined by the State of Arizona (AAC R-18-9-7).

As shown on Figure 7-1, the treated and disinfected (UV disinfection) effluent is pumped to the 1.8 MG lined holding pond at WWTP No. 2 and to the two 0.7 MG lined holding ponds at WWTP No. 1. The current pumping facilities at the WWTP consist of two 750 gpm vertical turbine pumps. The configuration of this pumping facility will allow a third pump to be installed. The pumps are controlled based on the water level in the 1.8 MG pond. All three ponds are lined with a geotextile membrane and have the same high water surface elevation. The ponds are manifolded together with a 16-inch transmission line which was installed to equalize the storage in the ponds. The automation of the pumps downstream of the tertiary treatment works at WWTP are controlled by level controls in the 1.8 MG pond.

In the southwest quadrant of WWTP No. 2 is a vertical can pump, with a rated capacity of 500 gpm and 223 feet total dynamic head (TDH). This pump suctions reclaimed water out of the holding ponds and lifts the flow to a 10,000 gallon surge tank located at Hatfield and Irwin Streets. This pump is the only supply to the upper portion of the existing system. The automatic controls to start and stop this pump are based on the water elevation within the surge tank, have a long history of problems. At the pump discharge, the reclaimed water is chlorinated by a single solution feed gas chlorinator. The chlorine dosage is manually controlled and the operation (start/stop) of the chlorinator is controlled by a solenoid valve.

Continuing along this portion of the system, reclaimed water is suctioned from the surge tank at Hatfield and Irwin by a single centrifugal pump rated at 500 gpm at 200 feet TDH. The pump discharges into the distribution system and supplied the irrigation system at the Outdoor Sports Complex and Chaffee Parade Field. This booster pump has no backup and it's operation is controlled by the irrigation controller. There is no hydropneumatic tank to equalize the flows, thus the pump runs whenever any zone of the irrigation system is running.

Adjacent to WWTP No. 1 is the fourth existing booster pump facility in the existing system. This facility includes three vertical turbine pumps rated for a total production of 1,600 gpm, and equipped with a hydropneumatic tank to equalize the minor flows for drip irrigation zones. The reclaimed water is chlorinated on the discharge side of the booster pumps, utilizing a single solution feed gas chlorinator with no back-up facility similar to the installation at WWTP No. 2.

The discharge from this pumping facility is conveyed to the golf course through a 12-inch main. At the golf course the reclaimed water system feeds the irrigation system, which branches out to supply the various irrigation zones as well as to supply make-up water for the three ponds located on the course.

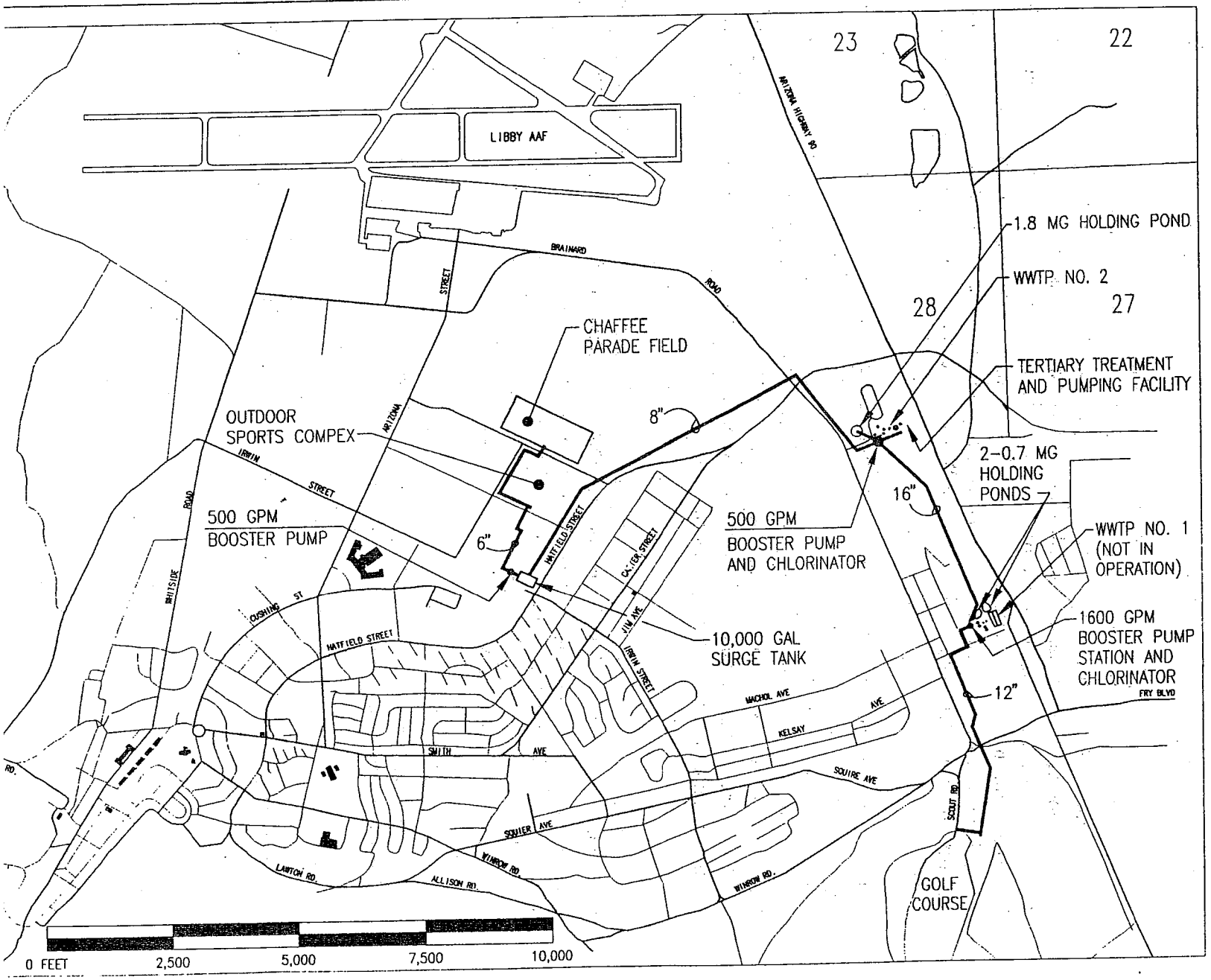

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FIGURE 7-1
EXISTING RECLAIMED WATER SYSTEM

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7.2 Deficiencies With the Existing System:

Based on a review of the existing facilities, discussion with the system operators, applicable codes and regulations, and engineering principles, the following deficiencies were noted:

» Holding ponds are uncovered, allowing for algae growth and increased suspended solids in the water. This arrangement increases the turbidity of the reclaimed water and can lead to clogging of irrigation drip systems. Thus, the three ponds should be covered.

» The 16" transmission line between the holding ponds at WWTP No. 1 and WWTP No. 2 has developed restrictions within the line. With the limited head available for gravity flow equalization, the operators are currently required to close the valve on the line supplying the 1.8 MG pond and utilize the effluent pumps at WWTP No. 2 to force the flow to the ponds at WWTP No. 1. The quality of the piping appears acceptable and thus it is recommended that this line be cleaned.

» Backup chlorinators should be installed at both pump stations to provide an acceptable level of reliability for the system.

» There is no provision to account for low flows at the booster pumping facility adjacent to the surge tank at Hatfield and Irwin Streets.

» The ponds at the golf course should be lined if reclaimed water continues to be supplied to the ponds per ADWR requirements.

» The controls for the booster pump facilities should be upgraded to provide increased reliability and reduce operational costs.

» Several areas rely on a single pump or series of single pumps. Thus, the reliability of portions of the system are marginal.

» The existing flow requirements at Chaffee Parade Field and the Outdoor Sport Complex are only being marginally met with the existing system.

» The 12-inch main line between the pump station at WWTP No. 1 and the golf course is failing. It appears that cost to repair the line would exceed the replacement cost. Thus, this line should be replaced.

The above deficiencies will be considered in the recommendations for the expanded reclaimed water system presented in the following sections.

8.0 EXPANSION OF THE RECLAIMED WATER REUSE SYSTEM

8.1 Design Flow:

As developed in the Master Landscaping and Irrigation Plan, Volume 2 of the study, the total irrigation consumptive use for reclaimed water has been estimated to be 269.4 MG per year. The specific flow usage demands on the system will be dependent on the weather, seasonal variations, and peaking factors. To develop the design flow rates for the system, an irrigation demand water balance was developed using local climatic conditions, consumptive uptake by turf grass, and pan evaporation rates. Based on this water balance, together with the projected cooling tower demands, the following daily demand design parameters were established.

Average Daily	-	0.841 MGD
Peak Month Daily	-	1.661 MGD
Peak Day	-	2.490 MGD

Based on these demand parameters, the flow rates were calculated based on the permissible periods and durations for irrigation which would mitigate the potential for contact by Fort personnel. The specific flow rates varied substantially in that transmission lines could operate the majority of the day, while facilities subject to evening and morning activities were limited to 5 or 6 hours of non-activity. Additionally, the peak day demand will be slightly higher than the average daily flow of the wastewater treatment plant. Thus, to meet this criteria, a minimum of 0.5 MG storage must be available.

8.2 Proposed System Expansion:

In the evaluation of the required expansion of the reclaimed water system, all of the various reuse sites were plotted on a map of the Post, as shown on Figure 8-1. Using this data, various routes and configurations were assessed utilizing the following criteria:

» Compatibility with the existing system.

» The quantity of the demand at the specific site.

» The ability to connect to the site. For example, the utilization of reclaimed water at Brown Field and similar facilities could be readily accomplished by connecting the new system to the existing irrigation system. On the other hand, the utilization of reclaimed water in the housing zone is dependent on the schedule for the functional replacement of the subdivision.

» Avoidance of recently constructed public works, such as the reconstruction of Hatfield Street.

» Locating above ground facilities in areas in which they will not have a negative impact on the surrounding facilities.

Utilizing these parameters, a conceptual layout of the proposed reclaimed water main line expansion of the reclaimed water system is shown on Figure 8-2. From this main line, services will be extended to the various reuse sites.

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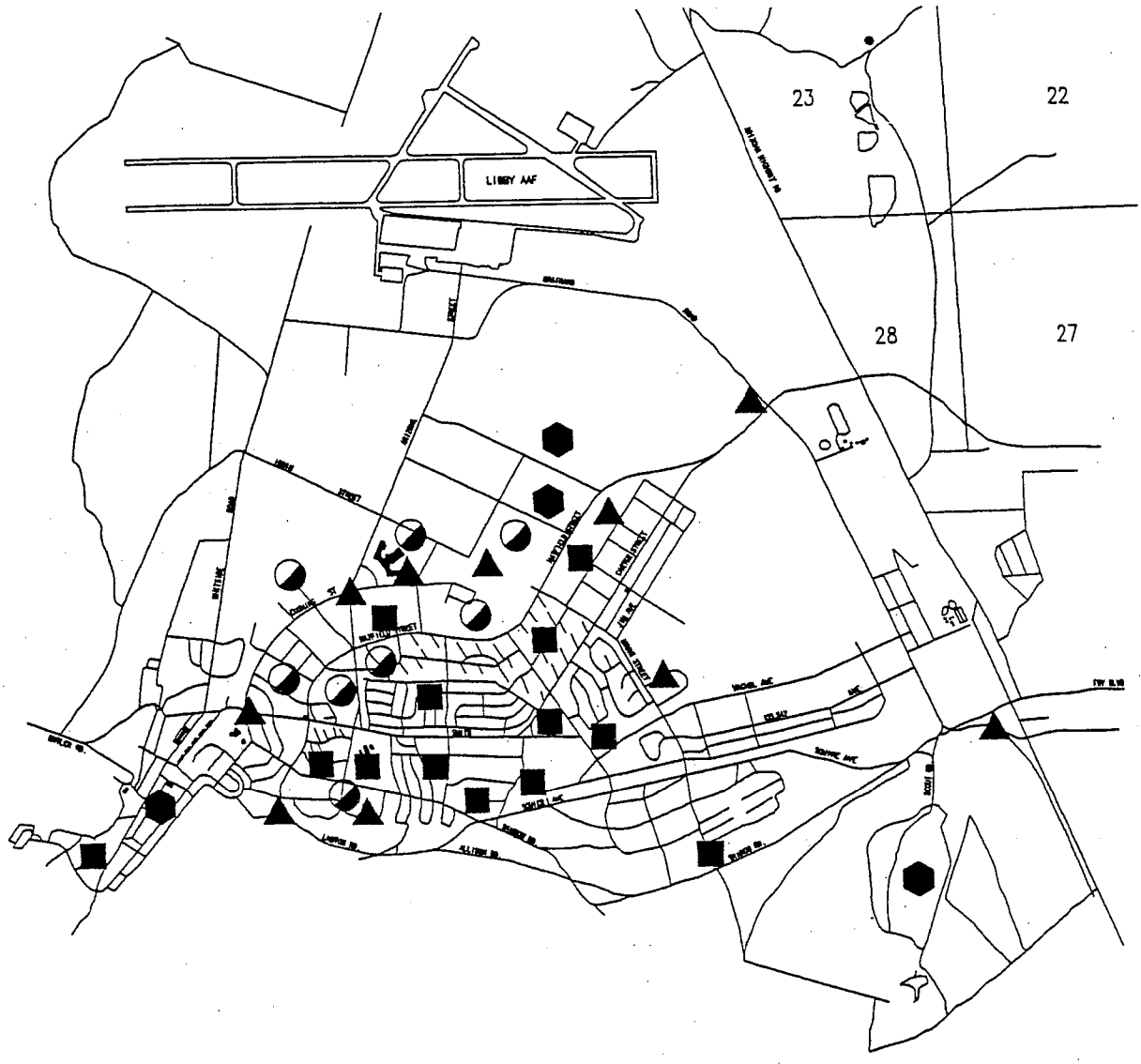

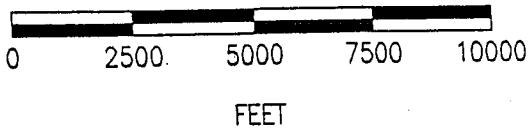

MAJOR TURF AREA (>5 ACRES)

MEDIUM TURF AREA (1-5 ACRES)

DRIP IRRIGATION

COOLING TOWERS

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FIGURE 8-1
RECLAIMED WATER REUSE SITES

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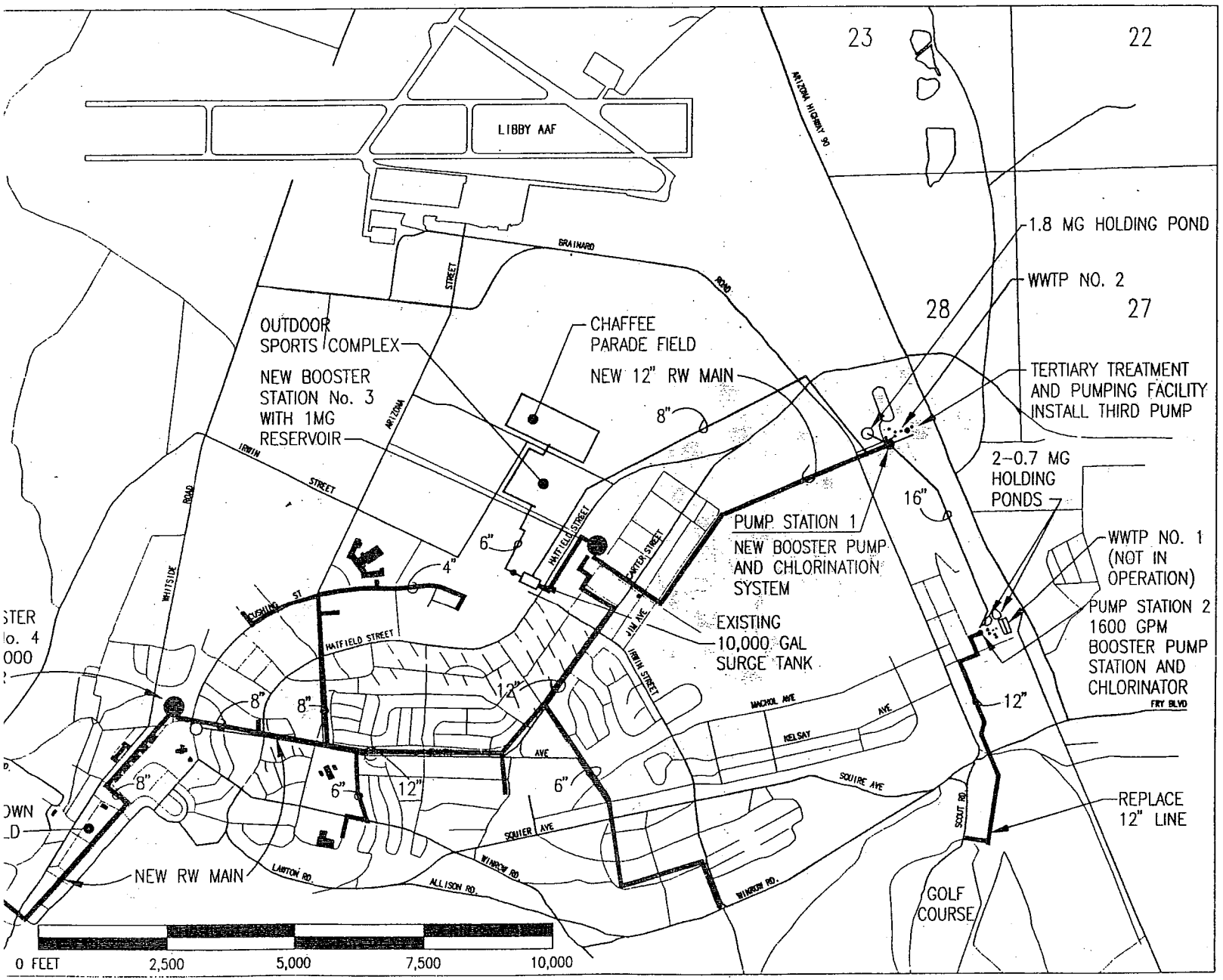

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FIGURE 8-2
RECLAIMED WATER SYSTEM EXPANSION
CONCEPTUAL MAIN LINE LAYOUT

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In assessing the ability of the existing system to support this expansion, the peak daily demand has been estimated to be 2.49 MG per day, thus the existing holding ponds with a combined capacity of 3.10 MG will be sufficient to accommodate 1.2 days of reserve. Additionally, as discussed below, storage will be provided in the system for flow equalization and additional reserve. The demand on the existing system supplying the golf course will remain as existing except for the drip zones around the main gate and the roadway streetscape. These drip zones can be operated during periods of the day when the golf course demands are at a minimum. The two 0.7 MG effluent holding ponds at WWTP No. 1 will be covered, to reduce algae growth and maintain the quality of the effluent. The chlorination system should be upgraded to provide a back-up chlorinator and ensure that the proper chlorine residual is maintained in the system. Based on the age of the pumps, the bowls on the vertical pumps should be replaced, and the discharge manifold modified to include a totalizing and recording meter.

At WWTP No. 2, a third pump will be required at the final treatment works, and new Effluent Pump Station (Station No. 1) will be constructed. As part of this construction, the 1.8 MG effluent holding pond will be covered. The new pump station would be a three pump configuration with two primary pumps and one back-up pump. The pump operation would be sequenced with the demands of the upper portion of the distribution system, as well as the effluent flow rate from the WWTP, to maximize the effective storage of the ponds. The pump station will also include the required meters and a new chlorination system with a back-up chlorinator.

A new 12 inch diameter line will be constructed from Pump Station No. 1 to a new Pump Station No. 3 and associated 1.0 MG welded steel reservoir located near K Street and Lebo Street. The booster pump station (Station No. 3) will supply the new expansion area, Chaffee Parade Field, the Outdoor Sports Complex, and the Old Post Area Storage Reservoir discussed below. The booster pump station will be similar to Station No. 1, with two primary pumps and a back-up pump. The pumps will be controlled by the pressure in the system and the upstream reservoir inflow will be equipped with a back pressure valve to prevent pressure drops in the system. Since the irrigation and cooling tower flow rates will vary, a hydropneumatic tank will be included to equalize pumping cycles. A meter will be installed to allow for operational control, and monitoring of the system.

Near the intersection of Smith Avenue and Christy Avenue, Booster Station No. 4 will be constructed, with an associated 250,000 gallon welded steel storage tank. This station will be a two-pump configuration, with the lead and lag pumps alternating. The station will be equipped with a hydropneumatic tank and the pump operation will be based on the pressure of the distribution system.

The booster pump and storage components of the reclaimed water system will be tied together with a master control system. This system will allow for the efficient monitoring and operation of the system.

The opinion of probable cost for the afore-described improvements has been estimated to be $4,590,163, as noted on Table 8-1.

USF200003409

Table 8–1
Conceptual Level – Opinion of Probable Cost
Expansion of Reclaimed Water System

System	Item	Unit of Measure	Unit Cost (Dollars)	Quanity	Estimated Cost
Survey	Field Survey	ls	$12,500.00	1	$12,500
Storage	Cover 1.8 MG Pond	sf	$3.50	54000	$189,000
	Cover Two .7 MG Ponds	sf	$3.50	58500	$204,750
	1 MG Steel Tank	ea	$505,000.00	1	$505,000
	250,000 Gal. Steel Tank	ea	$120,000.00	1	$120,000
Pumping	Pump at Final Treatment	ea	$13,000.00	1	$13,000
	Booster Station No. 1				
	–Building	sf	$35.00	1900	$66,500
	–Pumps	ea	$18,000.00	3	$54,000
	–Piping	ls	$25,000.00	1	$25,000
	–Electric	ls	$90,000.00	1	$90,000
	–Metering	ea	$8,500.00	1	$8,500
	–Site Improvements	ls	$38,000.00	1	$38,000
	Upgrade Booster Sta. 2				
	–Pumps	ls	$18,500.00	1	$18,500
	–Piping	ls	$5,000.00	1	$5,000
	–Electric	ls	$2,500.00	1	$2,500
	–Metering	ea	$8,500.00	1	$8,500
	Booster Station No. 3				
	–Building	sf	$35.00	1900	$66,500
	–Pumps	ea	$18,000.00	3	$54,000
	–Piping	ls	$45,000.00	1	$45,000
	–Electric	ls	$90,000.00	1	$90,000
	–Hydropnuematic Tank	ea	$16,500.00	1	$16,500
	–Metering	ea	$7,500.00	1	$7,500
	–Site Improvements	ls	$15,000.00	1	$15,000
	Booster Station No. 4				
	–Building	sf	$35.00	500	$17,500
	–Pumps	ea	$11,250.00	2	$22,500
	–Piping	ls	$35,000.00	1	$35,000
	–Electric	ls	$85,000.00	1	$85,000
	–Hydropneumatic Tank	ea	$12,500.00	1	$12,500
	–Metering	ea	$6,500.00	1	$6,500
	–Site Improvements	ls	$15,000.00	1	$15,000
Subtotal This Page					$1.849,250

USF200003410

Table 8–1
Conceptual Level – Opinion of Probable Cost
Expansion of Reclaimed Water System

System	Item	Unit of Measure	Unit Cost (Dollars)	Quanity	Estimated Cost
Conveyance	Repair 16" Manifold Between Ponds	lf	$13.50	4433	$59,846
	Piping – 12"	lf	$38.00	22000	$836,000
	Piping – 8"	lf	$32.00	7000	$224,000
	Piping – 6"	lf	$26.00	12000	$312,000
	Piping – 4"	lf	$18.00	2000	$36,000
	Valves – 12"	ea	$1,105.00	30	$33,150
	Valves – 8"	ea	$975.00	10	$9,750
	Valves – 6"	ea	$695.00	15	$10,425
	Valves – 4"	ea	$575.00	6	$3,450
	Trenching	cy	$2.50	19000	$47,500
	Bedding	cy	$14.00	7000	$98,000
	BackFill	cy	$1.00	19000	$19,000
Cooling Towers	Connections to Existing Cooling Towers	ls	$50,000.00	1	$50,000
Irrigation	Connections to Existing Irrigation Systems	ls	$45,000.00	1	$45,000
Treatment	Upgrade Chlorination–				
	– WWTP No. 1	ea	$28,000.00	1	$28,000
	– WWTP No. 2	ea	$50,000.00	1	$50,000
Controls	Reclaimed Water Sys	node	$15,000.00	6	$90,000
	Master Irrigation Sys.	ls	$75,000.00	1	$75,000
	Connect To Weather Sta.	ls	$5,000.00	1	$5,000
		Subtotal This Page			$2,032,121
		Subtotal First Page			$1,849,250
		Subtotal			$3,881,371
		SIOH (6%)			$232,882
		COE Contingency (5%)			$205,713
		Subtotal Construction Cost			$4,319,965
		Design (6%)			$259,198
		Subtotal Capital Cost			$4,579,163
Permitting		Premit to Construct			$1,000
		Reuse Permit / APP			$10,000
		Subtotal			$11,000
Total Probable Construction Cost					$4,590,163

USF200003411

8.3 Design Guidelines:

The design of the reclaimed water system shall comply with all rules and regulations of the Arizona Department of Environmental Quality (ADEQ). In general, the pumping, storage, and distribution systems should comply with the accepted design parameters utilized for a potable water system of similar flows and pressures. Where the design of reclaimed water systems vary from potable water systems is from a sanitary and identification standpoint. The following design criteria shall be incorporated into the plans and specifications for reclaimed water projects on the Fort. The following guidelines are intended to be minimum standards and shall be modified if site and project specific conditions warrant more stringent requirements.

A. Reclaimed lines shall be treated as sanitary force mains in respect to the horizontal and vertical separation between reclaimed and potable water mains. The horizontal separation between the reclaimed and potable water line shall not be less than 10 feet. Where reclaimed water lines cross potable water lines, the reclaimed water line shall pass a minimum of 2 feet below the potable water main.

B. All pipe lines shall be purple in color, or encased in purple polyethylene encasement per AWWA Standards. The pipe and/or the encasement shall be labeled "Caution Non-Potable Water--Do Not Drink".

C. Valve boxes shall be differentiated from the valve boxes utilized on the potable water system. Figure 8-3 indicates a typical shape and identification for valve boxes.

D. All appurtenances of the system shall be painted purple and labeled.

E. Prior to making the connection to the reuse site, the entire reuse site shall be dye tested to determine if there are any cross connections to the potable water system or building plumbing system. Further, the site should be inspected to ensure that no over-spray from the irrigation system will come in contact with drinking fountains or similar devices. The dye shall be a non-toxic, U.S. FDA approved dye.

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ALL MATERIAL SHALL BE CAST IRON PER ASTM. A-48, CLASS 30 B.

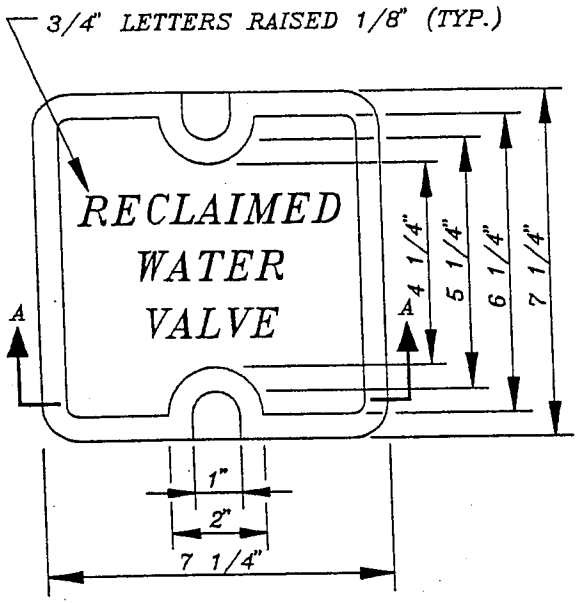
RECLAIMED WATER VALVE BOX SHALL BE PURPLE IN COLOR

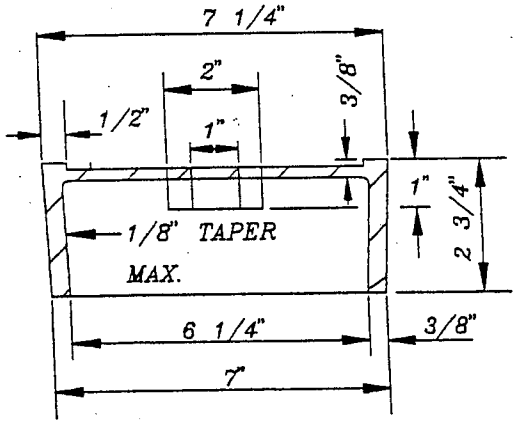
THE SURFACES OF THE COVER AND BOX WHICH COME IN CONTACT WITH EACH OTHER MUST BE SMOOTH AND FREE OF ALL CASTING RIDGES AND BURRS TO PROVIDE A SNUG FIT.

THE VALVE BOX SHALL HAVE A ROUND BOTTOM TO ACCOMMODATE RISER PIPE. THE TOP OF THE VALVE BOX SHALL BE SQUARE.

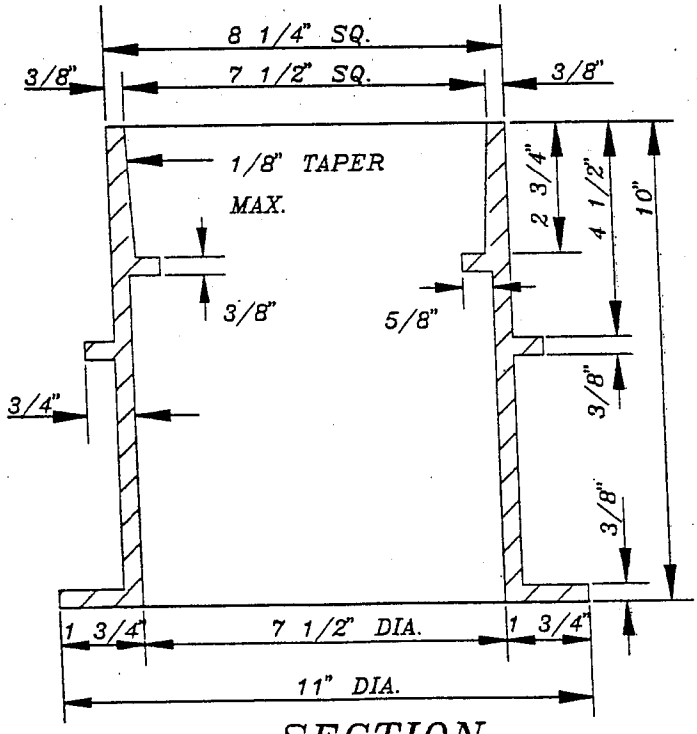
INSIDE OF THE RISER PIPE SHALL BE COLORED PURPLE. COLOR MAY BY INCORPORATED INTO PIPE DURING MANUFACTURE OR PAINTED ONTO PIPE SURFACE. WHEN PAINTED THE PAINT SHALL COAT BOTH THE INTERIOR AND EXTERIOR OF THE PIPE.

LETTERING SHALL BE RESTRICTED TO THAT SHOWN ON THE VALVE BOX COVER.





SECTION A-A
COVER



SECTION
VALVE BOX

GLHN ARCHITECTS & ENGINEERS, INC.
McGANN & ASSOCIATES
AJAY ENVIRONMENTAL CONSULTANTS
SAGUARO ENVIRONMENTAL SERVICES

WATER RESOURCE /REUSE STUDY, FORT HUACHUCA

FIGURE 8-3
TYPICAL VALVE BOX IDENTIFICATION

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F. The reuse sites, storage facilities, and pumping facilities shall be signed in accordance with ADEQ Rules and Regulations.

In addition to the above design and identification guidelines for new construction, the Fort needs to enact criteria to protect cross connections from being constructed on the existing portions of the reclaimed water system. Specifically, in areas where existing reclaimed water lines exist, the Fort shall prohibit contractors from making connections to water lines until the excavated line is visually inspected by the Fort's field personnel. Should the inspector have any questions as to if the line is a domestic or reclaimed water line, the inspector shall instruct the contractor to make the tap, collect a water sample, and analyze the sample to ensure the water in the pipeline is the intended source. Upon this verification, the final connection to the tap can be permitted.

8.4 Permitting Requirements:

The expansion of the reclaimed water system shall be reviewed by the Arizona Department of Environmental Quality (ADEQ) and a "Certificate of Approval to Construct Water and/or Wastewater Facilities" should be issued by ADEQ prior to the start of construction. Upon completion of the construction or construction phase, the close-out documents shall be submitted to ADEQ, along with a request to ADEQ to issue the "Approval of Construction" for the project.

The expansion of the reclaimed water reuse sites will also necessitate the preparation of a revised Reuse Permit Application. Currently, ADEQ is attempting to phase out reuse permits, and incorporate reuse sites under the APP Program. Thus, at the time that the design for this project is commenced, this issue should be reviewed with ADEQ. As indicated in the previous sections, the nitrate levels in the reclaimed water range as high as 22 mg/L. While this is a concern for the recharge components of this study, the irrigation is scheduled to be applied at consumptive use rates and nitrate content of the reclaimed water will be reduced to safe levels (< 10 ppm NO_3-N) by the turf via plant uptake (Kneebone and Pepper, 1982, 1984).

USF200003414

9.0 PHASING OF PROPOSED RECLAIMED WATER EXPANSION

ile it is the intention of the Post to construct the entire reuse and recharge aspects of this study as one ıstruction project, based on available funding sources, the reuse portion of this project may have to phased into projects which have a construction cost in the range of $250,000 to $400,000. In eviewing the cost data presented in Section 8, the following identifies a possible scenario which would attempt to balance this funding requirement with the efficient/productive use of the system.

Project No. 1: This project will include covering the 1.8 MG effluent holding pond at WWTP No. 2 and cleaning the 16-inch manifold between the ponds at WWTP No. 1 and No. 2. The probable cost of this work is $293,583 as shown on Table 9-1.

Project No. 2: This project will include covering the two 0.7 MG effluent holding ponds at WWTP No. 1, and upgrading the chlorination system to provide a back-up chlorinator for Pump Station No. 2, located at WWTP No. 1. The probable construction cost of this work is $274,594, as indicated on Table 9-2.

Project No. 3: This project will include the upgrade of Booster Station No. 2, and the construction of a replacement 12-inch diameter line between the pump station and the golf course. The probable construction cost for this work is $336,379, as indicated on Table 9-3.

Project No. 4: To improve the reliability of the existing system and to facilitate the expansion of the reclaimed water system on the Post, this project would include the construction of Booster Station No. 1 and new chlorination equipment. Initially the discharge from this facility would be transmitted through the existing 8-inch line to the existing surge tank near Hatfield Street. The probable construction cost for this work is $391,787, as indicated on Table 9-4.

Project No. 5: Construct new 1 MG storage tank and Booster Station No. 3 near Hatfield and Lebo Streets. This facility is required prior to extending the reclaimed water system beyond the existing service area. To facilitate it's use, the new facility will be tied into the existing 8-inch supply line from WWTP No. 2, and the discharge will be connected to the existing distribution system towards the east. The probable construction cost for the work is $1,135,715, as indicated on Table 9-5. The cost of this project far exceeds the project cost range discussed above, but to split this facility into various projects would not be economical.

Project Nos. 6, 7, 8, & 9: Will be the first, second, third, and fourth phases of the distribution piping in the new expansion, from Pump Station No. 3 to the Old Post area. The selection of the specific components of each phase can be adjusted to reflect the specific funding available. Generally, the work will progress from Pump Station No. 3 and proceed in a westerly direction. The probable construction cost for this work is $1,129,183, as indicated on Table 9-6.

Project No. 10: This project includes the upgrade of the transmission main from Pump Station No. 1 to Pump Station No. 3. The line will be 12-inches in diameter and will be required at this point to facilitate the expanding usage of reclaimed water on the Post. The probable construction cost is $401,632, as indicated on Table 9-7.

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ject No. 11: This project includes the construction of Pump Station No. 4, the associated 250,000 rage tank, and the distribution piping within the Old Post area. This project will complete the system d the probable construction cost is $627,289, as indicated on Table 9-8.

Due to the cost of some of the components and the efficient use of the facilities after construction, it would appear that constructing this as one overall project would be advantageous.

USF200003416

Table 9–1
Conceptual Level – Opinion of Probable Cost
Expansion of Reclaimed Water System
Project No. 1

System	Item	Unit of Measure	Unit Cost (Dollars)	Quanity	Estimated Cost
Storage	Cover 1.8 MG Pond	sf	$3.50	54000	$189,000
Conveyance	Repair 16" Manifold	lf	$13.50	4433	$59,846
		Subtotal			$248,846
		SIOH (6%)			$14,931
		COE Contingency (5%)			$13,189
		Subtotal Construction Cost			$276,965
		Design (6%)			$16,618
		Subtotal Capital Cost			$293,583
Total Probable Construction Cost					$293,583

Table 9–2
Conceptual Level – Opinion of Probable Cost
Expansion of Reclaimed Water System
Project No. 2

System	Item	Unit of Measure	Unit Cost (Dollars)	Quanity	Estimated Cost
Storage	Cover Two 0.7 MG Pond	sf	$3.50	58500	$204,750
Treatment	Chlorination – WWTP No.1	ea	$28,000.00	1	$28,000
		Subtotal			$232,750
		SIOH (6%)			$13,965
		COE Contingency (5%)			$12,336
		Subtotal Construction Cost			$259,051
		Design (6%)			$15,543
		Subtotal Capital Cost			$274,594
Total Probable Construction Cost					$274,594

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Table 9–3
Conceptual Level – Opinion of Probable Cost
Expansion of Reclaimed Water System
Project No. 3

System	Item	Unit of Measure	Unit Cost (Dollars)	Quanity	Estimated Cost
Pumping	Upgrade Booster Sta. 2				
	–Pumps	ls	$18,500.00	1	$18,500
	–Piping	ls	$5,000.00	1	$5,000
	–Electric	ls	$2,500.00	1	$2,500
	–Metering	ea	$8,500.00	1	$8,500
Conveyance	Piping – 12"	lf	$38.00	5800	$220,400
	Valves – 12"	ea	$1,105.00	7	$7,735
	Trenching	cy	$2.50	2400	$6,000
	Bedding	cy	$14.00	1000	$14,000
	BackFill	cy	$1.00	2400	$2,400
		Subtotal			$285,035
		SIOH (6%)			$17,102
		COE Contingency (5%)			$15,107
		Subtotal Construction Cost			$317,244
		Design (6%)			$19,035
		Subtotal Capital Cost			$336,279
Permitting		Premit to Construct			$100
Total Probable Construction Cost					$336,379

USF200003418

Table 9–4
Conceptual Level – Opinion of Probable Cost
Expansion of Reclaimed Water System
Project No. 4

System	Item	Unit of Measure	Unit Cost (Dollars)	Quanity	Estimated Cost
Pumping	Booster Station No. 1				
	–Building	sf	$35.00	1900	$66,500
	–Pumps	ea	$18,000.00	3	$54,000
	–Piping	ls	$25,000.00	1	$25,000
	–Electric	ls	$90,000.00	1	$90,000
	–Metering	ea	$8,500.00	1	$8,500
	–Site Improvements	ls	$38,000.00	1	$38,000
Treatment	Upgrade Chlorination– – WWTP No. 2	ea	$50,000.00	1	$50,000
		Subtotal			$332,000
		SIOH (6%)			$19,920
		COE Contingency (5%)			$17,596
		Subtotal Construction Cost			$369,516
		Design (6%)			$22,171
		Subtotal Capital Cost			$391,687
Permitting		Premit to Construct			$100
Total Probable Construction Cost					$391,787

USF200003419

Table 9–5
Conceptual Level – Opinion of Probable Cost
Expansion of Reclaimed Water System
Project No. 5

System	Item	Unit of Measure	Unit Cost (Dollars)	Quanity	Estimated Cost
Survey	Field Survey	ls	$1,500.00	1	$1,500
Storage	1 MG Steel Tank	ea	$505,000.00	1	$505,000
Pumping	Booster Station No. 3				
	–Building	sf	$35.00	1900	$66,500
	–Pumps	ea	$18,000.00	3	$54,000
	–Piping	ls	$45,000.00	1	$45,000
	–Electric	ls	$90,000.00	1	$90,000
	–Hydropnuematic Tank	ea	$16,500.00	1	$16,500
	–Metering	ea	$7,500.00	1	$7,500
	–Site Improvements	ls	$15,000.00	1	$15,000
Conveyance	Piping – 12"	lf	$38.00	300	$11,400
	Piping – 8"	lf	$32.00	2000	$64,000
	Piping – 6"	lf	$26.00	100	$2,600
	Piping – 4"	lf	$18.00	100	$1,800
	Valves – 12"	ea	$1,105.00	2	$2,210
	Valves – 8"	ea	$975.00	4	$3,900
	Valves – 6"	ea	$695.00	1	$695
	Valves – 4"	ea	$575.00	1	$575
	Trenching	cy	$2.50	1370	$3,425
	Bedding	cy	$14.00	685	$9,590
	BackFill	cy	$1.00	1370	$1,370
Controls	Reclaimed Water Sys	node	$15,000.00	4	$60,000
		Subtotal			$962,565
		SIOH (6%)			$57,754
		COE Contingency (5%)			$51,016
		Subtotal Construction Cost			$1,071,335
		Design (6%)			$64,280
		Subtotal Capital Cost			$1,135,615
Permitting		Premit to Construct			$100
Total Probable Construction Cost					$1,135,715

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Table 9–6
Conceptual Level – Opinion of Probable Cost
Expansion of Reclaimed Water System
Project Nos. 6, 7, 8, & 9

System	Item	Unit of Measure	Unit Cost (Dollars)	Quanity	Estimated Cost
Survey	Field Survey	ls	$5,500.00	1	$5,500
Pumping	Pump at Final Treatment	ea	$13,000.00	1	$13,000
Conveyance	Piping – 12"	lf	$38.00	8350	$317,300
	Piping – 8"	lf	$32.00	1900	$60,800
	Piping – 6"	lf	$26.00	9900	$257,400
	Piping – 4"	lf	$18.00	1400	$25,200
	Valves – 12"	ea	$1,105.00	12	$13,260
	Valves – 8"	ea	$975.00	2	$1,950
	Valves – 6"	ea	$695.00	11	$7,645
	Valves – 4"	ea	$575.00	1	$575
	Trenching	cy	$2.50	8931	$22,328
	Bedding	cy	$14.00	2809	$39,326
	BackFill	cy	$1.00	8930	$8,930
Cooling Towers	Connections to Existing Cooling Towers	ls	$50,000.00	1	$50,000
Irrigation	Connections to Existing Irrigation Systems	ls	$30,000.00	1	$30,000
Controls	Reclaimed Water Sys	node	$15,000.00	1	$15,000
	Master Irrigation Sys.	ls	$75,000.00	1	$75,000
	Connect To Weather Sta.	ls	$5,000.00	1	$5,000
		Subtotal			$948,214
		SIOH (6%)			$56,893
		COE Contingency (5%)			$50,255
		Subtotal Construction Cost			$1,055,362
		Design (6%)			$63,322
		Subtotal Capital Cost			$1,118,683
Permitting		Premit to Construct			$500
		Reuse Permit / APP			$10,000
		Subtotal			$10,500
Total Probable Construction Cost					$1,129,183

USF200003421

Table 9–7
Conceptual Level – Opinion of Probable Cost
Expansion of Reclaimed Water System
Project No. 10

System	Item	Unit of Measure	Unit Cost (Dollars)	Quanity	Estimated Cost
Survey	Field Survey	ls	$2,500.00	1	$2,500
Conveyance	Piping – 12"	lf	$38.00	7550	$286,900
	Piping – 8"	lf	$32.00	100	$3,200
	Valves – 12"	ea	$1,105.00	9	$9,945
	Trenching	cy	$2.50	4200	$10,500
	Bedding	cy	$14.00	1650	$23,100
	BackFill	cy	$1.00	4200	$4,200
		Subtotal			$340,345
		SIOH (6%)			$20,421
		COE Contingency (5%)			$18,038
		Subtotal Construction Cost			$378,804
		Design (6%)			$22,728
		Subtotal Capital Cost			$401,532
Permitting		Premit to Construct			$100
Total Probable Construction Cost					$401,632

USF200003422

Table 9–8
Conceptual Level – Opinion of Probable Cost
Expansion of Reclaimed Water System
Project No. 11

System	Item	Unit of Measure	Unit Cost (Dollars)	Quanity	Estimated Cost
Survey	Field Survey	ls	$3,000.00	1	$3,000
Storage	250,000 Gal. Steel Tank	ea	$120,000.00	1	$120,000
Pumping	Booster Station No. 4				
	–Building	sf	$35.00	500	$17,500
	–Pumps	ea	$11,250.00	2	$22,500
	–Piping	ls	$35,000.00	1	$35,000
	–Electric	ls	$85,000.00	1	$85,000
	–Hydropneumatic Tank	ea	$12,500.00	1	$12,500
	–Metering	ea	$6,500.00	1	$6,500
	–Site Improvements	ls	$15,000.00	1	$15,000
Conveyance	Piping – 8"	lf	$32.00	3000	$96,000
	Piping – 6"	lf	$26.00	2000	$52,000
	Piping – 4"	lf	$18.00	500	$9,000
	Valves – 8"	ea	$975.00	4	$3,900
	Valves – 6"	ea	$695.00	3	$2,085
	Trenching	cy	$2.50	2100	$5,250
	Bedding	cy	$14.00	1020	$14,280
	BackFill	cy	$1.00	2100	$2,100
Irrigation	Connections to Existing Irrigation Systems	ls	$15,000.00	1	$15,000
Controls	Reclaimed Water Sys	node	$15,000.00	1	$15,000
		Subtotal			$531,615
		SIOH (6%)			$31,897
		COE Contingency (5%)			$28,176
		Subtotal Construction Cost			$591,687
		Design (6%)			$35,501
		Subtotal Capital Cost			$627,189
Permitting		Premit to Construct			$100
Total Probable Construction Cost					$627,289

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