MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT

Preliminary Evaluation of a Multi-purpose Pilot Recharge Facility
for the Arizona Hydrological Society Symposium

BY

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Pima County Flood Control District
Water Resources Division
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ABSTRACT

THE MARANA HIGH PLAINS (DRIFTER) EFFLUENT RECHARGE PROJECT
Preliminary Evaluation of a Multi-purpose Pilot Recharge Facility

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The Marana High Plains Effluent Recharge Project is a two-year constructed pilot project to investigate the feasibility of using treated Santa Cruz River effluent to enhance riparian habitat while recharging the aquifer. The objectives include:

- Evaluating infiltration rates in basins side slopes vegetated with emergent plants and riparian trees, and in basins planted with native grasses tolerant of periodic inundation.
- Re-vegetating the areas outside recharge basins with plants that will improve wildlife habitat value.
- Characterizing wildlife, aquatic macro-invertebrates, and vegetative resources associated with an effluent-dominated stream.
- Identifying and monitoring any biological effects that may result from establishing other habitat types that are now rare to the area and increasing the extent of riparian vegetation.
- Providing trails, descriptive literature and interpretive signs describing the pilot project and supplying linkage to a longer riverine trail.

Infiltration rates ranged from 2.42 feet/day in a basin without vegetated side slopes, to 0.53 feet/day as recharge continued. Sustained infiltration rates were highest in basins with vegetated side slopes at 0.91 feet/day. Modifications correcting the problems and enhancing the facility's recharge capacity may allow up to 750 acre-feet recharge per year. Use of a pre-existing oxbow channel for diverting surface effluent has added 1.2 miles of rich and diverse riparian habitat.

Noticeable environmental benefits were observed as a result of the additional established native and non-native vegetation and wetland environment, including activity by residential songbirds and a number of waterfowl and wading species. Our preliminary conclusions indicate that multi-purpose effluent recharge, riparian enhancement and recreation can be successful and achieve the goals and objectives of these multi-use endeavors.

INTRODUCTION AND BACKGROUND

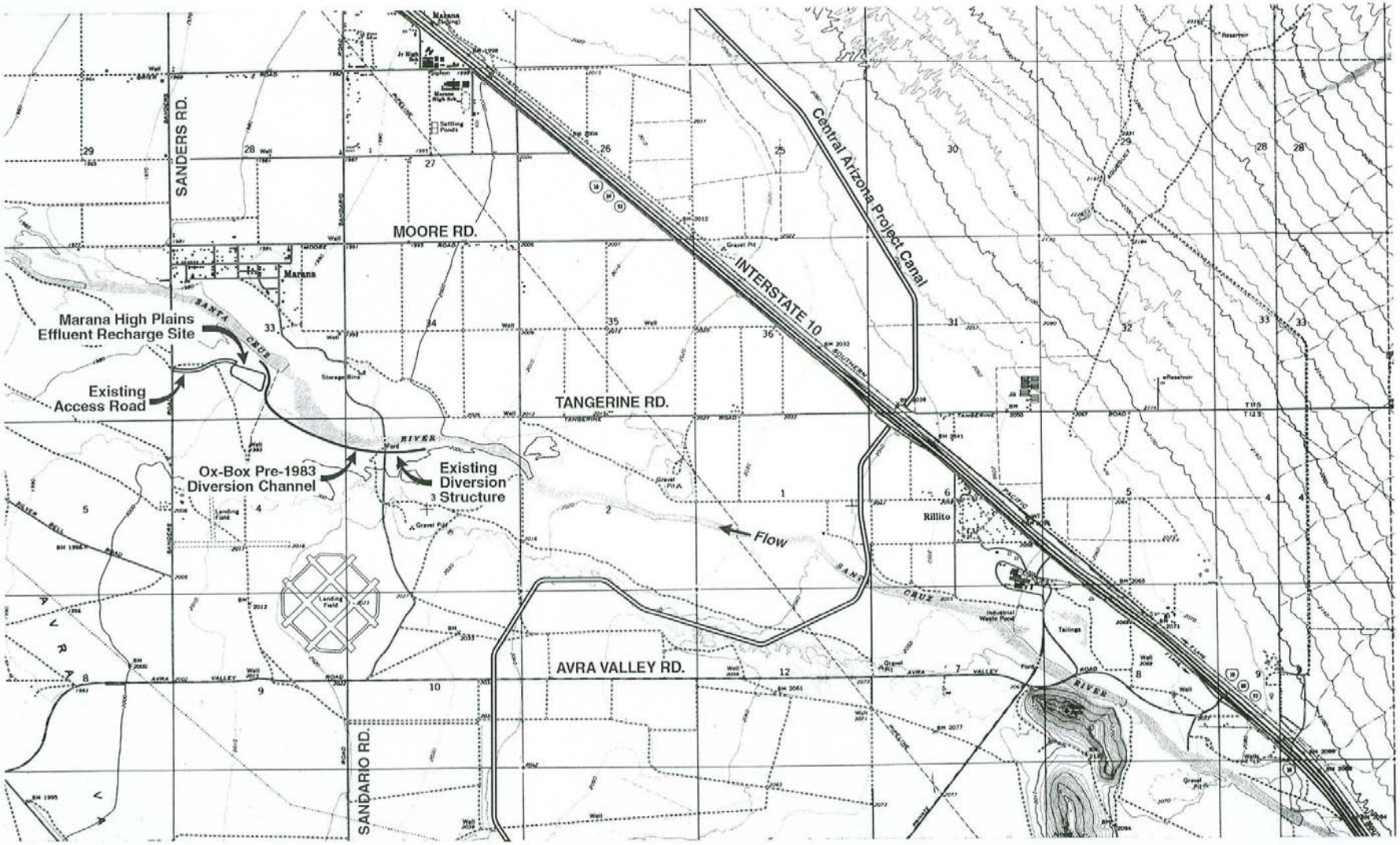
The Marana High Plains Effluent Recharge Project (Project) was established as a two-year pilot project to investigate the feasibility of using treated effluent to enhance riparian habitat while recharging the underlying ground-water aquifer (**Figures 1 and 2**). The Project is permitted by Arizona Department of Water Resources (ADWR) to recharge up to 600 acre-feet per year (af/yr).

The District's primary objective for the Project is to evaluate and research the operational costs and environmental benefits of a multi-purpose recharge facility, including comparisons of recharge of effluent in bare basins and basins re-vegetated with native emergent and riparian vegetation. The replenishment, riparian, vegetation, recreation and other related objectives are:

- Evaluating infiltration rates that can be maintained in basins having side slopes vegetated with emergent plants and riparian trees, and in basins fully vegetated with native grasses tolerant of periodic inundation.
- Re-vegetating the areas outside recharge basins with plants that will improve wildlife habitat value and which, once established, could survive if recharge activities cease
- Characterizing wildlife, aquatic macro-invertebrates, and vegetative resources associated with an important effluent-dominated stream.
- Identifying and monitoring any biological effects that may result from establishing other habitat types that are now rare to the area such as marsh and grassland, and increasing the aerial extent of riparian vegetation.
- Provide trails, descriptive literature and interpretive signs describing the pilot project and potentially supply linkage to a longer riverine trail network along the Santa Cruz River.

The pilot portion of the Project will end on December 31, 2004. The District will need to have in place the necessary arrangements to either shut the operation down or continue the Project. The purpose of this paper is to provide a preliminary look at the multi-purpose aspects of the facility and evaluate the objectives and if they have been met or, if they have not yet been met, and evaluate how much longer the Project would need to be operated to obtain the necessary research data.

Another purpose of this paper is to evaluate whether there are secondary benefits, outside of research, in continuing the Project long-term. Those benefits may include additional environmental riparian restoration, additional recreational and educational opportunities, obtaining storage credits for the District or other entities, thereby providing additional recharge benefits, and increasing wildlife habitat value on a more permanent basis.



SCALE IN FEET:

0 1500 3000 6000

FIGURE 1
Location Map

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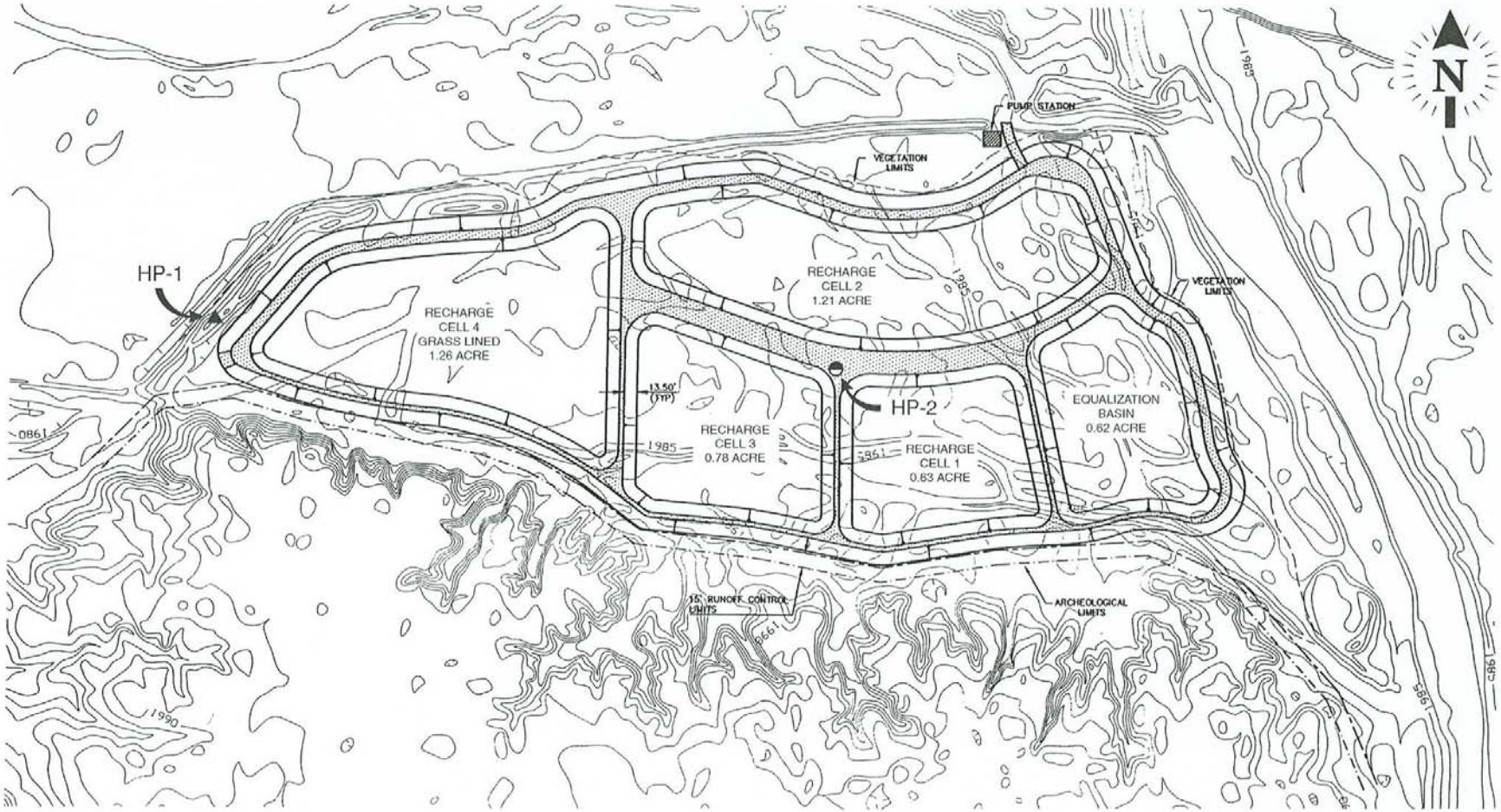

FIGURE 2
Facility Map

SCALE IN FEET:

TOTAL RECHARGE AREA = 3.88 ACRES
ESTIMATED RECHARGE VOLUME = 290 ACRE-FT/YR

LEGEND

▲ MONITOR WELL

PIEZOMETER

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FACILITY OPERATIONS AND MAINTENANCE

Recharge Operations

Water is delivered to the recharge site via an oxbow channel, a remnant channel of the Santa Cruz River from when the riverbed was less incised and the channel meandered back and forth across the floodplain (**Figure 3a**). A berm consisting of streambed materials is used to divert some of the effluent flowing down the main channel of the Santa Cruz River into the oxbow channel. Sources of the effluent discharges are the Roger Road Wastewater Treatment Plant and the Ina Road Wastewater Treatment Plant, which are located approximately 15 miles and 10 miles upstream of the diversion structure respectively. The effluent flows down the oxbow channel for about 1.2 miles before reaching the recharge site, thereby adding a considerable expanse of lush riparian habitat, including willow, cottonwood, and mesquite trees, prior to entering the effluent recharge basins **(Figure 3b).** Water is diverted pursuant to a surface water right with Cortaro Marana irrigation District (CMID).

Figure 3a. Aerial Photograph of Oxbow Basin

Figure 3b. Oxbow channel, March 2004

A constructed wet well (**Figure 4**) collects the oxbow channel flows and two non-clogging, submersible pumps (**Figure 5**) convey the effluent through an 8-inch line into an equalization basin. The equalization basin (**Figure 6**) is used to provide a more constant source of available effluent for recharge, and to help serve as a settling basin for removing particulate materials that could clog the recharge cells. A level sensor is installed in this basin to automatically turn the pumps on and off based on levels within the oxbow channel and the equalization basin. From the equalization basin, the effluent passes through a 16-inch isolation valve into the main distribution line, which feeds into each of the four recharge cells through motorized butterfly valves. A level sensor is installed at each cell to automatically open and close the valves based on pre-set water levels. The daily operator closes the valves manually, using an electronic switch, when the cells are scheduled for a drying cycle.

Deliveries to the Project are based on the daily cycle of discharges from the treatment plants to the Santa Cruz River. Peaks in water levels at this site normally occur in the late morning and early evening hours. Deliveries to the facility are impacted by storm water events in the Santa Cruz River that demolish the earthen diversion structure used to divert flows into the oxbow channel. The diversion structure must be rebuilt in order to resume flows to the Project.

Figure 4. Wet well for the Project, April 2004

Figure 5. Submersible pumps for the Project, April 2004.

Figure 6. Equalization basin, April 2004.

Monitoring

Daily inflows into the project and into each of the individual recharge cells are monitored to determine the number of recharge credits available through the facility's Water Storage and Recovery Well Permits, as well as to comply with the facility's Underground Storage Facility Permit. A flow meter is stationed along the main pipeline running into the equalization basin to monitored the total volume of deliveries into the recharge facility. Flow meters are also stationed at each of the outlet pipes running into the recharge cells to determine the total daily volumes of flow into each cell. Monitoirng flows into each cell is necessary, since the project is designed as a pilot study to measure the effects of different basin configurations on recharge quanitities.

For compliance with the Underground Storage Facility Permit, water levels are measured on a bi-weekly basis at the facility's monitoring well (**Figure 7**) and piezometer well, and on a monthly basis at three off-site wells in the surrounding area. The monitoring is performed for the purpose of assuring no negative impacts due to groundwater mounding at the project site.

Water quality sampling is performed to comply with the facility's Aquifer Protection Permit and to study the cleansing effects of soil and vegetation. Samples are taken along the oxbow channel, near the wet well intake system, and at the monitoring well, HP-1. Samples are analyzed on a monthly basis to study the effects of soil and vegetation on removing nitrogen constituents (NO_2-NO_3 as N, Total Nitrogen, and Total Kjeldhal Nitrogen) from the nitrogen rich effluent water. Total metals and volatile organic compounds are analyzed on a quarterly basis to comply with the State's aquifer quality standards.

Figure 7. Monitoring well for the Project, HP-1.

Due to the close proximity of the Project to the Marana Municipal Airport, PCFCD is required to conduct regular surveys of birds and their activities at the facility. Observations of birds at the Project site are recorded on a weekly basis during recharge operations and kept in PCFCD files. The facility operators follow a bird mitigation plan that was developed for the purposes of monitoring and, if necessary, mitigating for potential bird-strike hazards at both the Project and the Lower Santa Cruz Replenishment Project (Entranco, 1998).

Facility Operational Costs

Operational costs over the 2003 Calendar Year were approximately $28,000. A breakdown of the costs is displayed in **Table 1**. A total of 277.39 acre-feet of effluent have been recharged at the facility since operations began in mid-February 2003. Based on all the costs provided above, the cost per acre-foot for the Project is estimated to be $100 for the first year of operation. The largest part of this cost is related to water quality sampling and reporting of laboratory tests, which total about $12,000.

Electricity usage includes both the operation of the two submersible pumps for recharge and the monitoring well pump for landscape irrigation. The electricity costs per acre-foot of recharge ranged from $1.59 to $2.67.

A fair portion of the monitoring and maintenance costs for the Project is related to minor project design flaws and the lack of experience by the operators. These factors, along with increased storm activity, have also resulted in the low amount of recharge at the facility for the year. Modifications have been made to help correct the problems and enhance the facility's recharge capacity.

Table 1. Project Estimated Operational Costs for 2003

Activity	Cost	Payer
• Equipment repair	$ 1,730	Pima County FCD
• Electric	$ 2,584	Pima County FCD
• Monitoring/maintenance by BKW	$ 2,800	Town of Marana
• Weed control	$ 1,325	Pima County FCD
• Scraping basins	$ 794	Pima County FCD
• Maintenance by staff	$ 3,716	Pima County FCD
• Diversion berm repair	$ 0	Free of charge by Bob Honea
• Monitoring and reporting	$ 8,509	Pima County FCD
• Laboratory testing	$ 3,495	Pima County FCD
• APP annual fee	$ 3,000	Pima County FCD
Total	**$27,953**	

A gravity-fed intake system, using a canal and weir structure, could be more cost effective than the current use of pumps to feed into equalization basin. Based on topography surrounding the facility, however, the oxbow channel would have to be significantly modified to allow effluent to flow freely into the equalization basin. The construction would also disturb a significant amount of riparian vegetation that currently exists along the oxbow channel. The advantage of the pump system is that it is already in place, requiring no more construction costs. The estimated average monthly cost for running the pumps is $120.

SHORT AND LONG TERM OBJECTIVES

Recharge Objectives

The facility operated on consecutive days during the period of February 18, 2003 through July 2, 2003. At that time, Recharge Cells #1, #2 and #3 consisted of bare soil on the basin floors. Recharge cell #4 has a floor of native grasses tolerant of frequent inundation. The slopes of Cells #3 and #4 were vegetated with native riparian plants and trees, including mesquite. The slopes of Cells #1 and #2 were not vegetated. Effluent recharge was conducted using a seven-day wet/dry cycle as demonstrated below in **Table 2**.

Monthly recharge totals for this period are 22.94 acre-feet in February, 83.56 acre-feet in March, 62.58 acre-feet in April, 49.71 acre-feet in May, and 27.14 acre-feet in June. The low monthly total for February was due to the Project only operating during one-half of the month.[1] Recharge Cell #2 was inactive in June due to a malfunctioning flow meter, which accounts for the low amount of recharge for that month. Based on the recharge totals provided above, with consideration of the losses in February and June, the calculated monthly average for the Project is estimated to be 65.28 acre-feet.

1 Recharge operations started on February 18, 2003. The late start of operations for the 2003 Calendar Year was due to mechanical work required to repair the gravity line feed, water was leaking into the valve control box in Recharge Cell 2, and to obtain baseline data for water quality at the facility.

Table 2. Project Wet/Dry Recharge Cycle

Recharge Cell Number	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14
1	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Dry	Dry	Dry	Dry	Dry	Dry	Dry
2	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Dry	Dry	Dry	Dry	Dry	Dry	Dry
3	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Wet	Wet	Wet	Wet	Wet	Wet	Wet
4	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Wet	Wet	Wet	Wet	Wet	Wet	Wet

Infiltration rates for the individual recharge cells during Calendar Year 2003 are provided in **Table 3**. Infiltration rates were estimated using the volumetric method: total inflow divided by the wetted acreage for one wet cycle during each month. During the first quarter of operation, infiltration rates in Recharge Cell 4 were estimated over a period of two wet cycles for each month.

Table 3. Project Infiltration Rates

Date	Infiltration Rate (feet/day)			
	Cell 1	Cell 2	Cell 3	Cell 4
January	NR	NR	NR	NR
February	2.21	NR	1.40	1.29
March	2.42	1.75	1.17	1.13
April	1.66	1.42	1.29	0.88
May	2.06	1.03	0.88	0.87
June	0.56	0.91	0.91	0.53
July	NR	NR	NR	NR
August	NR	NR	NR	NR
September	NR	NR	NR	NR
October	1.07	0.43	1.19	1.18
November	0.57	NR	0.77	NR
December	NR	NR	NR	NR

NR = No Recharge

The decrease in rates over the second quarter is most likely due to a build-up of clogging materials at the bottoms of the recharge cells. However, inexperience by the operators could also be partly responsible for lower rates observed during the second quarter. Experience gained over the last year should help produce more accurate infiltration rate information for the Project.

We believe the recharge facility could be operated for nine months out of the year. This number is primarily based on the occurrence of annual storm-water events along the lower portion of the Santa Cruz River that could wash out the diversion berm and the time it takes to repair the berm each time it is washed out (up to two weeks). Based on a nine-month operation period using the monthly totals provided above, it is estimated that the facility could recharge an average of 588 acre-feet per year using the current wet/dry cycle. Using the highest monthly total to date, 83.56 acre-feet, the facility

has the potential for recharging up to 752 acre-feet per year using the current wet/dry cycle. Since the Equalization Basin level sensor was adjusted in July 2003 to increase the Project's recharge capacity, the projected average and peak recharge totals could now be higher. Higher recharge capacities may be obtained using a different wet/dry cycle or by scheduling constant deliveries into the recharge cells. Recharge Cell # 4 cannot receive constant delivery of effluent since the vegetation in the bottom is not able to withstand flooding over a prolonged period of time.

More data is needed to get an accurate assessment of the Project's effectiveness for recharging effluent through both vegetated and non-vegetated basins. Mechanical failures and wash out of the diversion berm have significantly reduced the amount of effluent deliveries into the facility. Also, a few modifications of the water level sensors in the equalization basin and recharge basins were needed to help increase the facility's recharge capacity.

Another full year's worth of data would be sufficient to meet the research objectives of the Project, although two years would be better. As vegetation matures, conditions may change. Long-term infiltration rates should be derived from a longer term of operation, encompassing all seasons. The question of whether sediment carried into the facility by the diversion will slowly reduce infiltration rates is still unknown. Some previous work by Bouwer at the Flushing Meadows facility suggests vegetation on the basin floor can reduce soil-sealing effects (Bouwer, 2003).

Environmental Objectives

There are noticeable environmental benefits due to the additional vegetation and wetland environment. Staff has observed increased activity by residential songbirds at the Project site. A good number of waterfowl and wading birds have been identified during periods when there is water in the recharge basins. The establishment of native vegetation at the site appears to be a success as shown by the photos in **Figures 8 and 9**. The Environmental Planning Group is in the process of conducting a biological study to help determine the overall benefits of the Project to the surrounding environment. A preliminary summary of their findings is as follows:

> *The presence of a dependable lentic water source at the High Plains Recharge Facility in the form of five recharge basins provides additional habitat for wildlife adjacent to the Santa Cruz River corridor, and augments the low-gradient riparian habitat of the Santa Cruz River channel. The facility was constructed on lands that originally consisted of a combination of agricultural lands, strand, and creosote bush habitats. The facility became operational in February of 2003, and in the brief time since then a variety of vegetation has taken hold in the basins, and is currently dominated by species of saltbush (Atriplex spp.), grasses, and forbs. Planting of mesquite, ash and acacia trees along the perimeter of the basins, which will be supported at maturity primarily by basin water, have augmented the natural influx of vegetation at the site. Emergent vegetation has not appeared in the basins to date, but may soon become established due to introduction of seed by aquatic birds that now utilize the basins. The overall increase in vegetation, along with the permanent lotic water source is attractive to many bird species. For comparison, during the*

Figure 8. Desert willow planted along Recharge Cell 4, April 2004.

Figure 9. Saltbush planted north of Recharge Cell 2, April 2004.

> *survey conducted on the site in 2002 six bird species were recorded in the constructed, but dry recharge basins. In 2004 the number of birds associated with the active recharge basin habitat was 12 species, seven of which are aquatic-associates, including mallard (Anas platyrhynchos), cinnamon teal (Anas cyanoptera), American coot (Fulica americana), black-necked stilt (Himantopus mexicanus), spotted sandpiper (Actitis macularia), and red-winged (Agelaius phoeniceus) and yellow-headed blackbirds (X. xanthocephalus). The increase in vegetation along with the associated lotic waters also attracts a variety of insect species to the site. This in turn provides a food resource for birds, bats, and other vertebrate species. Butterfly species recorded at the site increased from 11 species in 2002 to 23 species in 2004. Increases in bird and butterfly species are at least partially attributable to the presence of the lotic aquatic habitat and associated vegetation.* (Pape, 2004)

The invasion of non-native vegetation has been a problem at the site due to the proximity of established populations in the surrounding areas and along the Santa Cruz River upstream of the Project. The most notable invaders are Bermuda grass, Russian thistle, and tamarisk. Efforts are made to regularly control the weed populations so that they do not spread throughout the entire facility. The cost of this extra effort has been minor.

Environmental benefits of the Project are not just confined to the recharge facility. A ribbon of dense riparian vegetation extends approximately 1 ¼ miles along the oxbow channel from the earthen diversion structure to the Project site, as shown in **Figure 3b**. This vegetation is maintained by a relatively stable influx of surface water that is diverted into the channel for the recharge project. The vegetation along this channel is protected from a majority of the large, erosive flows that tend to wash out vegetation along the main channel of the Santa Cruz River in this area.[2]

The Long-term Future of Recharge at High Plains

Once the District has obtained the research information needed to achieve the Project's goals, the Project could be continued by several mechanisms. First, Marana and other parties without District involvement could expand the Project to recharge larger amounts of effluent dominated Santa Cruz River water as a constructed effluent recharge facility. Marana and CMID could certainly benefit from acquiring 100% of the credits from all water that is recharged at the site. However, this site is different from many other sites in that there is a "cut" to the riparian trees (portion of water as evapotranspiration used by the trees), grasses and shrubs planted in and adjacent to the recharge basins (3% calculated in 2003). The environmental, recreational and social benefits may outweigh the water consumptively lost to the riparian flora.

Several examples do show that multi-use recharge facilities can be and are highly successful. The Town of Gilbert, Arizona has combined effluent recharge with riparian habitat, education, tourism and recreational interests at The Water Ranch (**Figures 10 and 11**). The Water Ranch is on 110 acres and consists of seven recharge ponds and a small lake. The seven recharge ponds take tertiary

2 The earthen berm that is used to divert effluent flows into the oxbow channel will wash out during moderate runoff events, thus allowing the flood flows to continue down the main channel of the Santa Cruz River while diverting very little to no flood flows into the oxbow channel.

treated surplus effluent and recharge over 4 million gallons per day (mgd) or 4480 af/yr. The Town of Gilbert has applied for and is now obtaining recharge credits for the constructed recharge facility.

The recreational lake is filled with well water recovered from recharge of effluent, and stocked with a variety of fish for fishing enthusiasts. Riparian species of trees, grasses and shrubs have been planted along the banks of the recharge ponds and in the recreational lake. The ponds are drained occasionally for cyclic cleaning to enhance recharge. However, according to Scott Anderson, Director of the Riparian Institute , which is housed on the site, maintenance is not an issue and is not interfered with at the ponds. Walking paths surround the ponds and riparian vegetation rim the ponds. Educational programs are sponsored and conducted by The Riparian Institute, created as part of the facility to foster and protect unique water environments and their ecological value. A birding observation ramada and exhibits have been constructed. Additional areas have been set aside, including an ethno-botanical garden, and a hands-on educational area for children. With regard to effluent losses from riparian vegetation evapo-transpiration, Mr. Anderson mentioned that approximately 7%-8% is subtracted from the total amount of effluent for recovery credits (Anderson, 2004). This amount, 314-360 af/yr, is insignificant compared to the other educational and recreational benefits the Town of Gilbert derives. In 2001, the facility received over 54,000 visitors.

Pima County's Kino Riparian site is a similar site, but did not incorporate a recharge element (**Figures 12 and 13**). The 125-acre multipurpose facility incorporates flood detention, water harvesting, reuse of treated effluent, wildlife and bird habitat, maintenance of riparian plants, trees and shrubs and recreational elements of bird watching and a running trail. A recharge element was originally considered, but was rejected due to issues with obtaining permits and the intense use of water for irrigation of athletic fields.

Brad DeSpain, Marana Utilities Director, has verbally expressed their desire to expand the recharge capabilities for the Marana High Plains effluent recharge facility and become the operator with Cortaro Marana Irrigation District. Their desire is to begin operation after the District gathers the necessary data to satisfy the requirements of the Arizona Water Protection Fund (AWPF, 1996) and the Bureau of Reclamation (BOR, 1996). He was open to the possibilities of a multi-use facility that can use both elements along with educational and recreation potential (DeSpain, 2004).

Alternatively, the District might wish to consider obtaining storage credits for the purpose of future extraction for irrigation or use at other District or Pima County sites where effluent was not available. The District would be able to store Pima County owned effluent on a longer basis at the Project site with permission from the landowner, the State of Arizona.

Figure 10. Educational sign for the effluent recharge/riparian preserve at the Water Ranch in Gilbert, Arizona.

Figure 11. Effluent recharge basin at the Water Ranch in Gilbert, Arizona.

Figure 12. Tucson (Ajo) Detention Basin, Plan Overview

Figure 13. Tucson (Ajo) Detention Basin

RECOMMENDATIONS

Based on our evaluation of all the information collected, more data is needed to accurately assess and compare the project's effectiveness for recharging effluent through both vegetated and non-vegetated basins. Mechanical failures and wash out of the diversion berm have significantly reduced the amount of effluent deliveries into the facility. Also, a few modifications of the water level sensors in the equalization basin and recharge basins were needed to help increase the facility's recharge capacity. We recommend another full year to two years of data is necessary to meet the research objectives of the project.

Continued discussion with others is recommended regarding this project with the vision of a multi-use riparian recharge facility, regardless of who are the owner and operator. In addition, we foresee benefits from the recharge credits and multiple parties could obtain effluent recharge credits from this facility. Finally, we also recommend further evaluation of other multipurpose recharge sites to gather information and ideas that may potentially be incorporated into the Marana site.

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