# High Plains Effluent Recharge Project: Biological Monitoring, 2002

PIMA COUNTY
DEPARTMENT OF TRANSPORTATION
AND FLOOD CONTROL DISTRICT
October 29, 2002

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# HIGH PLAINS EFFLUENT RECHARGE PROJECT
## BIOLOGICAL STUDIES
## MONITORING REPORT - 2002

# 1 INTRODUCTION

The Pima County Flood Control District (PCFCD) has constructed an aquifer recharge demonstration project on an approximately 18-acre (7.28 ha) site on the Santa Cruz River near Marana, Pima County, Arizona (see Figure 1). The demonstration project will provide floodplain aquifer recharge using treated effluent from the Santa Cruz River. Recharge will be via infiltration from five shallow basins

Prior to construction, a baseline description of the site was prepared by ENTRANCO (1998) under contract to PCFCD. That report included a brief history of the site with regard to human-caused changes in the surface flow, groundwater hydrology and land use of the region. The report also included baseline data collection and a description of the biological characteristics of the site.

The present report is intended to be the first of a long-term series of monitoring reports on the aquifer recharge site. The recharge basins have been constructed, but they are not yet in full operation.

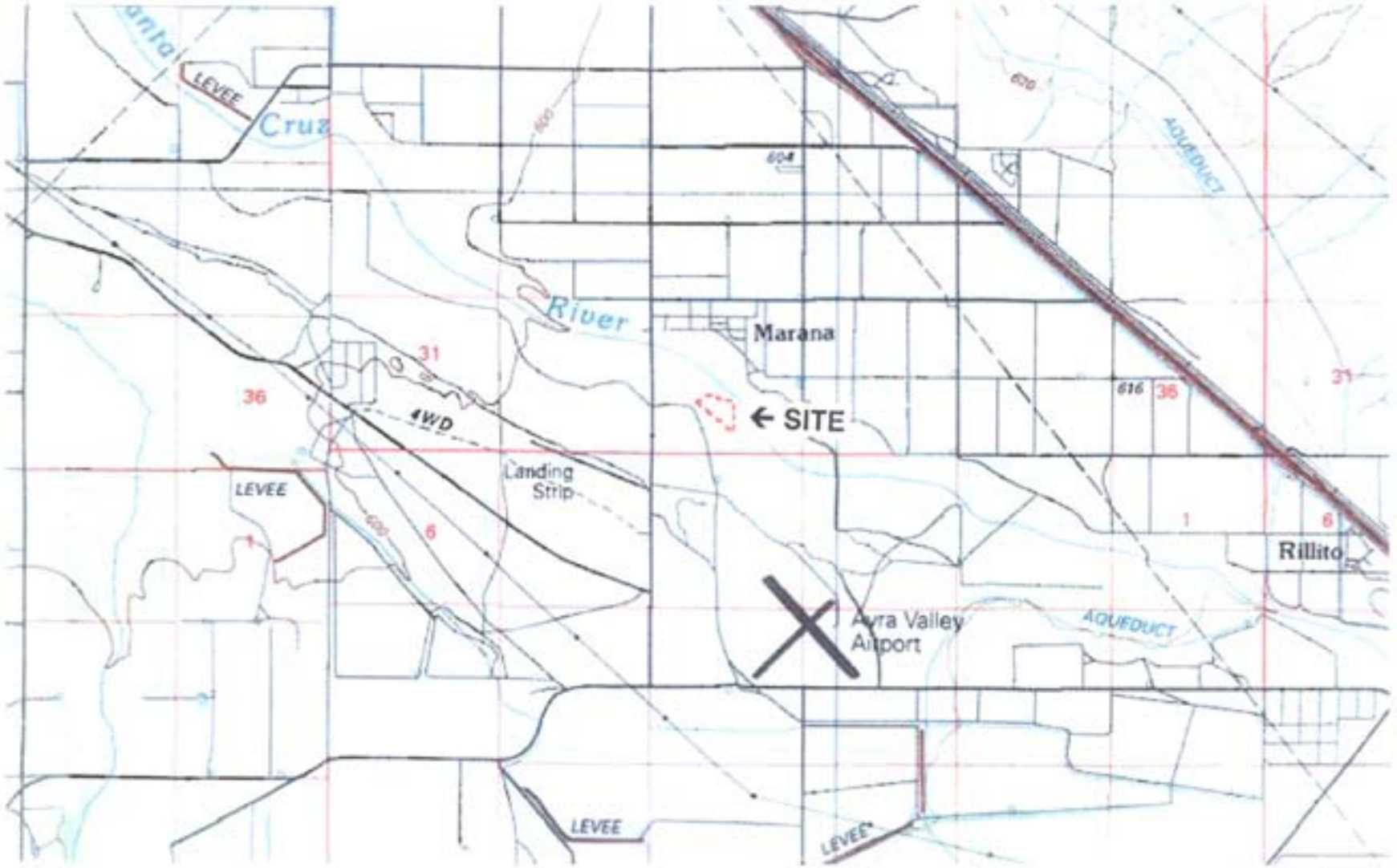
# 2 METHODS

## 2.1 VEGETATION

Vegetation at the High Plains Effluent Recharge Site was quantified using methods similar to those in ENTRANCO (1998). Plant communities were identified on a large-scale aerial photograph of the site, and each community was treated as a separate stratum in the data collection. Plant communities were classified using the Brown, Lowe, Pase (1979) digital community classification system. To randomize sample point location within each community, a grid of points spaced at 6 m was placed on the aerial photograph. Within a community, random points were selected using a random number table. The location of each point was found in the field by reference to identifiable features such as trees, large shrubs, open areas, and channels.

Eight points were selected in each of the three habitats dominated by relatively undisturbed, natural vegetation. The desert broom community previously described by ENTRANCO (1998) was not quantified because of the complete removal of vegetation to create the recharge basins and the surrounding road network.

Each point selected in this random process was used as the center point of a 4 m by 4 m plot, with an area of 16 sq. m. These squares were oriented with the boundaries in north-south and east-west directions. Using a square plot eliminated the need for the additional randomization ENTRANCO (1998) used to locate smaller rectangular plots.

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|---|---|---|
| Environmental Planning Group, Inc.<br>1430 E. Ft. Lowell Road, Suite 304<br>Tucson, Arizona 85719 | Scale: 1 inch = 1 mile<br>Project No. 1215<br>October 28, 2002 | Figure 1. Site Location Map<br>High Plains Effluent Recharge Site<br>Pima County Floodwater District |

For each live perennial plant on a study plot, the following data were recorded:

- maximum height within the plot;
- canopy length and width at one meter intervals above ground level; and
- location of stem inside or outside plot.

For plants under 1 meter in height, the maximum canopy was measured. For most plants the maximum height was below 7 m, and canopy extent was measured at each interval up to that point. One Goodding willow was over 10 m tall, and canopy extent was measured up to that height. Annual plants were not measured, but the percent cover of annual plants was estimated on each plot. Annual plant cover is not a useful measurement for long-term monitoring because of the extreme variability in annual or seasonal rainfall patterns.

For plants that were entirely within the plot, the canopy area was calculated by assuming that the area could be approximated by the area of an ellipse, defined as area = $\pi ab$, where a is half of the larger measurement and b is half of the smaller measurement. Where these measurements are equal, this equation reduces to the area of a circle. When the two measurements differ greatly, the ellipse is a much more accurate representation of the canopy area. For plants with stems outside the plot, but with branches overhanging the plot, the canopy area was approximated by the area of a triangle with a base measured along the plot boundary and a height measured in from the boundary.

Within each plot, the total canopy area was calculated for each species at each height interval by adding the areas for individual plants. The total density of plants was calculated by dividing the total number of stems within the plot by 16 sq. m and multiplying by 10,000 sq. m/ha.

Within each community type, the following values were calculated:

- Species frequency (fraction of total plots with at least one individual of a species;
- Mean height and standard deviation for each species (based on all individuals measured within the community);
- Mean canopy cover area and standard deviation for each species at each height interval;
- Mean percent canopy cover and standard deviation for each species at each height interval;
- Mean density and standard deviation for each plant community.

When possible, these calculated values were compared with values reported by ENTRANCO (1998). For the comparison of two means, the *t*-test is an appropriate

statistical test. Differences can be considered significant when the probability that the means are equal is less than 0.05.

Four documentary photographs were taken at each of the vegetation plots. Two photos were taken from the center of the south boundary looking to the north, and two were taken from the center of the north boundary looking south. Each of these pairs of photos included one photo with a 55-mm lens and one photo with a 35-mm lens. Examples of these photos are given in Appendix E.

Panoramic sets of photographs were taken from the same two points used by ENTRANCO (1998). Stakes indicating these locations were still present on the site. At each point, the camera was mounted on a tripod and series of overlapping photos were taken with 55-mm and 35-mm lenses. These panoramic photos are shown in Appendix E.

A preliminary list of vascular plants on the site was compiled from general observations made during vegetation plot data collection and from incidental observations made during the six site visits. The list is not intended to be comprehensive. The plant list is provided in the Appendix D.

## 2.2 AQUATIC ALGAE

Sampling for aquatic algae was performed on June 19, 2002. Upstream and downstream locations were sampled within the Santa Cruz River Diversion Channel. Two Hester-Dendy samplers were installed at each sampling location for collection of periphyton. The sampling devices were retrieved after a one-week exposure period. Periphyton organisms were removed from three plates representing a total area of 0.0342 square meters. The scraped material was volumetrically diluted with laboratory de-ionized water and aliquots were prepared for microscopic examination using wet and burn mount techniques.

Because the channel was flowing rapidly at the time of sampling, the upstream and downstream phytoplankton grab samples were volumetrically combined in the laboratory to form a single representative composite sample. Aliquots were transferred to Utermohl settling chambers to concentrate cells. Observations were made using a Nikon phase-contrast inverted microscope. Identifications were made using taxonomic keys in Bold and Wynne (1978), Chapman (1964), Collins (1970), Czarnecki and Blinn (1978), Dodd (1987), Irvine and John (1983), LaRivers (1978), Patrick and Reimer (1975), Pickett-Heaps (1975), Prescott (1978), Round, Crawford, and Mann (1990), Smith (1950), and Sze (1986). Aquatic Consulting & Testing, Inc. performed the sampling and analysis for aquatic algae.

## 2.3 AQUATIC INVERTEBRATES

Sampling for aquatic invertebrates was performed on June 19, 2002. Upstream and downstream locations were sampled within the Santa Cruz River Diversion Channel. Macro-invertebrates were surveyed using two separate kick net collections of 30-second

duration at each location. Samples were preserved with alcohol-formalin solution. Initial identifications were made using McCafferty (1998), Thorp and Covisch (1991), and Arnett (1993). Aquatic Consulting & Testing, Inc. performed sampling and analysis for aquatic invertebrates.

## 2.4 BUTTERFLIES AND MOTHS

Butterflies were observed and sampled primarily during two concentrated efforts on May 1st and May 30th, 2002. Efforts were concentrated rather than time constrained in an attempt to document all species present. Knowledge of all species using each habitat is important for the determination of the butterfly riparian quality (BRQ) for each habitat. Each of the three defined habitats was surveyed. Additional information was obtained as incidental data during four other site visits and was included in the determination of the BRQs for each habitat.

Observations and sampling of butterflies were performed in general conformance with the procedure developed by Nelson and Andersen (1994). This method utilizes butterfly species composition and relative species disturbance susceptibility to assign a measure of riparian habitat condition, or index of butterfly riparian quality (BRQ) for a given riparian site. Each butterfly species found is given a weighted value in each of four ecologic categories. The sum of the four values is the disturbance susceptibility score (DSS) for each species. A higher DSS is indicative of greater species sensitivity to ecological disturbance. A mean DSS is then determined from the total of the individual disturbance susceptibility scores for all the species documented. The BRQ is calculated as the product of species richness and the proportion of species having a DSS greater than the mean DSS. Any BRQ value is relative, and it is a significant measure only when compared with other riparian habitats. BRQs were calculated for each of the three plant associations that were identified on the project site. Since the scope of our work did not allow for control studies, the values obtained may be compared with each other and with the values obtained by Nelson and Anderson (1994) for the Bill Williams Delta (BWD) site on the lower Colorado River near Parker, AZ. The BWD site, which was less disturbed and non-channelized, was used as the reference riparian site in their original study.

The four ecologic categories ranked for each species were: species mobility, larval host-plant form, larval food-plant specificity and riparian dependency. The original values assigned by Nelson and Andersen (1994) were based on a maximum weight of 5 representing the "idealized" riparian condition, 3 for values deviating somewhat from the ideal, and 0 for those deviating strongly from the idealized condition. Modifications to the methodology were made only for the values previously assigned for the larval host-plant form category. The original values assigned by Nelson and Anderson for this category were: trees = 5, grass = 3, herbs (forbs) = 2, and shrubs = 1. It was felt that a more appropriate assignment of values for this category would be: trees = 5, shrubs = 3, forbs = 2 and grass = 1. These adjustments to the larval host-plant form values do not greatly affect the calculated disturbance susceptibility scores. These reassigned values were applied to the species listed by Nelson and Andersen (1994), ENTRANCO (1998), and species found at the High Plains Effluent Recharge Project site during this study.

Additionally, the remaining ecological category values assigned each species by Nelson and Andersen (1994) and ENTRANCO (1998) were reviewed and minor adjustments were made to some of the values based on species ecological information obtained from Stewart et al. (2001) and the USGS website on butterflies (2002).

The value of the methodology developed by Nelson and Andersen (1994) is dependent on an accurate assessment of all species of butterflies present in a habitat. For this reason, a concerted effort was made to determine all species that were present in each of the three habitats present on the project site. Susceptibility to disturbance varies in butterflies from species to species, and highly sensitive or species marginal for a habitat may be present in small numbers. Time constrained or cursory observations may not establish the presence of such species and could adversely affect the accuracy of the BRQ obtained. To minimize the chance of non-detection of species present in small numbers, efforts spent observing and sampling butterflies in each of the habitats were not time constrained. Possibly due to this additional effort, four species of butterflies were added to the project list in 2002. A composite list of butterfly species for the site was compiled from the censuses performed by EPG in May and September of 2002, and includes the earlier information from ENTRANCO (1998) (Tables B-2a and B-2b).

Additional sampling for moths was originally performed at the site by ENTRANCO (1998). The purpose of the sampling was to determine if a significant community of moth species was present, whose ecology was known and which could be used for the application of an index of riparian quality similar to the BRQ used for butterflies.

Their efforts turned up a single unidentified species of moth, and their determination was that it was not possible to apply the test method to moths without species variation among habitat types. We elected not to perform sampling of moths for this purpose for several reasons. The establishment of meaningful disturbance susceptibility scores is dependent on knowledge of life histories for all species present in any given habitat. The natural histories of moth species are generally less completely known than those of butterflies. This compromises the accuracy of individual disturbance susceptibility scores developed for such species. The exclusion of species that are present, due to lack of knowledge of their life histories, would adversely affect a riparian quality index that was derived from incomplete information.

A concern was expressed in the methodology section of the ENTRANCO (1998) report that operation of the ultra-violet light for long periods could draw moths from adjacent habitats. This is a valid concern since moths often travel large distances to ultra-violet light sources. Operation of the light source for several brief time periods in an attempt to increase the total sample time would be ineffective since some moth species may take a long time to travel large distances, but would reach the light source by intermittent flight, at some indeterminate time. Additionally, since different species of moths are active at different times of night, short sampling times are inherently ineffective in compiling a reasonably complete list of moth species present in any given habitat.

Because of the lack of an effective sampling methodology, and particularly the lack of general knowledge of the life histories of many species of moths, the application of the disturbance susceptibility test to moths is probably not a useful tool.

## 2.5 REPTILES AND AMPHIBIANS

Transects for reptiles were located in each of the four habitats on the site. Each transect was 50 meters long by 4 meters wide. Transects in the creosote bush association, the mesquite/palo verde community, and the recharge basin had one end at the bird census point for that habitat. In the tamarisk/willow community, the reptile transect was offset from the bird census point because of the proximity of the diversion channel and the density of vegetation. Each transect was surveyed for at least ten minutes on two different days. During these surveys, woody debris and rocks were moved to search for reptiles that could be hiding.

Additional reptile and amphibian observations were recorded during the course of other data collection on the site. Lists of all species observed on the site were kept for each site visit and compiled for an overall species list for the site.

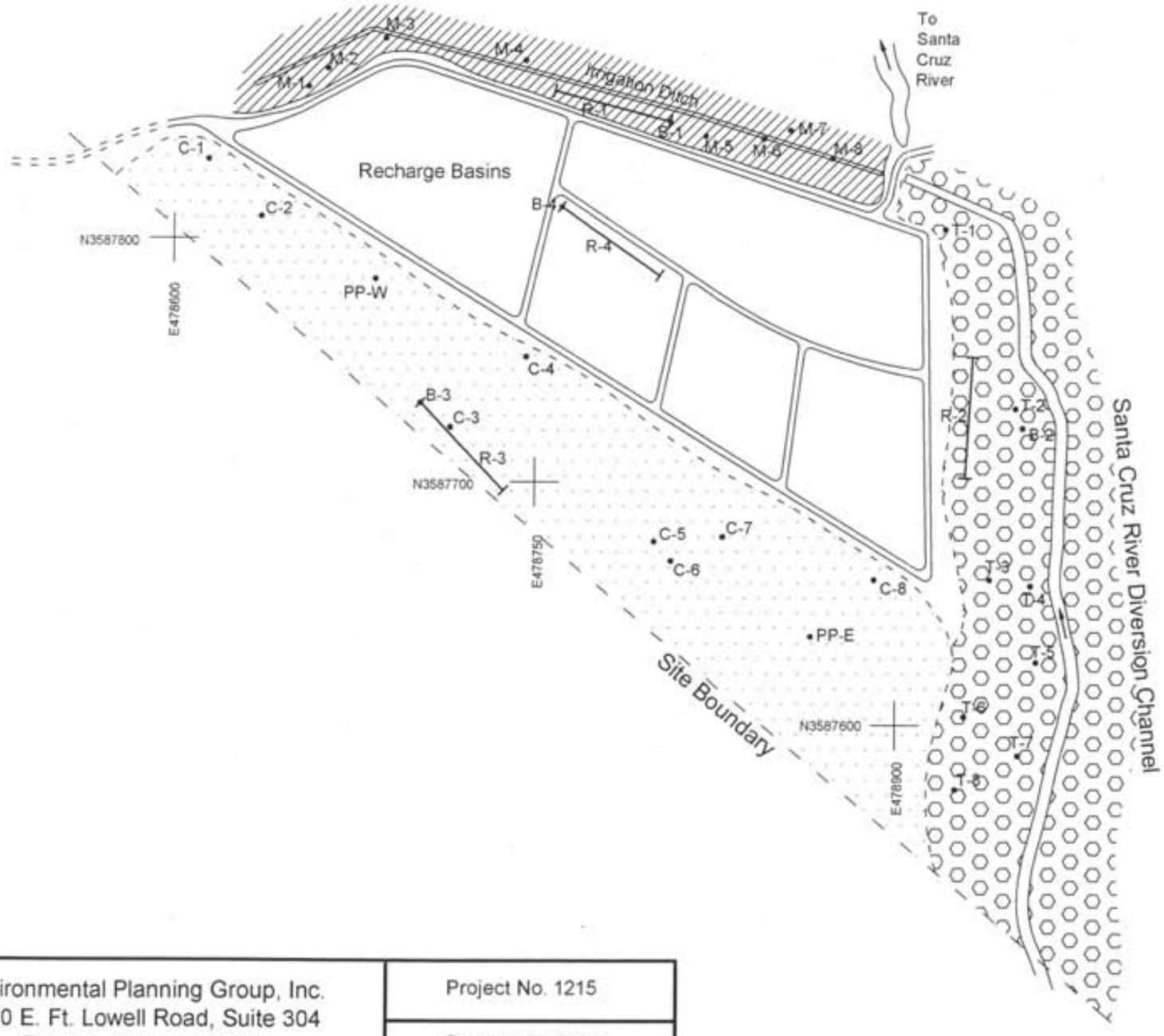
## 2.6 BIRDS

Point counts for birds were conducted using the variable circular-plot method described by Reynolds et al. (1980). Counts were made at four locations on the property, with one point in each of the habitat types (see Figure 2). During each census, all birds observed (seen or heard) were recorded, with an estimated distance from the central point. For each individual, the habitat use was recorded as in the habitat of the central point, in an adjacent habitat, or flying over the site. Each point was censused twice during May, to include the early breeding season and the end of the spring migration. From the combined results, it is possible to estimate the density of species observed within the habitat of the central point.

Other bird observations were recorded during the course of other data collection on the site. Lists of all species observed on the site were kept for each site visit and compiled for an overall species list for the site. Observations included the immediate vicinity of the project site, including the Santa Cruz River Diversion Channel and adjacent pastures and irrigated fields. Any unusual species, behaviors, and evidence of breeding were noted on the incidental observation data sheets.

## 2.7 MAMMALS

No specific mammal surveys were conducted on the site. However, any observations of mammals using the area were recorded on incidental observation data sheets. Observations included direct sightings, tracks, scat, and burrows.





## Legend

**Plant Communities**

- Creosote Bush Association
- Mesquite-Palo Verde Association
- Tamarisk-Willow Association

**Sample Points**

Creosote Bush Association Plots = C
Mesquite-Palo Verde Association Plots = M
Tamarisk-Willow Association Plots = T

Bird Point Counts = B
Reptile Transects = R
Panorama Photo Points = PP

Figure 2. Site Plan Sketch
High Plains Effluent Recharge Site
Pima County Floodwater District

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Project No. 1215

October 28, 2002

# 3 RESULTS AND DISCUSSION

## 3.1 VEGETATION

ENTRANCO (1998) described four vegetation communities on the High Plains Effluent Recharge Project site, using the Brown, Lowe, Pase (1979) classification system. The high ground on the southwestern part of the site was mapped as a creosote bush association (1,154.111 – Sonoran Desertscrub, creosote bush association). The central part of the site was mapped as a desert broom association (1,254.711 – Sonoran Interior Strand, mixed shrub, *Baccharis* sp. association or 1,234.711 – Sonoran Deciduous Swamp and Riparian Scrub, mixed scrub series, *Baccharis* sp. association). The riparian area adjacent to the Santa Cruz River Diversion Channel at the east end of the site was mapped as a desert broom-tamarisk association (1,254.712 – Sonoran Interior Strand, mixed scrub series, *Baccharis-Tamarix* association or 1,234.711 - Sonoran Deciduous Swamp and Riparian Scrub, mixed scrub series, *Baccharis* sp. association). The riparian area adjacent to the irrigation ditch on the north edge of the project site was mapped as a desert broom-mesquite association (1,234.713 – Sonoran Deciduous Swamp and Riparian Scrub, mixed scrub, *Baccharis-Prosopis* association).

There are a number of difficulties with these designations. The central and eastern associations should each have been assigned to a single category rather than suggesting two possibilities for each. Because of the high contrast between these two associations, it is not appropriate to suggest that they could be in the same category. The category 1,234.711 is not a *Baccharis* sp. association, but it is named as a *Prosopis pubescens-Prosopis juliflora torreyana-Pluchea sericea* association by Brown et al. (1979). The categories 1,254.712 and 1,234.713 (listed by ENTRANCO) are not defined by Brown et al. (1979).

Because of these difficulties, and because of modifications to the site since the original study, we have revised the vegetation designations for the High Plains Effluent Recharge Project site. The following plant associations are currently found on the site.

1. Creosote Bush Association. This association is present on the higher ground on the southwest side of the project site and is consistent with the community mapped by ENTRANCO (1998). The land surface is relatively flat, but it is dissected by shallow, eroded gullies. Creosote bush (*Larrea tridentata* [*divaricata*]) is the dominant species, with a few chollas (*Opuntia* sp.) present. This association is in the category 1,154.111 – *Larrea tridentata* (*divaricata*) association (Brown et al. 1979). It is a subcategory of the creosote bush-bursage series of the Lower Colorado River Subdivision of Sonoran Desertscrub.

2. Mesquite-Palo Verde Association. This association is found along the irrigation canal on the north edge of the site. Dominant species include velvet mesquite (*Prosopis velutina*), Mexican palo verde (*Parkinsonia aculeata*), and Mexican elderberry (*Sambucus nigra*). Desert broom (*Baccharis sarothroides*) is a minor component of this association. This association corresponds with the area mapped by ENTRANCO (1998) as a desert broom-mesquite association.

Because this habitat is adjacent to the river channel and subject to infrequent but periodic submersion, it would fit the definition of a strandland (Brown et al. 1979). This association would also fit into the category 1,254.71 – Sonoran Interior Strand, mixed shrub series, but no association has been defined with this set of species (Brown et al. 1979).

3. Tamarisk-Willow Association. This association is present adjacent to the Santa Cruz River Diversion Channel. Dominant species include athel (*Tamarix aphylla*), tamarisk (*Tamarix* sp.), Goodding willow (*Salix gooddingii*), and seep-willow (*Baccharis salicifolia*). Desert broom (*Baccharis sarothroides*) is a minor component of this association. This association was mapped by ENTRANCO (1998) as a desert broom-tamarisk association. Because this habitat is a river channel community subject to infrequent but periodic submersion, it would fit the definition of a strandland (Brown et al. 1979). This association would fit into the category 1,254.71 – Sonoran Interior Strand, mixed shrub series, but no association has been defined with this set of species (Brown et al. 1979).

4. Recharge Basins. The central portion of the site has been highly modified since the ENTRANCO study in 1998. This area has been cleared and graded, and berms have been built to separate it into five separate recharge basins, with pipes and gates to control water flow. This area was mapped as a desert broom association by ENTRANCO (1998), but in May of 2002 it supported no natural vegetation. Native tree and shrub species have been planted around the perimeter of the basins, with a drip irrigation system to get them established. At this time, this area cannot be assigned to any category in the Brown et al. (1979) classification system.

CREOSOTE BUSH ASSOCIATION.

The creosote bush association, which forms the southwest portion of the project site, southwest of the recharge basins, is dominated by creosote with only a handful of cholla (*Opuntia* sp.) scattered within the habitat. Results of vegetation sampling in this habitat are summarized in Appendix A. The habitat is elevated several feet above the remainder of the project site, and may represent an old embankment of the Santa Cruz River. This elevated section is currently being dissected from the northeast at its boundary with the site perimeter roadway. No annual ground cover was present in this habitat during our visits in 2002. The lack of rain over the 2001/2002-winter season precluded the presence of any spring annuals in the few open spaces among the creosote, and there was no response this year from the summer rains, which were of normal quantity. The presence of cattle further reduces the potential for the development of any annual ground cover over time due to trampling and persistent grazing. Several cattle trails cross this habitat, and have seen recent use. The two permanent panoramic photo points are located in this habitat (see Figure 2). Panoramic photos from these points are given in Appendix E, Figure E-1 from the west point and Figure E-2 from the east point.

Creosote bush was present in each of the eight study plots in this habitat. No other woody plant species was present in any of the eight study plots. Average measured plant

height for creosote bush was 1.38 m, which compares reasonably well with the 1.2 m height reported by ENTRANCO (1998). A *t*-test of these values indicates no significant difference ($t = 0.588$, $df = 16$, $p > 0.5$). The mean canopy cover for the study plots is 35.4 percent at a height of one meter, which is more than twice the canopy cover of 13.4 percent listed by ENTRANCO (1998). A *t*-test of these values indicates a significant difference ($t = 2.904$, $df = 16$, $p < 0.05$). At a height of 2 m, the mean canopy cover for the study plots is 7.16 percent, which is more than twice the canopy cover of 2.7 percent listed by ENTRANCO (1998). However, a *t*-test of these values indicates no significant difference ($t = 0.741$, $df = 16$, $p > 0.4$), because of the high variance in the data.

The overall plant density in this habitat, 1,523 plants per hectare, was less than the density of 1,867 plants/ha reported by ENTRANCO (1998). However, a *t*-test of these values indicates no significant difference ($t = 0.431$, $df = 16$, $p > 0.5$), again because of the high variance in the data.

This essentially monotypic plant community provides a thin canopy where approximately 85 percent of the plants are less than 2 m in height. Some desert broom and desert-willow are present at the lower edge of this habitat, close to the recharge basins. Representative photos from this habitat are given in Figures E-3 and E-4, Appendix E.

MESQUITE-PALO VERDE ASSOCIATION

The mesquite-palo verde association is present along the northeast boundary of the project site along the existing irrigation ditch. In ENTRANCO (1998) this habitat was described as a desert broom-mesquite association. It is evident from the panoramic photographs in the ENTRANCO (1998) report that several mesquite and palo verde trees were removed along the southern edge of this habitat during construction of the recharge basins and surrounding roads. Either some of these trees were replanted, or new mesquite and palo verde trees were planted at the southwest boundary of this habitat along the recharge basin perimeter road. This habitat continues northeast beyond the irrigation ditch and off the project site towards the Santa Cruz River. The density of the habitat north of the project site increases to the southeast where it intergrades with the tamarisk-willow habitat along the Santa Cruz River Diversion Channel.

Much of this habitat is quite open, with the dominant canopy elements being mesquite and Mexican palo verde. Other woody plants found in the eight plots were four-wing saltbush (*Atriplex canescens*), tree tobacco (*Nicotiana glauca*), desert broom (*Baccharis sarothroides*), and burroweed (*Isocoma tenuisecta*). Mexican elderberry occurs in the habitat, but was not present in any of the random study plots.

The total canopy cover measured in this study and corresponding results from ENTRANCO (1998) are reported in Table 1. Although the recent values are lower or much lower at each canopy height, these differences are not statistically significant. The lower values for canopy cover, particularly at the upper levels, could be the result of the removal of trees during construction of the recharge basins and roads.

Table 1. Comparison of canopy cover observations, mesquite-palo verde association.

| Height above ground, m | Canopy Cover % – EPG (2002) | Canopy Cover % – ENTRANCO (1998) | t-value | Probability |
|---|---|---|---|---|
| 1 | 21.24 | 23.5 | 0.159 | > 0.5 |
| 2 | 12.12 | 53.4 | 1.682 | > 0.1 |
| 3 | 9.28 | 33.4 | 1.511 | > 0.1 |
| 4 | 1.47 | 9.4 | 0.887 | > 0.2 |
| 5 | 0.77 | 9.4 | 0.971 | > 0.2 |

The average estimated percent annual ground cover of forbs and grasses for the eight plots is approximately 35 percent. The grass is predominantly Bermuda grass (*Cynodon dactyon*). A few bulrushes (*Scirpus* sp.) and buffalo bur (*Solanum rostratum*) were present along the edges of the irrigation ditch.

Average woody plant density for the mesquite-palo verde association is 1,602 plants/ha, which is only slightly higher than the creosote bush association density of 1,523 plants/ha. This plant density is not significantly different from the density of 1,524 plants/ha reported by ENTRANCO (1998) for this habitat ($t = 0.121$, $df = 13$, $p > 0.9$).

The plant species composition of this habitat appears to be different from that previously reported. In the ENTRANCO (1998) study, velvet mesquite, baccharis species, and Mexican elderberry were recorded in these study plots. In the recent evaluation, velvet mesquite is also common, but desert broom is minimal and no Emory baccharis was observed. Mexican elderberry was observed in the habitat, but it was not recorded on any of the study plots. Mexican palo verde is now present in this habitat, but it may have been planted following the road construction. Representative photos from this habitat are given in Figures E-5 and E-6, Appendix E.

## TAMARISK-WILLOW ASSOCIATION

The tamarisk-willow association is present on the project as a relatively narrow band of vegetation bordering the Santa Cruz River Diversion Channel. The boundary with the adjacent, more xeric, creosote bush habitat is generally well defined, and abrupt. The tamarisk-willow association indistinctly intergrades with the mesquite-palo verde habitat at the northeast corner of the site. The plant community is dominated by *Tamarix* spp. and Goodding willow. Other important woody plants present are desert broom, velvet mesquite, seep-willow, and Mexican elderberry. Mature plants of Goodding willow, *Tamarisk* sp., and athel (*Tamarix aphylla*) form the overstory in this habitat. The mid-story is comprised primarily of *Tamarix* sp. and velvet mesquite, while other woody species, generally less than 3 m in height (Table A-3a), form the understory. A typical multi-tiered riparian habitat is thus present. Total canopy cover is 42.0 percent at 1 m,

decreasing gradually up to the 5 m level, and rapidly diminishing between 5 and 6 meters (Table A-3b). Canopy cover for one of the plots was measured up to 10 m due to the presence of a single mature Goodding willow.

The total canopy cover measured in this study and corresponding results from ENTRANCO (1998) are reported in Table 2. The corresponding values are generally comparable at each canopy height, and the differences are not statistically significant.

Table 2. Comparison of canopy cover observations, tamarisk-willow association.

| Height above ground, m | Canopy Cover % – EPG (2002) | Canopy Cover % – ENTRANCO (1998) | t-value | Probability |
|---|---|---|---|---|
| 1 | 42.19 | 53.0 | 0.603 | > 0.5 |
| 2 | 32.02 | 44.2 | 0.548 | > 0.5 |
| 3 | 20.62 | 22.4 | 0.133 | > 0.5 |
| 4 | 15.20 | 11.9 | 0.278 | > 0.5 |
| 5 | 11.75 | 6.8 | 0.461 | > 0.5 |
| 6 | 3.05 | 4.7 | 0.310 | > 0.5 |
| 7 | 2.03 | 2.9 | 0.246 | > 0.5 |
| 8 | 1.02 | * | - | - |
| 9 | 1.12 | * | - | - |
| 10 | 0.76 | * | - | - |

*No data at these canopy heights.

The average estimated percent annual ground cover of forbs and grasses for the eight plots is approximately 20 percent. Some small areas along the edge of the diversion channel have a ground cover consisting primarily of Bermuda grass estimated between 40 and 98 percent cover. In some areas however, woody plant density is high enough to preclude any annual ground cover. In particular, *Tamarisk* sp. and *B. sarothroides* exist either as monotypic stands or together at densities that are almost impenetrable.

Average density of plants is 4180 plants/ha, which is substantially greater than either the creosote bush or mesquite-palo verde associations as present on the project site. However, these differences are not statistically significant ($t = 1.756$, $df = 14$, $p > 0.1$ for creosote bush association and $t = 1.737$, $df = 14$, $p > 0.1$ for mesquite palo verde association). Likewise, this plant density is not significantly different from the density of 2,910 plants/ha reported by ENTRANCO (1998) for this habitat ($t = 0.807$, $df = 17$, $p > 0.4$). Representative photos from this habitat are given in Figures E-7 and E-8, Appendix E.

## 3.2 AQUATIC ALGAE

At the time of sampling for algae and aquatic invertebrates, the Santa Cruz River Diversion Channel had steeply sloping banks, creating a V-channel. Water was visibly turbid. There was limited riffle area; the channel had little cobble, leaf litter, or other submerged substrates. The bottom was composed of approximately 80 percent silt, 15 percent sand, and 5 percent (<1/2 inch) rock. Water temperature was 30.4 C, pH was 7.5 SU, and dissolved oxygen concentration was 3.6 mg/L.

Phytoplankton: A total of ten species were identified. Total cell density was $1.2 \times 10^4$ cells/mL. Algae species, division, form, density, and relative abundance are presented in Table 3.

Table 3. Phytoplankton observed at the High Plains Effluent Recharge Site.

| Species | Division & Form | Density (cells/mL) | Composition, % |
|---|---|---|---|
| *Achnanthes affinis* | Bacillariophyta Unicell | 658 | 5.54 |
| *Achnanthes* sp. | Bacillariophyta Unicell | 60 | 0.51 |
| *Cymbella microcephala* | Bacillariophyta Unicell | 1,317 | 11.10 |
| *Euglena* sp. | Euglenophyta Flagellated unicell | 7 | 0.06 |
| *Gomphonema parvulum* | Bacillariophyta Unicell | 2,095 | 17.65 |
| *Navicula accomoda* | Bacillariophyta Unicell | 60 | 0.51 |
| *Navicula cryptocephala* | Bacillariophyta Unicell | 120 | 1.01 |
| *Nitzschia kutzingiana* | Bacillariophyta Unicell | 5,327 | 44.88 |
| *Oscillatoria* sp. | Cyanophyta Filament | 2,166 | 18.25 |
| *Pinnularia divergentissima* | Bacillariophyta Unicell | 60 | 0.51 |

Periphyton: Eight algae species were found upstream and six species were found downstream. Cell density was similar at both locations. Unicellular diatoms (*Gomphonema* and *Nitzschia*) dominated the collections. Calculated cell density and percent composition for each species are summarized in Tables 4a and 4b.

Table 4a. Periphyton observed upstream from the High Plains Effluent Recharge Site.

| Species | Density (cells/sq m) | Composition, % |
|---|---|---|
| *Nitzschia* sp. | 2,100 | 12.5 |
| *Pinnularia substomatophora* | 580 | 3.5 |
| *Synedra affinis* | 580 | 3.5 |
| *Nitzschia accedans* | 3,740 | 22.2 |
| *Cymbella* sp. | 580 | 3.5 |
| *Gomphonema parvulum* | 7,600 | 45.1 |
| *Navicula* sp. | 580 | 3.5 |
| *Surirella ovalis* | 1,050 | 6.2 |
| **Total** | **16,810** | **100.0** |

Table 4b. Periphyton observed downstream from the High Plains Effluent Recharge Site.

| Species | Density (cells/sq m) | Composition, % |
|---|---|---|
| *Nitzschia accedans* | 9,120 | 47.1 |
| *Pinnularia substomatophora* | 1,050 | 5.4 |
| *Navicula* sp. | 1,640 | 8.4 |
| *Nitzschia* sp. | 585 | 3.0 |
| *Navicula cryptocephala* | 585 | 3.0 |
| *Gomphonema parvulum* | 6,430 | 33.1 |
| **Total** | **19,410** | **100.0** |

## 3.3 AQUATIC INVERTEBRATES

Macro-invertebrates: Few taxa were observed in the samples. Aquatic earthworms (*Amphichaeta* sp.) and amphipods (*Hyalella azteca*) dominated the collections. A total of 254 organisms were collected upstream and 181 organisms were collected downstream. Table 5 provides a list of the major taxa and the number found.

Table 5. Aquatic macroinvertebrates found at the High Plains Effluent Recharge Site.

| Taxon/Family | Species | Upstream | Downstream |
|---|---|---|---|
| Odonata (Dragonflies, damselflies)<br>Coenagrionidae | Undetermined sp. | 0 | 1 |
| Hemiptera (True bugs)<br>Naucoridae | *Ambrysus* sp. | 0 | 1 |
| Diptera (Flies)<br>Chironomidae | *Bryophaenocladius* sp.<br>*Glyptotendipes* sp. | 2<br>1 | 0<br>0 |
| Annelida (Segmented worms)<br>Naididae | *Amphichaeta* sp. | 168 | 40 |
| Cladocera (Water fleas)<br>Daphnidae | *Daphnia pulex* | 0 | 1 |
| Amphipoda (Scuds, sideswimmers)<br>Talitridae | *Hyalella azteca* | 83 | 138 |
| **TOTAL** | | **254** | **181** |

## 3.4 BUTTERFLIES AND MOTHS

Butterfly observation and capture data, and calculated disturbance susceptibility scores for each species are shown in Tables B-1a through B-1e.

The report provided by ENTRANCO (1998) listed eight species of butterflies for the High Plains Effluent Recharge site (Table B-2a). Four of the species recorded in 1998 were positively confirmed to still be present at the site in 2002. A fifth species, the fiery skipper (*Hylephila phyleus*) was apparently seen once, but was not captured, and its presence could not be confirmed. Three species recorded in 1998 were not seen in 2002 (Table B-2a). These were the viceroy (*Limenitis archippus*), the sennae sulphur (*Phoebis sennae*), and the cabbage butterfly (*Pieris rapae*). Four butterfly species new to the project site were recorded in 2002 (Table B-2b). These were the western pygmy blue (*Brephidium exile*), the checkered white (*Pontia protodice*), the white checkered-skipper (*Pyrgus albescens*), and the gray hairstreak (*Strymon melinus*).

The viceroy butterfly, recorded as present by ENTRANCO (1998), would be expected in the tamarisk-willow habitat, since willows (*Salix* spp.) are one of their food plants. However, no viceroys were observed in 2002. The sennae sulfur was not observed in 2002, though its presence is likely since sennas (*Senna* spp.), its food plants, are likely to occur either on the project site, or in the vicinity. However, no senna plant species were recorded on the project site in 2002. The cabbage butterfly (*Pieris rapae*) was reported in ENTRANCO (1998) based on seven observations, but no captures. The cabbage butterfly is a widespread and common species, which is likely to occur at the project site. Its larval food plants are various species of mustards that are common in disturbed areas. The cabbage white was not observed on the project during our six site visits in 2002. Since only the checkered white butterfly was documented in 2002, based on 23 observations and 5 captures, and the 1998 records for the cabbage white were

observations only, it appears that the checkered white is the more dominant species present at the project site. While the cabbage white may occur here as well, it was not seen in 2002, and the records from are 1998 could be in error.

Butterfly riparian quality values were calculated for each of the three habitat types identified at the project site utilizing the disturbance susceptibility values assigned to each species (Tables B-3a – B3c). Because observations in the creosote bush association resulted in only a single butterfly sighting, the BRQ is 0.0. Four species of butterflies were found in the mesquite-paloverde association. The BRQ for the mesquite-paloverde association is 2.0. Eight species of butterflies were found in the tamarisk-willow association, and its BRQ is 8.0. The corresponding BRQs for each of the three habitats based on the data from ENTRANCO (1998) are creosote bush 0.0, mesquite-paloverde 3.3, and tamarisk-willow 3.3. That the BRQ for the creosote bush association is 0.0 for each year would be expected due to the low plant species diversity within that habitat and a lack of significant moisture or nectar sources available to butterflies. The BRQs for the mesquite-paloverde association of 2.0 in 2002 and 3.3 in 1998 are essentially the same. However, due to the lack of rains locally during the 2001/2002-winter season, and the subsequent lack of spring annual plants, the BRQ for this habitat in 2002 may be temporarily depressed, and probably does not indicate a decline in overall riparian quality. The BRQ of 8.0 for 2002 is considerably higher than that based on the 1998 data. This appears to be due to the significant increase (60%) in the number of species found in the association, and may be a reflection of the greater effort expended in locating as many of the species present in the habitat as possible.

A comparison of these data with the original results of Nelson and Anderson (1994) shows the creosote association at the High Plains site to be depauperate of butterfly species, not unlike a portion of the No Name Lake (NNL) site of Nelson and Anderson, which was dominated by saltcedar (BRQ 0.3). Plant associations exhibiting low species diversity and lacking variability in plant form tend to have a correspondingly low BRQ.

The mesquite-paloverde association (BRQ 2.0) at the High Plains site has some value as habitat for butterflies, primarily from the presence of mesquite trees, which are utilized as food by the larvae of some butterfly species, and whose blossoms provide a supply of nectar. The BRQ for the mesquite-paloverde association is rather low however, and is considerably less favorable to butterfly species diversity than even a riparian habitat possessing a low BRQ. If vegetation density or diversity were higher in this habitat, it could support greater butterfly species diversity and a higher BRQ.

The tamarisk-willow association has the highest BRQ (8.0) of the three plant associations present at the High Plains site. The NNL site of Nelson and Anderson (BRQ 7.8) most closely approximates the tamarisk-willow association at the High Plains site. The NNL site had been cleared of tamarisk and had been replanted with cottonwood and mesquite. Some willows and large mesquite were present among the original vegetation, and were not disturbed during the clearing operations. The NNL habitat is mostly xeric, not unlike the tamarisk-willow association at the High Plains site, where water is available only intermittently in the Santa Cruz Diversion Channel, which runs through the habitat. The tamarisk at the High Plains site provides little of value to butterflies except a moderate

quantity of nectar, and has the deleterious effects of crowding and shading out native understory plants, which results in loss of plant species diversity, and co-opting a large portion of the available water resource.

None of the three habitats present at the High Plains site currently has a high BRQ. Nelson and Anderson reported a BRQ of 14.2 for the BWD site in their 1994 paper. This site was not a pristine riparian site, but one in relatively robust condition with a relatively natural and non-channelized hydrologic regime and a greater species diversity of grasses and herbaceous plants.

## 3.5 REPTILES AND AMPHIBIANS

Reptile transects were surveyed in each of the four habitats on May 1 and May 30, 2002. These surveys were conducted between 7:50 a.m. and 10:00 a.m. Each transect was surveyed for 10 minutes on each day, for a total of 80 minutes of intense searching for reptiles. No reptiles were found during any of these transect surveys. During the course of other studies on the site, a few lizards were seen, as listed in Table 6. The most common lizards observed on the site were the western whiptail (*Cnemidophorus tigris*) and side-blotched lizard (*Uta stansburiana*). No snakes were seen during these studies. The only amphibian identified during these monitoring studies was a bullfrog (*Rana catesbeiana*) heard calling near the diversion channel.

The scarcity and the low species diversity of reptiles on this site are surprising. It is possible that surveys at night might have located some snake species that tend to be more nocturnal. One possible explanation is the severe drought that this region experienced in the early part of this year, although very few lizards were seen on the site even after the monsoon rains.

The results of our observations are consistent with the observations of ENTRANCO (1998). They also found that the western whiptail and the side-blotched lizard were the most common species on the site, and they suggested that other whiptail species could also be present.

Table 6. Reptile and amphibians species observed at the High Plains Effluent Recharge Facility

| Scientific Name | Common Name | Habitat Type | | | |
|---|---|---|---|---|---|
| | | CBA | MPV | TW | RB |
| *Rana catesbeiana* | Bullfrog | | ✓ | ✓ | |
| | | | | | |
| *Dipsosaurus dorsalis* | Desert iguana | ✓ | | | |
| *Uta stansburiana* | Side-blotched lizard | ✓ | ✓ | | |
| *Cnemidophorus tigris* | Western whiptail | ✓ | ✓ | ✓ | |

Habitat Types:
CBA – Creosote Bush Association
MPV – Mesquite/Palo Verde Association
TW – Tamarisk/Willow Association
RB – Recharge Basin (no natural vegetation remaining)

## 3.6 BIRDS

Birds were counted at four points, one in each habitat, on May 1 and May 30, 2002. Point locations are shown on Figure 2. Results of these observations are given in Tables 7-a through 7-d. Because of the small sample sizes for all species, densities for these species were not calculated. In order to obtain meaningful density estimates, multiple points in each habitat should be counted on several days. For common species, a reasonable estimate could be obtained with four to six replicate points in each habitat, and each point should be counted at least six times. For uncommon species, these efforts would need to be increased to get adequate sample sizes.

Table 7a. Bird Point Count Results, Creosote Bush Association. Combined results for two observation periods: May 1, 2002, 0715-0725 and May 30, 2002, 0711-0721.

| Species Observed | Number of Observations | | |
|---|---|---|---|
| | Within Habitat | Adjacent Habitat | Fly-over |
| Red-tailed Hawk | 1 | | |
| Gambel's Quail | 8 | | |
| Mourning Dove | | 2 | 6 |
| White-winged Dove | | 2 | 2 |
| Ladder-backed Woodpecker | 1 | | |
| Ash-throated Flycatcher | 2 | 1 | |
| Western Kingbird | 2 | | |
| Cactus Wren | 3 | | |
| Phainopepla | 12 | | |
| Red-winged Blackbird | | | 2 |
| Bronzed Cowbird | | | 1 |
| House Finch | 10 | | 3 |

Table 7b. Bird Point Count Results, Mesquite - PaloVerde Association. Combined results for two observation periods: May 1, 2002, 0646-065 and May 30, 2002,

| Species Observed | Number of Observations | | |
|---|---|---|---|
| | Within Habitat | Adjacent Habitat | Fly-over |
| Gambel's Quail | 6 | 10 | |
| Killdeer | | | 1 |
| Mourning Dove | 2 | 2 | 3 |
| White-winged Dove | | 3 | |
| Western Kingbird | | 1 | |
| Bell's Vireo | 3 | | |
| Cactus Wren | 1 | | |
| Black-tailed Gnatcatcher | 1 | | |
| Phainopepla | 4 | | |
| Lucy's Warbler | 1 | | |
| Yellow-breasted Chat | 1 | | |
| Brown-headed Cowbird | 2 | | |
| Bronzed Cowbird | | | 1 |
| Hooded Oriole | 2 | | |
| Northern Cardinal | 1 | | |
| Blue Grosbeak | 1 | | |

Table 7c. Bird Point Count Results, Tamarisk-Willow Association. Combined results for two observation periods: May 1, 2002, 0738-0748 and May 30, 2002, 0733-0743.

| Species Observed | Number of Observations | | |
|---|---|---|---|
| | Within Habitat | Adjacent Habitat | Fly-over |
| Gambel's Quail | 9 | 4 | |
| Killdeer | | | 1 |
| Mourning Dove | 2 | 3 | 1 |
| White-winged Dove | | 3 | 1 |
| Hummingbird sp. | | | 1 |
| Ash-throated Flycatcher | 1 | | |
| Common Raven | | | 1 |
| Bell's Vireo | 2 | | |
| Northern Rough-winged Swallow | | | 6 |
| Phainopepla | 2 | | |
| Common Yellowthroat | 2 | | |
| Yellow-breasted Chat | 1 | | |
| Brown-headed Cowbird | 5 | | |
| Bronzed Cowbird | 2 | | |
| Abert's Towhee | 1 | | |
| Song Sparrow | 2 | | |

Table 7d. Bird Point Count Results, Recharge Basin. Combined results for two observation periods: May 1, 2002, 0715-0725 and May 30, 2002, 0654-0704.

| Species Observed | Number of Observations | | |
|---|---|---|---|
| | Within Habitat | Adjacent Habitat | Fly-over |
| Red-tailed Hawk | | 1 | |
| Gambel's Quail | 2 | 4 | |
| Mourning Dove | | 2 | 2 |
| White-winged Dove | | 2 | 1 |
| Hummingbird sp. | | 1 | |
| Ash-throated Flycatcher | | 1 | |
| Western Kingbird | 2 | 2 | |
| Rough-winged Swallow | | | 3 |
| Cactus Wren | | 1 | |
| Phainopepla | | 1 | 2 |
| Loggerhead Shrike | | 1 | |
| Red-winged Blackbird | | | 6 |
| Brown-headed Cowbird | | | 13 |
| Bronzed Cowbird | | | 1 |
| Great-tailed Grackle | 1 | | 2 |
| Northern Cardinal | | 2 | |
| Blue Grosbeak | | 1 | |
| House Finch | | | 2 |

In addition to the point counts, lists of species observed on the site were kept during each site visit. The combined species list for six site visits is given on Table C-1. This table includes data on the habitats used by each of the species.

During the course of this study, 56 species of birds were observed on or near the High Plains Effluent Recharge Facility. Thirty of these species are permanent residents in this vicinity, and the other 26 species are neotropical migrants. Only two species (mourning dove and white-winged dove) were seen in all available habitats. Five species (black-bellied whistling duck, turkey vulture, purple martin, northern rough-winged swallow, and barn swallow) were only observed flying over the site. The whistling-duck is likely to utilize aquatic habitats along the Santa Cruz River. Turkey vultures are likely to use the site for foraging, if any carrion is present. The three species of swallows forage on aerial insects that are probably attracted to the riparian vegetation and aquatic resources on the north and east edges of the site.

The recharge basins had the fewest bird species, with only six species observed during our site visits. Four of these species are permanent residents, and two are neotropical migrants. Low avian diversity in this habitat is expected because of the lack of woody vegetation and the extensive areas of bare soil.

The creosote bush association also had low species diversity, but 16 species were found in this habitat. Eleven of these species are permanent residents, and five are neotropical migrants. This habitat has very low vegetative species diversity, and the shrubs provide limited structural diversity.

The mesquite/palo verde and the tamarisk/willow habitats had similar bird species diversity, with 39 and 37 species, respectively. There was a high degree of overlap in species between these two habitats, with 32 species observed in both habitats. In each of these habitats, 21 of the observed species were permanent residents. Eighteen neotropical migrants were observed in the mesquite/palo verde habitat, and there were 16 neotropical migrants in the tamarisk willow habitat.

The similarity in avian diversity in these two habitats is not surprising. These habitats are similar in their vegetative species diversity and vegetative structural diversity, and they have similar proximity to water. Even late in the summer when the diversion channel and the irrigation canal were dry, these habitats are still relatively close to the main river channel.

The total number of species observed (56) is comparable to the 49 species listed by ENTRANCO. However, ENTRANCO reported 20 species that we did not observe (see Table C-2), and we found 27 that they did not. The Chihuahuan ravens (*Corvus cryptoleucus*) reported by ENTRANCO as common residents were more likely common ravens (*Corvus corax*) that were misidentified. The Chihuahuan raven is generally restricted to grasslands and Chihuahuan desertscrub, and it is rarely found northwest of the Sonoita grasslands. ENTRANCO also reported Scott's oriole (*Icterus parisorum*) as a breeding species in this vicinity, but it normally breeds in mesquite-yucca grasslands or higher elevation habitats. Similarly, the white-throated swift (*Aeronautes saxatalis*) is unlikely to breed at low elevations with no nearby cliffs.

## 3.7 MAMMALS

No specific surveys were conducted for mammal species on the High Plains Effluent Recharge Facility site. However, notes were kept on incidental observations of any evidence of mammals using the site. During our time on the site, only two mammal species, black-tailed jack rabbit (*Lepus californicus*) and round-tailed ground squirrel (*Spermophilus tereticaudus*), were actually seen on the site. The presence of other species on the site was confirmed by the presence of bones, tracks, or scat, as listed in Table 8. The diversion channel was a good location for observing tracks as it was drying out, leaving a fine-grained mud that preserved tracks of several species. It is likely that other mammal species are using this site, and more observation time, particularly at night, would probably confirm several other species. To identify small mammals on the site, live-trapping in different habitats would be necessary.

ENTRANCO (1998) did not report any mammal observations, so no comparisons with that study are possible.

Table 8. Mammal species observed (including indirect evidence) at the High Plains Effluent Recharge Facility.

| Scientific Name | Common Name | Notes |
|---|---|---|
| | | |
| *Lepus californicus* | Black-tailed jack rabbit | Observed in recharge basin cells. |
| *Spermophilus tereticaudus* | Round-tailed ground squirrel | Observed at edge of creosote bush habitat. |
| *Dipodomys* sp. | Kangaroo rat | Tracks in fine sand in recharge basin. |
| *Canis latrans* | Coyote | Scat and tracks in numerous locations. |
| *Procyon lotor* | Raccoon | Tracks in diversion channel. |
| *Felis rufus* | Bobcat | Tracks in diversion channel. |
| *Pecari tajacu* | Collared peccary | Jaw bone in tamarisk/willow habitat. |

## 4 REFERENCES


American Ornithologists' Union (AOU). 1998. Check-list of North American Birds. 7th Edition. American Ornithologists' Union, Washington, D. C. 829 p.

Arnett, R. H. 1993. American Insects: a handbook of the insects of America north of Mexico. Sandhill Crane Press, Inc., Gainesville, Fl. 850 p.

Bold, H. C. and Wynne, M. J. 1978. Introduction to the algae: structure and reproduction. Prentice-Hall, Englewood Cliffs, N.J. 706 p.

Brown, D. E., C. H. Lowe, and C. P. Pase. 1979. A digitized classification system for the biotic communities of North America, with community (series) and association examples for the Southwest. Journal of the Arizona-Nevada Academy of Science 14 (Suppl. 1):1-16.

Chapman, V. J. 1964. The Algae. St. Martin's Press, New York, NY. 472 p.

Collins, F. S. 1970. The Green Algae of North America. J. Cramer Lehre, New York. 546 p.

Czarnecki, D. B. and Blinn, D. W. 1978. Diatoms of the Colorado River in Grand Canyon National Park and vicinity. J. Cramer Vaduz. 181 p.

Dodd, J. J. 1987. Diatoms. Southern Illinois University Press, Carbondale. 477 p.

Ehrlich, P. R., D. S. Dobkin and D. Wheye. 1988. The birder's handbook: a field guide to the natural history of North American birds. Simon and Schuster, Inc., New York. 785 p.

ENTRANCO. 1998. Biological Studies: High Plains Effluent Recharge Project, Marana, Pima County, Arizona. Report prepared for Pima County Flood Control District, August, 1998. 25 p. + appendices.

Irvine, D. E. G. and John, D. M. 1983. Systematics of the Green Algae. Academic Press, Orlando, Florida. 449 p.

Kearney, T. H. and Peebles, R. H. 1960. Arizona Flora. University of California Press, Berkeley. 1085 p.

LaRivers, I. 1978. Algae of the Western Great Basin. Desert Research Institute, University of Nevada, Reno. 390 p.

McCafferty, W. P. 1998. Aquatic Entomology. Jones and Bartlett Publishers, Sudsbury, MA.

Morris, I. 1967. An Introduction to the Algae. Hutchinson, London. 189 p.

National Geographic. 1999. Field Guide to the Birds of North America. Third edition. National Geographic. Washington, D.C. 480 p.

Nelson, S. M. and Andersen, D. C. 1994. An assessment of riparian environmental quality by using butterflies and disturbance susceptibility scores. The Southwestern Naturalist, 39(2): 137-142.

Patrick, R. and Reimer, C. W. 1975. The Diatoms of the United States. Academy of Natural Sciences, Philadelphia, PA.

Phillips, A. R., J. Marshall, and G. Monson. 1964. The birds of Arizona. University of Arizona Press, Tucson, Arizona. 220 p.

Pickett-Heaps, J. D. 1975. Green algae: structure, reproduction and evolution in selected genera. Sinauer Associates, Sunderland, MA. 606 p.

Prescott, G. W. 1978. How to know the freshwater algae. W. C. Brown Co., Dubuque, IA. 293 p.

Reynolds, R. T., J. M. Scott, and R. A. Nussbaum. 1980. A variable circular-plot method for estimating bird numbers. Condor, 82:309-313.

Round, F. E., Crawford, R. M. and Mann, D. G. 1990. The Diatoms: biology & morphology of the genera. Cambridge University Press, New York. 747 p.

Smith, G. M. 1950. The Fresh-water Algae of the United States. Second Edition. McGraw-Hill, New York. 719 p.

Stewart, B., Brodkin, P and Brodkin, H. 2001. Butterflies of Arizona. West Coast Lady Press, Arcata, California. 415 p.

Sze, P. 1986. The Biology of the Algae. William C. Brown Publishers, Dubuque, IA. 251 p.

Terres, J. K. 1980. The Audubon Society Encyclopedia of North American Birds. Alfred A. Knopf, New York. 1109 p.

Thorp, J. H. and Covich, A. P. 1991. Ecology and classification of North American freshwater invertebrates. Academic Press, San Diego, Ca. 911 p.

USGS – Butterflies of North America, 2002. Website: http://npwrc.usgs.gov/resource/distr/lepid/bflyusa/usa Accessed: April and May, 2002.

## APPENDIX A. VEGETATION SAMPLE PLOT RESULTS AND LOCATIONS.

**Table A-1a.** Frequency (%) and average height by species in the Creosote bush Association. (Based on eight sample plots).

| Species | Frequency | Plant Height (S.D.), m | Number of Individuals |
|---|---|---|---|
| *Larrea tridentata* | 100 | 1.38 (0.64) | 32 |

**Table A-1b.** Average percent canopy cover in the Creosote Bush Association (Based on eight sample plots).

| Species | Mean % Canopy Cover (S.D.) at Height Interval | |
|---|---|---|
| | 1m | 2m |
| *Larrea tridentata* | 35.4 (16.8) | 7.16 (15.8) |
| **Total Plant Canopy, %** | **35.4** | **7.16** |

Average density of all plants: **1,523 plants/ha (S.D. = 1,479)**

**Table A-2a.** Frequency and average height by species in the Mesquite-Paloverde Association (Based on eight sample plots).

| Species | Frequency | Plant Height (S.D.), m | Number of Individuals |
|---|---|---|---|
| *Prosopis velutina* | 50 | 2.47 (1.78) | 12 |
| *Parkinsonia aculeata* | 37.5 | 2.72 (1.08) | 3 |
| *Atriplex canescens* | 37.5 | 0.64 (0.26) | 9 |
| *Isocoma tenuisecta* | 12.5 | 1.05 (0.13) | 4 |
| *Baccharis sarothroides* | 12.5 | 1.20 (*) | 1 |
| *Nicotiana glauca* | 12.5 | 1.70 (*) | 1 |

*Only one individual observed.

**Table A-2b.** Average percent canopy cover in the Mesquite-Palo Verde Association (Based on eight sample plots).

| Species | Mean % Canopy Cover (S.D.) at Height Interval | | | | |
|---|---|---|---|---|---|
| | 1m | 2m | 3m | 4m | 5m |
| *Prosopis velutina* | 9.35 (15.0) | 7.77 (14.8) | 6.14 (11.4) | 1.47 (4.10) | 0.77 (2.19) |
| *Parkinsonia aculeata* | 2.18 (5.05) | 4.36 (12.2) | 3.14 (8.88) | | |
| *Atriplex canescens* | 5.61 (10.2) | | | | |
| *Isocoma tenuisecta* | 2.04 (5.77) | | | | |
| *Baccharis sarothroides* | 1.77 (5.00) | | | | |
| *Nicotiana glauca* | 0.30 (0.84) | | | | |
| **Total Plant Canopy, %** | **21.24 (16.17)** | **12.12 (16.98)** | **9.28 (12.83)** | **1.47 (4.10)** | **0.77 (2.19)** |

Average density of all plants: **1602 plants/ha (S.D. = 1244)**

**Table A-3a.** Frequency and average height by species in the Tamarisk-Willow Association. (Based on eight sample plots)

| Species | Frequency | Plant Height (S.D.), m | Number of Individuals |
|---|---|---|---|
| *Tamarix* sp. | 25 | 4.19 (2.37) | 7 |
| *Salix gooddingii* | 25 | 8.10 (2.69) | 2 |
| *Baccharis sarothroides* | 100 | 1.68 (0.86) | 31 |
| *Prosopis velutina* | 25 | 3.58 (3.29) | 2 |
| *Sambucus nigra* | 12.5 | 1.62 (1.69) | 12 |
| *Tamarix aphylla* | 12.5 | 6.60 (*) | 1 |
| *Larrea tridentata* | 25 | 2.04 (0.80) | 7 |
| *Baccharis salicifolia* | 37.5 | 1.63 (0.99) | 8 |
| *Isocoma tenuisecta* | 12.5 | 0.63 (0.11) | 10 |
| *Arctium minus* | 12.5 | 0.6 (*) | 1 |
| *Chilopsis linearis* | 12.5 | 1.30 (*) | 1 |
| *Nicotiana glauca* | 12.5 | 2.40 (*) | 1 |

*Only one individual observed.

**Table A-3b.** Average percent canopy cover in the Tamarisk-Willow Association (Based on eight sample plots).

| Species | Mean % Canopy Cover (S.D.) at Height Interval | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1m** | **2m** | **3m** | **4m** | **5m** | **6m** | **7m** | **8m** | **9m** | **10m** |
| *Tamarix* sp. | 6.20 (17.5) | 9.73 (27.0) | 5.47 (15.5) | 8.74 (24.7) | 9.54 (27.0) | 2.84 (8.04) | 0.47 (1.33) | | | |
| *Salix gooddingii* | 0.00 (0.00) | 1.45 (4.09) | 3.19 (9.02) | 2.92 (7.00) | 1.41 (3.85) | 0.09 (0.26) | 1.56 (4.42) | 1.25 (3.54) | 1.12 (3.18) | 0.76 (2.17) |
| *Baccharis sarothroides* | 15.95 (17.8) | 8.27 (16.7) | 0.09 (0.24) | | | | | | | |
| *Prosopis velutina* | 9.88 (27.8) | 4.91 (13.9) | 5.67 (16.0) | 3.31 (9.37) | 0.33 (0.93) | | | | | |
| *Sambucus nigra* | 3.09 (8.72) | 3.68 (10.4) | 3.34 (9.43) | | | | | | | |
| *Tamarix aphylla* | 0.00 (0.00) | 0.59 (1.68) | 2.81 (7.95) | 0.22 (0.64) | 0.47 (1.33) | 0.12 (0.33) | | | | |
| *Larrea tridentata* | 3.22 (7.54) | 2.68 (7.58) | 0.05 (0.15) | | | | | | | |
| *Baccharis salicifolia* | 2.27 (4.59) | 0.72 (1.27) | | | | | | | | |
| *Isocoma tenuisecta* | 1.34 (3.8) | | | | | | | | | |
| *Arctium minus* | 0.19 (0.53) | | | | | | | | | |
| *Chilopsis linearis* | 0.05 (0.13) | | | | | | | | | |
| *Nicotiana glauca* | 0.00 (0.00) | 0.008 (0.022) | | | | | | | | |
| **Total Plant Canopy, %** | **42.19 (37.36)** | **32.02 (35.57)** | **20.62 (26.12)** | **15.20 (24.38)** | **11.75 (26.35)** | **3.05 (7.97)** | **2.03 (4.43)** | **1.25 (3.54)** | **1.12 (3.18)** | **0.76 (2.17)** |

Average density of all plants: **4180 plants/ha (S.D. = 4009).**

**Table A-4. Sample Plot Locations.** GPS - UTM coordinates, referenced to NAD27, Zone 12S (estimated error ±5 m)

| Plot Number | Easting | Northing |
|---|---|---|
| C-1 | 478608 | 3587831 |
| C-2 | 478634 | 3587808 |
| C-3 | 478711 | 3587722 |
| C-4 | 478742 | 3587752 |
| C-5 | 478799 | 3587676 |
| C-6 | 478805 | 3587668 |
| C-7 | 478826 | 3587679 |
| C-8 | 478890 | 3587664 |
| M-1 | 478655 | 3587870 |
| M-2 | 478659 | 3587886 |
| M-3 | 478683 | 3587881 |
| M-4 | 478743 | 3587874 |
| M-5 | 478818 | 3587845 |
| M-6 | 478842 | 3587843 |
| M-7 | 478858 | 3587847 |
| M-8 | 478870 | 3587838 |
| T-1 | 478917 | 3587806 |
| T-2 | 478947 | 3587735 |
| T-3 | 478937 | 3587664 |
| T-4 | 478954 | 3587661 |
| T-5 | 478958 | 3587629 |
| T-6 | 478926 | 3587606 |
| T-7 | 478949 | 3587590 |
| T-8 | 478924 | 3587579 |
| | | |
| West Photo Point | 478679 | 3587783 |
| East Photo Point | 478864 | 3587638 |

**Table A-5. Other Sample Locations.** Centers of bird point counts and endpoints of reptile transects. GPS - UTM coordinates, referenced to NAD27, Zone 12S (estimated error ±5 m)

| Sample Point | Easting | Northing |
|---|---|---|
| B-1. Bird Count – Mesquite-Palo Verde | 478808 | 3587853 |
| B-2. Bird Count – Tamarisk-Willow | 478950 | 3587728 |
| B-3. Bird Count – Creosote Bush | 478702 | 3587734 |
| B-4. Bird Count – Recharge Basin | 478762 | 3587814 |
| R-1. Reptile Transect – Mesquite-Palo Verde – West End | 478763 | 3587860 |
| R-1. Reptile Transect – Mesquite-Palo Verde – East End | 478808 | 3587853 |
| R-2. Reptile Transect – Tamarisk-Willow – North End | 478932 | 3587757 |
| R-2. Reptile Transect – Tamarisk-Willow – South End | 478930 | 3587706 |
| R-3. Reptile Transect – Creosote Bush – West End | 478702 | 3587734 |
| R-3. Reptile Transect – Creosote Bush – East End | 478736 | 3587697 |
| R-4. Reptile Transect – Recharge Basin – West End | 478762 | 3587814 |
| R-4. Reptile Transect – Recharge Basin – East End | 478802 | 3587779 |

## APPENDIX B. BUTTERFLY SURVEY RESULTS.

**Table B-1a.** Butterflies observed and/or sampled on 05-01-02, 0643 to 1110.

| Species | No. Observed/ Captured | Habitat | DSS* |
|---|---|---|---|
| *Danaus gilippus* (Queen) | 1/0 | Tamarisk-Willow | 12 |
| *Leptotes marina* (Marine Blue) | 12/4 | Tamarisk-Willow | 8 |
| *Papilio polyxenes* (Black Swallowtail) | 1/0 | Tamarisk-Willow | 8 |
| *Pontia protodice* (Checkered White) | 7/2 | Tamarisk-Willow | 8 |
| *Pontia protodice* (Checkered White) | 3/2 | Mesquite-Paloverde | 8 |
| *Pyrgus albescens* (White Checkered-skipper) | 1/0 | Tamarisk-Willow | 8 |
| **Total Number** | **25/8** | | |

*Disturbance susceptibility score.

**Table B-1b.** Butterflies observed and/or sampled on 05-30-02, 0636 to 0943.

| Species | No. Observed/ Captured | Habitat | DSS* |
|---|---|---|---|
| Danaus gilippus (Queen) | 1/0 | Tamarisk-Willow | 12 |
| Leptotes marina (Marine Blue) | 29/5 | Tamarisk-Willow | 8 |
| Leptotes marina (Marine Blue) | 4/0 | Mesquite-Paloverde | 8 |
| Brephidium exile (Western Pygmy-Blue) | 1/0 | Mesquite-Paloverde | 9 |
| Pontia protodice (Checkered White) | 9/1 | Mesquite-Paloverde | 8 |
| Pontia protodice (Checkered White) | 4/0 | Tamarisk-Willow | 8 |
| Calephelis nemesis (Fatal Metalmark) | 4/2 | Tamarisk-Willow | 18 |
| Strymon melinus (Gray Hairstreak) | 1/1 | Tamarisk-Willow | 4 |
| Hylephila phyleus ? (Fiery Skipper) | 1/0 | Tamarisk-Willow | 7 |
| Pyrgus albescens (White Checkered-skipper) | 1/1 | Tamarisk-Willow | 8 |
| **Total Number** | **55/10** | | |

*Disturbance susceptibility score.

**Table B-1c.** Butterflies observed and/or sampled on 09-04-02, 0900 (Incidental record).

| Species | No. Observed/ Captured | Habitat | DSS* |
|---|---|---|---|
| *Papilio polyxenes* (Black Swallowtail) | 1/0 | Creosote Bush | 8 |
| **Total Number** | **1/0** | | |

*Disturbance susceptibility score.

**Table B-1d.** Butterflies observed and/or sampled on 09-11-02, 1030 to 1130 (Incidental records).

| Species | No. Observed/ Captured | Habitat | DSS* |
|---|---|---|---|
| *Calephelis nemesis* (Fatal Metalmark) | 4/0 | Tamarisk-Willow | 18 |
| **Total Number** | **4/0** | | |

*Disturbance susceptibility score.

**Table B-1e.** Butterflies observed and/or sampled on 09-18-02, 0710 to 1200 (Incidental records).

| Species | No. Observed/ Captured | Habitat | DSS* |
|---|---|---|---|
| *Calephelis nemesis* (Fatal Metalmark) | 3/0 | Tamarisk-Willow | 18 |
| *Danaus gilippus* (Queen) | 1/0 | Mesquite-Paloverde | 12 |
| **Total Number** | **4/0** | | |

*Disturbance susceptibility score.

**Table B-2a.** Butterfly species recorded by ENTRANCO at the High Plains Effluent Recharge Project site, Marana, AZ. (1998).

| Species | Common Name | Confirmed by EPG/yr |
|---|---|---|
| *Calephelis nemesis* | Fatal metalmark | Yes/2002 |
| *Danaus gilippus* | Queen | Yes/2002 |
| *Hylephila phyleus* | Fiery skipper | Yes?/2002 |
| *Leptotes marina* | Marine blue | Yes/2002 |
| *Limenitis archippus* | Viceroy | No |
| *Papilio polyxenes* | Black swallowtail | Yes/2002 |
| *Phoebis sennae* | Sennae sulphur | No |
| *Pieris rapae* | Cabbage butterfly | No |

**Table B-2b.** Additional butterfly species recorded by EPG at the High Plains Effluent Recharge Project site, Marana, AZ. (2002).

| Species | Common Name |
|---|---|
| *Brephidium exile* | Western pygmy blue |
| *Pontia protodice* | Checkered white |
| *Pyrgus albescens* | White checkered-skipper |
| *Strymon melinus* | Gray hairstreak |

**Table B-3a.** Riparian Environmental Quality Assessment for the Creosote Bush Association.

| Species | Relative Abundance | Disturbance Susceptibility Score (DSS) |
|---|---|---|
| *Papilio polyxenes* (Black Swallowtail) | Rare | 8 |

Total number of species: 1 (Fly-over). Butterfly Riparian Quality **(BRQ) = 0**

**Table B-3b.** Riparian Environmental Quality Assessment for the Mesquite-Paloverde Association.

| Species | Relative Abundance | Disturbance Susceptibility Score (DSS) |
|---|---|---|
| *Danaus gilippus* (Queen) | Uncommon | 12 |
| *Leptotes marina* (Marine Blue) | Abundant | 8 |
| *Pontia protodice* (Checkered White) | Abundant | 8 |
| *Brephidium exile* (Western Pygmy Blue) | Uncommon | 9 |

Total number of species: 4. Butterfly Riparian Quality **(BRQ) = 2.0**

**Table B-3c.** Riparian Environmental Quality Assessment for the Tamarisk-Willow Association.

| Species | Relative Abundance | Disturbance Susceptibility Score (DSS) |
|---|---|---|
| *Papilio polyxenes* (Black Swallowtail) | Uncommon | 8 |
| *Danaus gilippus* (Queen) | Uncommon | 12 |
| *Leptotes marina* (Marine Blue) | Abundant | 8 |
| *Pontia protodice* (Checkered White) | Abundant | 8 |
| *Pyrgus albescens* (White Checkered Skipper) | Uncommon | 8 |
| *Calephelis nemesis* (Fatal Metalmark) | Common | 18 |
| *Strymon melinus* (Gray Hairstreak) | Uncommon | 4 |
| *Hylephila phyleus ?* (Fiery Skipper) | Rare | 9 |

Total number of species: 8. Butterfly Riparian Quality **(BRQ) = 8.0**

## APPENDIX C. BIRD SPECIES LISTS.

Table C-1. Bird species observed in various habitats at High Plains Recharge Site.

| Scientific Name | Common Name | Status | Habitat Type | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | CBA | MPV | TW | RB | FO | AA |
| *Dendrocygna autumnalis* | Black-bellied Whistling-duck | N | | | | | ✓ | |
| *Anas platyrhynchos* | Mallard | P | | | ✓ | | ✓ | |
| *Cathartes aura* | Turkey Vulture | N | | | | | ✓ | ✓ |
| *Buteo jamaicensis* | Red-tailed Hawk | P | ✓ | | | | ✓ | ✓ |
| *Falco sparverius* | American Kestrel | P | | ✓ | ✓ | | | |
| *Falco mexicanus* | Prairie Falcon | P | | ✓ | | | | |
| *Callipepla gambelii* | Gambel's Quail | P | ✓ | ✓ | ✓ | ✓ | | ✓ |
| *Charadrius vociferus* | Killdeer | P | | ✓ | ✓ | ✓ | | ✓ |
| *Columba livia* | Rock Dove | P | | | | | ✓ | ✓ |
| *Zenaida asiatica* | White-winged Dove | N | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| *Zenaida macroura* | Mourning Dove | P | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| *Columbina passerina* | Common Ground-Dove | P | ✓ | | | | | |
| *Bubo virginianus* | Great Horned Owl | P | | ✓ | | | | |
| *Archilochus alexandri* | Black-chinned Hummingbird | N | ✓ | ✓ | ✓ | | | |
| *Calypte costae* | Costa's Hummingbird | N | | ✓ | | | | |
| *Melanerpes uropygialis* | Gila Woodpecker | P | | ✓ | ✓ | | | |
| *Picoides scalaris* | Ladder-backed Woodpecker | P | ✓ | ✓ | ✓ | | | |
| *Colaptes chrysoides* | Gilded Flicker | P | | | ✓ | | | |
| *Empidonax* sp. | Empidonax Flycatcher | N | | | ✓ | | | |
| *Sayornis nigricans* | Black Phoebe | P | | ✓ | ✓ | | | |
| *Myiarchus cinerascens* | Ash-throated Flycatcher | N | ✓ | ✓ | ✓ | | | |
| *Tyrannus verticalis* | Western Kingbird | N | ✓ | ✓ | ✓ | ✓ | | |
| *Lanius ludovicianus* | Loggerhead Shrike | P | ✓ | | | | | ✓ |
| *Vireo bellii* | Bell's Vireo | N | | ✓ | ✓ | | | |
| *Vireo gilvus* | Warbling Vireo | N | | ✓ | ✓ | | | |
| *Corvus corax* | Common Raven | P | | | | | ✓ | |
| *Eremophila alpestris* | Horned Lark | P | | | | | | ✓ |
| *Progne subis* | Purple Martin | N | | | | | ✓ | |
| *Stelgidopteryx serripennis* | Northern Rough-winged Swallow | N | | | | | ✓ | |
| *Hirundo rustica* | Barn Swallow | N | | | | | ✓ | |
| *Auriparus flaviceps* | Verdin | P | ✓ | ✓ | ✓ | | | |
| *Campylorhynchus brunneicapillus* | Cactus Wren | P | ✓ | ✓ | ✓ | | | |
| *Thryomanes bewickii* | Bewick's Wren | P | | ✓ | ✓ | | | |
| *Polioptila melanura* | Black-tailed Gnatcatcher | P | | ✓ | ✓ | | | |
| *Toxostoma curvirostre* | Curve-billed Thrasher | P | ✓ | ✓ | ✓ | | | ✓ |
| *Phainopepla nitens* | Phainopepla | P | ✓ | ✓ | ✓ | | | ✓ |
| *Vermivora luciae* | Lucy's Warbler | N | | ✓ | ✓ | | | |
| *Dendroica petechia* | Yellow Warbler | N | | ✓ | ✓ | | | |
| *Dendroica townsendi* | Townsend's Warbler | N | | | ✓ | | | |
| *Geothlypis trichas* | Common Yellowthroat | N | | ✓ | ✓ | | | |
| *Wilsonia pusilla* | Wilson's Warbler | N | | ✓ | | | | |
| *Icteria virens* | Yellow-breasted Chat | N | | ✓ | ✓ | | | |
| *Pipilo aberti* | Abert's Towhee | P | | ✓ | ✓ | | | |

| Scientific Name | Common Name | Status | Habitat Type | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | CBA | MPV | TW | RB | FO | AA |
| *Chondestes grammacus* | Lark Sparrow | N | ✓ | ✓ | ✓ | | | ✓ |
| *Melospiza melodia* | Song Sparrow | P | | ✓ | ✓ | | | |
| *Zonotrichia leucophrys* | White-crowned Sparrow | N | | ✓ | ✓ | | | ✓ |
| *Cardinalis cardinalis* | Northern Cardinal | P | | ✓ | ✓ | | | |
| *Guiraca caerulea* | Blue Grosbeak | N | | ✓ | | | | |
| *Agelaius phoeniceus* | Red-winged Blackbird | P | | | | | ✓ | ✓ |
| *Quiscalus mexicanus* | Great-tailed Grackle | P | | ✓ | ✓ | ✓ | ✓ | ✓ |
| *Molothrus aeneus* | Bronzed Cowbird | N | | | ✓ | | ✓ | ✓ |
| *Molothrus ater* | Brown-headed Cowbird | N | | ✓ | ✓ | | ✓ | ✓ |
| *Icterus cucullatus* | Hooded Oriole | N | | ✓ | | | | |
| *Icterus bullockii* | Bullock's Oriole | N | | ✓ | | | | |
| *Carpodacus mexicanus* | House Finch | P | ✓ | ✓ | ✓ | | ✓ | |
| *Carduelis psaltria* | Lesser Goldfinch | P | | ✓ | ✓ | | | |
| | | | | | | | | |
| **Total Number of Species** | | | 16 | 39 | 37 | 6 | 16 | 17 |
| **Permanent Residents** | | | 11 | 21 | 21 | 4 | 8 | 11 |
| **Neotropical Migrants** | | | 5 | 18 | 16 | 2 | 8 | 6 |

Status:
P – Permanent Resident
N – Neotropical Migrant

Habitat Types:
CBA – Creosote Bush Association
MPV – Mesquite/Palo Verde Association
TW – Tamarisk/Willow Association
RB – Recharge Basin (no natural vegetation remaining)
FO – Fly-over
AA – Adjacent Agricultural Areas

Table C-2. Additional Bird Species Reported by ENTRANCO (1998).

| Scientific Name | Common Name |
|---|---|
| | |
| *Plegadis chihi* | White-faced Ibis |
| *Nycticorax nycticorax* | Black-crowned Night-Heron |
| *Parabuteo unicinctus* | Harris's Hawk |
| *Himantopus mexicanus* | Black-necked Stilt |
| *Actitis macularia* | Spotted Sandpiper |
| *Geococcyx californianus* | Greater Roadrunner |
| *Aeronautes saxatalis* | White-throated Swift |
| *Sayornis sayi* | Say's Phoebe |
| *Contopus sordidulus* | Western Wood-Pewee |
| *Pyrocephalus rubinus* | Vermilion Flycatcher |
| *Myiarchus tyrannulus* | Brown-crested Flycatcher |
| *Vireo plumbeus* | Plumbeous (Solitary) Vireo |
| *Corvus cryptoleucus* | Chihuahuan Raven |
| *Tachycineta thalassina* | Violet-green Swallow |
| *Regulus calendula* | Ruby-crowned Kinglet |
| *Mimus polyglottos* | Northern Mockingbird |
| *Sturnus vulgaris* | European Starling |
| *Piranga rubra* | Summer Tanager |
| *Piranga ludoviciana* | Western Tanager |
| *Icterus parisorum* | Scott's Oriole |

## APPENDIX D. PLANT SPECIES.

**Table E-1.** High Plains Effluent Recharge Project – Plant Species Observed on Project Site.

| Family | Species | Common Name |
|---|---|---|
| Amaranthaceae | *Amaranthus (palmeri?)* | Pigweed |
| Asteraceae | *Baccharis salicifolia* | Seep willow |
| | *Baccharis sarothroides* | Desert broom |
| | *Cirsium* sp. | Thistle |
| | *Heterotheca subaxillaris* | Camphorweed |
| | *Hymenoclea monogyra* | Cheeseweed burrobrush |
| | *Isocoma tenuisecta* | Burroweed |
| | *Pectis* sp. | Fetid-marigold |
| | *Silybum marianum* | Milk thistle |
| | *Sonchus (oleraceus?)* | Common sowthistle |
| | *Xanthium strumarium* | Cocklebur |
| Bignoniaceae | *Chilopsis linearis* | Desertwillow |
| Boraginaceae | *Amsinckia* sp. | Fiddleneck |
| | *Cryptantha* sp. | Popcorn flower |
| | *Heliotropium curassavicum* | Salt heliotrope |
| Cactaceae | *Opuntia (spinosior?)* | Cane cholla |
| Caprifoliaceae | *Sambucus nigra* | Mexican elder |
| Chenopodiaceae | *Atriplex canescens* | Fourwing saltbush |
| | *Salsola tragus* | Russian thistle |
| Cruciferae | *Descurainia* sp. | Mustard |
| Cyperaceae | *Scirpus* sp. | Bulrush |
| Ephedraceae | *Ephedra* sp. | Ephedra |
| Fabaceae | *Medicago* sp. | Clover |
| | **Olneya tesota* | Ironwood |
| | **Parkinsonia florida* | Blue paloverde |
| | *Parkinsonia aculeata* | Mexican paloverde |
| | *Prosopis velutina* | Velvet mesquite |
| Geraniaceae | *Erodium cicutarium* | Filaree |

| | | |
|---|---|---|
| Lamiaceae | *Marrubium vulgare* | Horehound |
| Loasaceae | *Mentzelia* (*pumila*?) | Dwarf blazing star |
| Oleaceae | **Fraxinus* sp. | Ash |
| Poaceae | *Cynodon dactyon* | Bermuda grass |
| | *Sorghum halepense* | Johnson grass |
| Polygonaceae | *Polygonum* sp. | Polygonum |
| | *Rumex* (*hymenosepalus* ?) | Canaigre |
| Portulacaceae | *Portulaca* (*oleracea*?) | Common purslane |
| Salicaceae | *Salix gooddingii* | Goodding willow |
| Solanaceae | *Datura* sp. | Datura |
| | *Nicotiana glauca* | Tree tobacco |
| | *Solanum* (*elaeagnifolium*?) | Silverleaf nightshade |
| | *Solanum rostratum* | Buffalobur |
| Tamaricaceae | *Tamarix aphylla* | Athel |
| | *Tamarix* sp. | Salt cedar |
| Scrophulariaceae | **Leucophyllum frutescens* | Texas ranger |
| | *Veronica* sp. | |
| Zygophyllaceae | *Larrea tridentata* | Creosote bush |

*Planted species.

# APPENDIX E. DOCUMENTARY PHOTOGRAPHS.

Edge Match A ►

◄Edge match A

Figure E-1. Panoramic photograph, 35 mm lens, August 28, 2002, from west photo point (see Figure 2)

Edge Match B ▶

◀Edge Match B

Figure E-2. Panoramic photograph, 35 mm lens, August 28, 2002, from east photo point (see Figure 2)

Figure E-3a. Vegetation Plot C-2, Creosote Bush Association, view north, August 28, 2002, 55-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.

Figure E-3b. Vegetation Plot C-2, Creosote Bush Association, view north, August 28, 2002, 35-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.


Figure E-3c. Vegetation Plot C-2, Creosote Bush Association, view south, August 28, 2002, 55-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.

Figure E-3d. Vegetation Plot C-2, Creosote Bush Association, view south, August 28, 2002, 35-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.

Figure E-4a. Vegetation Plot C-6, Creosote Bush Association, view north, September 4, 2002, 55-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.

Figure E-4b. Vegetation Plot C-6, Creosote Bush Association, view north, September 4, 2002, 35-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.

Figure E-4c. Vegetation Plot C-6, Creosote Bush Association, view south, September 4, 2002, 55-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.

Figure E-4d. Vegetation Plot C-6, Creosote Bush Association, view south, September 6, 2002, 35-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.

Figure E-5a. Vegetation Plot M-3, Mesquite-Palo Verde Association, view north, September 18, 2002, 55-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.

Figure E-5b. Vegetation Plot M-3, Mesquite-Palo Verde Association, view north, September 18, 2002, 35-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.

Figure E-5c. Vegetation Plot M-3, Mesquite-Palo Verde Association, view south, September 18, 2002, 55-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.

Figure E-5d. Vegetation Plot M-3, Mesquite-Palo Verde Association, view south, August 28, 2002, 35-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.

Figure E-6a. Vegetation Plot M-5, Mesquite-Palo Verde Association, view north, September 4, 2002, 55-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.

Figure E-6b. Vegetation Plot M-5, Mesquite-Palo Verde Association, view north, September 4, 2002, 35-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.

Figure E-6c. Vegetation Plot M-5, Mesquite-Palo Verde Association, view south, September 4, 2002, 55-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.

Figure E-6d. Vegetation Plot M-5, Mesquite-Palo Verde Association, view south, September 4, 2002, 35-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.


Figure E-7a. Vegetation Plot T-4, Tamarisk-Willow Association, view north, September 11, 2002, 55-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.

Figure E-7b. Vegetation Plot T-4, Tamarisk-Willow Association, view north, September 11, 2002, 35-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.


Figure E-7c. Vegetation Plot T-4, Tamarisk-Willow Association, view south, September 11, 2002, 55-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.

Figure E-7d. Vegetation Plot T-4, Tamarisk-Willow Association, view south, September 11, 2002, 35-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.

Figure E-8a. Vegetation Plot T-7, Tamarisk-Willow Association, view north, September 18, 2002, 55-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.

Figure E-8b. Vegetation Plot T-7, Tamarisk-Willow Association, view north, September 18, 2002, 35-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.

Figure E-8c. Vegetation Plot T-7, Tamarisk-Willow Association, view south, September 18, 2002, 55-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.

Figure E-8d. Vegetation Plot T-7, Tamarisk-Willow Association, view south, September 18, 2002, 35-mm lens. Black and white board is 25 x 50 cm and 4 m from lens.