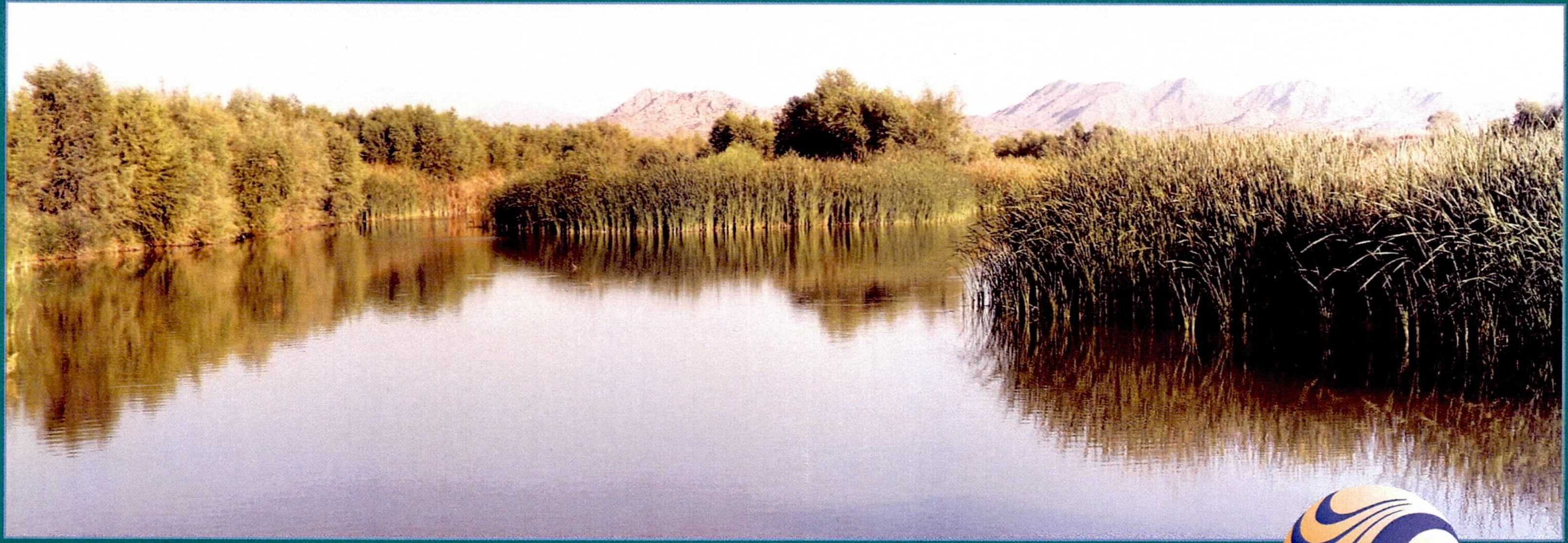
Attachment 7
ENVIRONMENTAL RESOURCES REPORT

El Rio Watercourse Master Plan and Area Drainage Master Plan

Contract FCD 2001C024
Stantec Project No. 82000240



July 2003

Flood Control District of Maricopa County

Stantec

FINAL REPORT

El Rio Watercourse Master Plan

EL RIO ENVIRONMENTAL RESOURCES REPORT

EXECUTIVE SUMMARY

PREPARED FOR:

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of
Maricopa County

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EXECUTIVE SUMMARY

The El Rio Project Area

The Flood Control District of Maricopa County (District) has embarked on an important project to prepare a Watercourse Master Plan (WCMP) for a 17.5-mile stretch of the Gila River. This WCMP is known as the El Rio project. The El Rio project area is a complex mosaic of interconnected and interdependent resources. The area includes the river bottom, stream banks, floodway, and portions of the adjacent flood plain, on both sides of the Gila River floodway. The project area also includes the terrestrial and aquatic ecosystems and the communities that are dependent on these hydrological resources.

The project area extends from the confluence of the Gila and the Agua Fria Rivers, downstream to the State Route 85 Bridge. This 17.5-mile stretch of river bottom and the adjacent floodway are currently free of major dams or diversion structures, although there are several important water intakes and outfalls for irrigation water. Major bridges span the floodway at half a dozen locations. Land ownership is mixed, with a majority of lands along the floodway managed by county, state and federal agencies. Private parcels abut the public lands along the floodway. Loose networks of unmaintained trails and off-road vehicle tracks provide access for hikers, campers, boaters, fishermen, bird watchers, and other recreationists. A looser network of wildlife trails and travel corridors connects various habitat types that provide food, cover, nesting, rearing, migration, and hunting areas for important native and introduced aquatic and terrestrial wildlife species. There are two federally protected species that are listed as threatened or endangered; a third species is a candidate for listing, and must also be considered in the El Rio project area. These protected species rely on the riparian area along the river bottom for habitat. There are many user groups with vested interests in the fate of the El Rio project area.

There are currently no developed recreation amenities in the project area, although a regional park is adjacent to the upstream end of the project area. There are no public facilities for water, sanitation, telephone, parking, or trash services. There are no formal security or emergency services dedicated to the project area.

Periodic flooding has continued to define the project area in many ways. The Gila River floodway is scoured by flood actions on a recurring cyclical basis. Significant floods occur about once each decade. Upstream dams and diversions on the Salt River, Gila River, and on the Agua Fria manage seasonal flooding on the major tributaries above the El Rio project area. These dams have affected the hydrology and water quality of the project area by reducing peak flood flows. These peak flows have been replaced by extended flow periods when irrigation return water and treated effluent dominate the sources of water. The historically seasonal flows have been modified by water management and flood control, but major floods such as occurred in 1993, still define the stream channels, determine the river bottom vegetation, and affect adjacent and downstream communities in the floodplain. It is these major flood events that drive the need for a more effective flood management program for the El Rio project area.

This environmental resources report presents the results of field studies, archival research, community studies, agency interviews, and interdisciplinary team discussions, as an introduction to developing opportunities and identifying constraints for protection, maintenance, enhancement, and management of the resources in the El Rio project area.

Background to El Rio Project

The Gila River has been the source of eight significant flood events since 1891. These floods have severely damaged property and disrupted the local commerce. Recent flood management efforts date to 1987, when advance planning efforts led by the District and involving more than 20 local, city, county, Native American Communities, and other user groups were underway on an extensive 97-mile stretch of the Gila and Salt Rivers. This scale of planning effort proved to be too complex and ambitious for available funding, and smaller units of floodway were identified.

In 1999, community leaders and officials identified the 17.5-mile El Rio project area as a candidate for development of a Watercourse Master Plan using innovative multiple use management programs. At the same time, the realities of public and agency expectations for flood control programs were integrating environmental resource protection, mitigation, and enhancement with the more traditional goals of floodwater management using confinement, retention and diversion.

The scope and approach for the El Rio Watercourse Master Plan were developed by application of the District vision and mission statements.

District Vision and Mission Statements

The mission statement of the District includes a statement regarding environmental resources. This statement is presented here as it forms the charter and the basis of the El Rio Watercourse Master Plan.

> "The **vision** of the District is that the people of Maricopa County and future generations will have the maximum amount of protection from the effects of flooding through fiscally responsible flood control actions and multiple-use facilities that complement or enhance the beauty of our desert environment.
>
> The **mission** of the District is to provide flood control hazard programs benefiting Maricopa County that prevent loss of life or injury to residents and the elimination or reduction of damages to real and personal property from flooding while enjoying the natural and beneficial values served by floodplains."

In carrying out these vision and mission statements, the District has committed planning efforts to the Gila River through the El Rio Watercourse Master Plan.

El Rio Vision Statement, Mission Statement, Goals and Objectives

Large floods in 1978, 1980, and 1993 kept the public and the District focused on the El Rio project area as a critical part of public asset and resource protection. The 1993 floods in particular, affected public and private assets. Entire stretches of mature, native riparian habitat, as well as stream channels themselves, were overwhelmed, eliminated, or relocated by high floodwaters. Community costs were such that local officials and the District addressed the area with renewed planning attention. One result of these advance planning efforts was the document entitled: *The EL RIO Vision, Multi-Agency Review and Response to Planning and Policy*

Opportunities on the Gila River. This El Rio Vision guides the present environmental studies. As stated in an initial letter to the US Army Corps of Engineers:

> "The Gila River has the potential to be restored, enhanced, and to provide multiple uses such as ecosystem restoration, water quality improvements, flood control, natural environmental recreation experiences, and other recreational opportunities"

In 1999, a Mission Statement was derived from the El Rio Vision.

> "Restore the river,
> Retain heritage landscape character,
> Focusing on multiple use,
> Linked to the surrounding communities, through public-private partnerships
> While enhancing public safety with flood control measures."

During a three-month process of workshops, this Mission statement was restated in October 1999 as a series of five objectives that should shape any future planning efforts:

- Restore And Maintain The Natural Functions Within The River Corridor (As A) Riparian Habitat
- Focus On Multi-Use Facilities And Functions
- Maintain Or Enhance Flood Control Elements Or Mitigate
- Focus On Public/Private Partnerships
- Link Functional Compatibility Outside The Riparian Habitat Limits

Each of the five El Rio Vision objectives has been broken down into more detailed lists of goals. Some, but not all, of the goals are environmental in nature. The fieldwork and research reported in the Environmental Resources Report is meant to provide the technical basis and background to help achieve these goals. It is expected that the El Rio Watercourse Master Plan will be developed, evaluated, and implemented to restore, enhance, or protect these environmental values and goals. These environmental values and goals are revisited at the end of the Executive Summary. The next step in the process will be to determine how the conclusions and recommendations can be integrated with the El Rio Vision goals and objectives.

TECHNICAL ENVIRONMENTAL CONSIDERATIONS

The technical sections that follow are developed to allow both qualitative and quantitative evaluation of resource values within the El Rio project area. To aid in this evaluation, the project area ecosystem has been approached as having three separate major functional components: physical, biological, and anthropogenic resources. Clearly these are interconnected and interdependent in the mosaic of habitat types and ecosystem functions.

Each of these major resource categories contains both opportunities and constraints for development of flood management plans, practices and activities. The environmental resources report presents the most significant elements of these three major resource areas, so that the development of flood management alternatives can achieve a suitable balance between what are sometimes seen as competing issues and values. Each of the three sections of the environmental resource report is derived from a combination of archival information and field data collected by the EL Rio project team during the fall of 2002 and spring of 2003.

PHYSICAL AND WETLAND RESOURCES SECTION

Surface Water Quantity

Existing and potential riparian resources in the desert environment are totally dependent on water. Sustainable riparian areas require a dependable water supply with adequate water quality. Fluctuations in both amount and quality are tolerable within limits, and the desert riparian plant species are more tolerant than most. Seasonal and cyclical drought and flooding are facts of life for the native cottonwood and willow plant community. In the El Rio project area these cycles have changed due to land and water resource development in every major tributary. The remaining riparian community within the project area proves the tenacity of desert species to survive even in the face of change. Water quantity and quality affect riparian vegetation habitat types and the potential for restoration and enhancement of these valuable resources; these are discussed in the sections following.

Upstream development has altered the perennial character of the Gila River. Peak spring flood flows have been retained behind upstream dams, distributed to municipalities, and diverted onto agricultural fields. Low fall and summer flows have been sustained by recycled and reused wastewater. Groundwater levels have changed due to pumping and recharge. However, the El Rio project area still contains substantial surface water. Even in seasons of drought years, open water is found along most of the El Rio project area. These water bodies provide an adequate water supply to effect sustainable economical restoration of the three classes of riparian vegetation habitats in the El Rio project area: xero-riparian (includes drought tolerant plants), hydro-riparian (water dependent plants) and wetland ecosystem (saturation dependent plant species).

Surface water sources for the area are precipitation, treated effluent, agricultural irrigation drains, and canal discharges. Also important is the geological setting, which is characterized by relatively shallow depth to groundwater. The shallow groundwater tables and multiple surface water inputs mentioned above, provide flexibility in approaching ecosystem restoration in the El Rio project area.

The amount of surface water and depth to groundwater affects the restoration potential and methodologies that can be used the project area. Shallow groundwater tables allow use of economical pole planting techniques for establishing dominant riparian species. Shallow groundwater combined with the surface water inputs should also reduce the cost of establishing or enhancing wetland and aquatic habitat features. Vegetation management achieved through the replacement of terrestrial species with wetland plants or open water aquatic areas via excavation will also be more cost effective because of the reduced amount of material to be removed.

Because annual precipitation is low (approximately 7 inches/yr) and its occurrence is variable, restoration efforts should not rely upon runoff as a primary water source. Runoff could however be used to augment wetland irrigation systems in appropriate locations. Treated effluent is likely the most consistent and reliable year around contributor of surface water to the El Rio project area. Agricultural irrigation and dewatering discharges are secondary. Combined with the presence of shallow groundwater, existing surface water sources appear sufficient to support restoration efforts in some areas.

Conclusions and recommendations made on the basis of water quantity within the project area:

- Surface water flows are adequate to restore and sustain diverse riparian communities
- Maintenance of surface water flows will be required to sustain desirable riparian communities
- Groundwater is currently shallow enough to allow economical pole planting techniques
- Stormwater runoff is not adequate, by itself, to allow sustainable riparian communities in the project area, and irrigation would be required outside of the shallow groundwater areas

Surface Water Quality

Riparian and aquatic communities that are desirable and diverse are dependent on adequate water quality. Although short-term fluctuations can be tolerated during a flood event, consistent quality of water is required for regeneration of plants and for reproduction of aquatic species. The species of plants and animals found in the El Rio project area have become adapted or selected to tolerate the seasonal water quality variations found in this low humidity and high evaporation desert environment. The less tolerant plant and animal species have been eliminated or become less abundant within the project area.

The surface water quality of the El Rio project area is also influenced by local and regional drainage. Regional surface flows occur in response to releases from upstream dams. The flows can mobilize and transport contaminants to the project area from throughout the contributing watershed. Locally, the major surface water sources in the project area are treated effluent, dewatering wells, agricultural return flows, and stormwater runoff. There is a close interaction between the soils and the water quality in some areas along the fringe of the riparian area. Here is where salts accumulate in the soil as water is evaporated in summer, and water quality is affected as salts leach out when soils are saturated during runoff events.

The Gila River in the El Rio project area is designated as an effluent dominated stream by the Arizona Department of Environmental Quality (ADEQ). It is fed primarily from 91st Avenue Wastewater Treatment Plant (WWTP) effluent and agricultural return flows. Historical quality of water in the river has been poor. High residual pesticide and trace metal concentrations have resulted in contaminated fish; a human health advisory is in place warning against consumption of fish and shellfish. Because of these issues, planning and conceptual design restoration alternatives should include a complete characterization of proposed water sources. The characterization would assess the need for pretreatment and or to identify water quality issues that may not meet guidelines for protection of human health or wildlife. A summary of water quality concerns from the various sources is shown on the table below.

Summary of Water Quality Concerns from Sources in the El Rio Project Area

	Dissolved Oxygen	pH	Nutrient	Pathogens	Metals	Organics
WWTP Effluent	X	*	X	X	X	X
Agricultural return flows	X	*	X	X	X	X
Dewatering flows		X	X			
Animal operations	X	X	X	X		X
Stormwater	X	X	X	X	X	X

* pH may become an issue in cases where nutrients are excessive.

Conclusions and recommendations made on the basis of water quality within the project area:

- Water quality concerns are based on levels of pathogens, trace metals, pesticides, nutrients, and organic compounds
- Due to the nature of effluent dominated waters, full body contact recreation and potable water uses are not advisable
- Consumption of aquatic fish and wildlife is not advisable at this time
- Development of recreational opportunities that encourage consumption of fish is not advisable
- Movement of water through the system is recommended to maintain dissolved oxygen and to prevent stagnation
- Dissolved solids levels will require occasional leaching or flushing of soils to prevent salt buildup

Revegetation Potential

The wetland and riparian habitat types currently in place within the project area are modified from historical conditions. The current conditions support twelve vegetative cover types in the El Rio project area. These cover types are typified by plant communities with varying salinity and moisture tolerance. Historical plant communities were probably similar in nature, but significantly different in distribution. Salt cedar, now the dominant species in the project area, was not present in historical times, and there were no salt cedar dominated community types. This aggressive species has little habitat value for wildlife, impedes flood flows, consumes enormous volumes of water, degrades soil with salt accumulations, and can lead to extreme fire hazard conditions. On the positive side, salt cedar is recognized by land management agencies for its cover values because there are few other species so able to produce thick impenetrable shelter for wildlife.

An opportunity exists to preserve the remaining high quality habitat and to enhance marginal habitat in the El Rio project area. This can ultimately be achieved through selective removal and replacement of exotic species with open water, wetland marsh, native-riparian and upland vegetative communities, where appropriate. Creation of additional high quality native habitat, where none is present, is also possible within some areas of the El Rio project area. The selection of type and location will be subject to appropriate soil conditions and available water.

Conclusions and recommendations made on the basis of wetland communities within the project area:

- Protect highest quality habitat types such as wetland marsh, cottonwood, willow, and other plant communities dominated by native species
- Restore and enhance higher quality habitat types such as native cottonwood and willow, through conversion of poor quality types such as salt cedar, where conditions are favorable
- Remove exotic species, replacing them with open water, wetland marsh, and native riparian in areas where conditions are favorable
- Enhance and upgrade lower quality upland habitat types where soil and water quality allow

Soil

Salinity and potential contamination are the two primary concerns with respect to soils and the establishment and maintenance of native riparian and wetland plant species in the El Rio reach of the Gila River. Soil forms the fundamental base for vegetation productivity, diversity, and sustainability. Soil types in an area are generally derived from a combination of weathered products of underlying bedrock geology, sediments left by wind or water, and organic material derived from plant growth. Soil types are described by parameters such as mineral content, structure, grain size, porosity, permeability, fertility, depth, source, trace metal content, salinity levels, and many others.

Specific soil data are lacking in the project area, but the vegetation type and the appearance of salt deposits on the soil surface indicates that soil salinity increases in the direction of river flow. This is reasonable because the El Rio reach of the Gila River is historically an area of increased salinity resulting from its location near the downstream end of a large contributing watershed and arid climate conditions. The dominance of salt tolerant vegetation indicates that existing soil conditions in the El Rio project area have elevated salinity. Native riparian species such as cottonwood and willow have lower salt tolerance than salt cedar and other species.

Select contaminants such as heavy metals and hydrophobic pesticides and herbicides may adhere to the surfaces of soil particles. Contaminated particles are then transported via runoff to the receiving water bodies where they can influence water quality and impact both flora and faunal fitness.

Sediment sampling and quality analysis have been conducted in the El Rio project area but the data are dated and considered insufficient for formulation of prudent restoration decisions. The existing data indicates a potential for extreme soil salinity values and soil contamination from organic compounds and heavy metals.

Specific soil recommendations are:

- Conduct agronomic testing on soils at proposed sites for active restoration of native vegetation
- Identify soil conditions that pose limitations for project facilities using site assessments

- Consider leachability of contaminants for soils in areas that may be developed as permanent open water areas.
- Consider soil banking or stockpiling from sand and gravel operations to provide high quality sources of fine materials for restoration and mitigation

Nuisance Insect and Vector Populations

The water resources within the El Rio project area provide aesthetic, recreational, and wildlife habitat opportunities. Water resources include streams, large and small ponds, side pools, and marsh wetlands. The nature of the lentic systems also provides opportunities for development of nuisance and vector insects, particularly midgeflies and mosquitoes. Historical data collected within and near the project boundaries document the presence of these organisms, sometimes in very high numbers. Midgeflies are associated with disruption of work and recreational activities, and possibly allergic reactions. Mosquitoes can carry a number of disabling diseases that impact humans, wildlife, and domestic animals. Establishing an ecological balance through an integrated pest management plan that incorporates vegetation and water resource management, enhancement of natural predator habitat, and judicious use of target-specific larvicides can minimize the development of midge and mosquito populations and help achieve project goals.

Specific vector control recommendations for the project area:

- Nuisance and vector species exist, sometimes in high numbers, and will require control
- Locate, design, and manage facilities with consideration of vectors
- Encourage biological control of vectors by optimizing conditions such as water depths and water levels for natural predators
- Larvicides and pesticides may be required elements of integrated management plans

BIOLOGICAL RESOURCES SECTION

Plant community types are the basic building blocks of an ecosystem the size of the El Rio project area. The plant community defines the types and diversity of animals that depend on the plants for primary productivity and food. Animals also may depend on the plants for ambush cover, nesting materials, perches, shade, moisture, territory demarcation, and shelter from predators. Plant communities in turn are defined by soil type, ground water level, seasonal variation, slope aspect, soil depth, and other variables. Soil types and other parameters are difficult to define and more difficult to map. However, plant community types can be readily identified in the field and from aerial photography. By identifying the types and extent of plant communities, and correlating these with other beneficial resource values, ecologists and planners can gauge the success, health, and rates of change of ecosystems. For this report, the terms plant community, vegetation community type, plant cover type, and vegetation habitat type can be considered synonymous. Each of these interchangeable terms describes a collection of plant species that can be recognized by the primary dominant species.

Plant Communities within the Study Corridor

Twelve distinct plant communities were identified by ground-truthing both aerial photos and infrared photographs of vegetation communities within the El Rio project area. Vegetative communities classified in the project area have been adapted from Anderson and Ohmart (1984), with changes and additions based on local conditions. Based on a review of aerial photos, combined with known vegetation cover characterizations, and photos taken in the field, vegetative communities and cover types were mapped.

The distribution of vegetation cover types shown below is a snapshot of the El Rio project area in 2002/2003. Salt cedar dominates the area at 54.5% of the riparian vegetation within the project area. This monotypic vegetation type, when combined with 38.2 % cobble strand (barren sand and gravel bars), makes up over 90 % of the habitat types.

El Rio Vegetative Cover Types

Cover Type	Acreage	% of Total
Salt Cedar	4,349	54.5 %
Cobble Strand	3,048	38.2 %
Saltbush/Quail brush	179	2.2 %
Willow/Salt Cedar	168	2.1 %
Cottonwood/Willow	100	1.3 %
Arrow-weed/Willow/Salt Cedar	49	0.6 %
Salt Cedar/Cottonwood/Willow	33	0.4 %
Arrow-weed/Willow	32	0.4 %
Marsh 1 and Marsh 2 (combined)	17	0.2 %
Sonoran Desert scrub	na	na
Agricultural	na	na
Total	7,975	100.0 %

Note to table: agricultural lands and Sonoran desert scrub are not included in the acreage figures, because they are considered to be outside of the floodway.

Specific vegetation community recommendations are:

- The salt cedar/cottonwood/willow community presents the best opportunity for enhancement
- Restoration and enhancement projects must be self-sustaining
- Preserve the existing marsh habitat wherever possible
- Increase marsh habitat wherever possible
- Protect or enhance existing habitat types with willow as a component
- Increase all habitat types with cottonwood or willow as a component
- Reduce or eliminate salt cedar habitat in favor of all habitat types except cobble / strand
- Evaluate replacement of monotypic salt cedar habitat with native mesquite bosque

Endangered Species Habitat within the Study Corridor

Most species are adaptable to several different vegetation communities and habitat types. Some species are adaptable to almost any type. Others are obligated and dependent on only specific types or even specific types within specific climatic or elevation limitations. As is often the case, more specific habitat requirements serve to limit the species distribution. And where very specific habitat requirements are coupled with limited connectivity between like habitat types, marginal suitability of habitat, and disruption of breeding cycles or disease, some species cannot maintain sustainable numbers. These are the species that become protected through federal designation as threatened or endangered. Failure to reestablish an endangered species can result in regional elimination from an area of suitable habitat, extirpation, or even extinction. For these reasons, special attention has been made to identify species, habitat requirements, and areas of suitable or restorable habitat, which meets the specific needs of threatened and endangered species in the El Rio project area. For this study, habitat type is seen as a subset of vegetation community type or types.

Two endangered species and one candidate species potentially inhabit the El Rio project area. The two endangered species are: the Yuma clapper rail (YCR), one of seven North American bird subspecies of clapper rail, and the southwestern willow flycatcher (WIFL), a riparian obligate bird species restricted to dense stands of vegetation along perennial waters. The candidate species is the yellow-billed cuckoo (YBC), a relatively rare bird species that occurs in mature native riparian stands of cottonwood and willow and large mesquite bosques.

Important Wildlife Habitat

Some habitat types are more diverse than others, some are more productive, and some are more rare. It is not always the case that rare habitat is more valuable to the ecosystem, but it is common that the more rare is home to the more restricted, less adaptable species. The more uncommon a habitat type, the more difficult it becomes for the species dependent on that habitat to move or increase its range. For these reasons the El Rio study has focused on the identification and location of the less common habitat types and features.

Certain vegetation cover types have been associated with the protected species, and are given special planning status. Other plant and wildlife species benefit as well from habitat improvements that are undertaken for special status and protected species. Marsh habitat in the project area should be preserved and if possible enhanced to benefit the YCR. The plant communities of salt cedar/cottonwood, arrow-weed/willow/salt cedar, arrow-weed/willow, salt cedar/cottonwood/willow, cottonwood/willow and willow/salt cedar should be considered potentially suitable habitat for the WIFL when they occur adjacent to perennial water, and given the appropriate level of protection. Although the YBC populations have declined in this area of the Gila River, their continued presence on the eastern and western ends adjacent to the project area indicates the species' willingness to occupy similar habitats as are found in the El Rio project areas. All the larger native deciduous galleries and mixed native/non-native stands adjacent to perennial water should be preserved. In addition, since the study area includes dense stands of exotic and native plant communities and perennial water, the entire study area could be considered a travel corridor for this species.

The larger deciduous stands should be preserved, and overspray from insecticide spraying in the agricultural areas should be kept away from the riparian areas of the river corridor. Surveys for the affected species may be warranted in suitable habitat areas if they are to be impacted by any project activities.

Field survey crews have identified other important wildlife habitat types. Numerous beaver lodges and dams were encountered in the project area. These structural modifications to the open water and marsh systems are often constructed at the expense of adjacent stands of willow and cottonwood. In the short term this harvest of mature trees can be a setback to restoration and management efforts. In the long term a balance of beaver populations and cottonwood willow habitat goals will be required.

Heron rookeries were found at two locations in the project area. These rookeries are dependent on standing dead cottonwood trees, and other large mature trees to support the large nests. These sites have been located on the appropriate maps to allow for avoidance and protection.

Opportunity Areas for Wildlife Habitat Enhancement

The field survey data were compiled onto vegetation cover type maps that delineate the plant communities within the corridor. The team identified and evaluated endangered species habitat during these field surveys. Areas that presented opportunity for possible restoration or enhancement, and areas that contain important or unique wildlife habitat, were mapped. Each of these components from the field reconnaissance is presented within the report. The components are presented with a narrative description, supplemented with references to the appendices which contain a Geographic Information Systems (GIS) overlay map and representative photographs. Collectively, the field survey data maps include specific recommended areas for protection and enhancement of wildlife habitat.

Specific recommendations for endangered species and unique wildlife habitat types:

- Surveys for Yuma clapper rail, southwestern willow flycatcher, and yellow billed cuckoo should be conducted in areas of suitable habitat that may be impacted by project activity
- Restore or enhance all marsh habitat types to benefit the Yuma clapper rail
- Protect and enhance dense stands of vegetation along water where possible to benefit southwestern willow flycatcher
- Protect and enhance mature cottonwood and willow habitat type to benefit yellow billed cuckoo
- Temporal losses of habitat need to be considered when removing large expanses of any plant community

- Avoid the two known heron rookeries
- Avoid the known egret roosts
- Protect and avoid known nesting locations for all protected species
- Overspray from insecticide spraying in the agricultural areas should be kept away from the riparian areas of the river corridor
- Create or enhance suitable habitat types for protected species wherever possible
- Remove or reduce exotic species where encroachment into suitable habitat lessens its habitat value to protected species of wildlife
- Design flood control facilities to be compatible with beaver populations
- Develop a beaver management protocol
- Public access needs to be controlled and limited to non-motorized travel in sensitive areas or during sensitive breeding seasons
- Project activities should result in a net increase in either habitat values or total acreage; those activities not meeting this criterion must be mitigated

ANTHROPOGENIC ISSUES AND RESOURCES

This portion of the environmental resources report characterizes the features on the El Rio project area landscape that have been influenced by human activities. In many cases these features can represent both opportunities and constraints for flood control project planners and designers. These features include sources of surface water, cultural resource sites from historical and pre-historical civilizations, hazardous waste sites, solid waste sites, and current land ownership as it relates to rules and regulations governing potential flood control projects. Each of these issues becomes important in the analysis of what can be done and where it can be done in the El Rio project area.

The anthropogenic features of the El Rio project area are described in five sections of Volume III of the Environmental Resources Report. Each topical area was reviewed or researched to allow the preparation of a mapping overlay using GIS layers so that project planning and design, as well as interested groups and stakeholders, could consider these important resource opportunities and constraints as they relate to the flood control project goals.

Open Water

The areas of open water are included in this section of the report because surface water in the project area is completely dependent on water management for commercial, municipal, and agricultural purposes. Historical aerial photos and field survey techniques were used to identify the extent of surface water in the El Rio project area during the winter period (December-March). Historic photos from wet years that showed high flood flows during the winter were not evaluated. The analysis determined that over 200 acres of surface water are present in the 17.5-mile reach of the project area. This surface water is the result of discharges of treated municipal effluent, agricultural drain waters, unused irrigation canal tailwater, as well as natural groundwater expression at the downstream end of the project area.

These discharges of surface water support habitat for aquatic plants and animals. The quality of the surface water is determined by the discharge water source as well as interactions with soil substrate and biogeochemical processes within the water column.

The analysis of aerial photographs from the last half-century determined that surface water area in El Rio appears to have increased. There was roughly twice the surface water habitat during the fall 2002-spring 2003, as compared to the surface water showing on aerial photos from the 1940-1960 period. Although the sources of the water may have changed from previous times, the aerial photographs indicate that the amount of open water habitat has not diminished over the last half century.

Recommendations for open surface water:

- Maintain or increase the amount of surface water available as aquatic habitat
- Restore or maintain adequate water quality for diverse fish and wildlife resources
- Maintain connections between surface water bodies to allow wildlife and fish migration
- Reduce active waterfowl habitat near operating airports
- Maintain continuous flows through the corridor to maintain dissolved oxygen levels
- Avoid stagnation and isolation of surface water
- Develop access for recreational fishing, while acknowledging challenges of health advisories for consumption of fish from the project area
- Improve water quality to allow removal of health advisories for consumption of fish
- Plan for beaver management and water level manipulation at selected open-water bodies

Hazardous Materials

The presence of hazardous materials in the project area would limit flood control options for areas that could be sources of contamination. Various environmental records from federal, state, county, and local agencies were reviewed by the District to identify whether hazardous material sites or potential hazardous material sites are located within or adjacent to the El Rio project area. The sites that are located in or near the project area are listed below.

- A hazardous waste generator site is located at the Gila River and the Tuthill Road Bridge. The type of hazardous material is not listed.
- The Arizona Superfund Program List contains one potential site for management under the Water Quality Revolving Fund program (WQARF); the site is known as the Middle Gila site and may be located in or within one mile of the project area. The location description for the Middle Gila site is not listed and additional research is being done to identify the location of the site. The status of the site as of April 1997 is listed as "pending preliminary investigation".
- A leaking aboveground storage tank was identified in the Gila River Floodway between the Sarival Road and Cotton Lane alignments. The tank owner and leaking substance are unknown. The leaking substance appears to be oil or diesel fuel. This site has potential for soil and groundwater contamination.
- A closed solid waste landfill is located at Miller Road and the Gila River. The former operator is listed as the Town of Buckeye.
- The ADEQ lists eleven hazardous material incident sites that may be located in the project area. One site, located at the Tuthill Bridge and the Gila River, is definitely in the project area. The other sites do not have clear location information.

When these types of hazardous material incidents are reported, the ADEQ or the identified responsible party removes the hazardous materials and mitigates resulting contamination.

If any of the El Rio project alternatives include land near the sites listed above in the summary, then more research will be conducted to find out information such as the type and extent of contamination or environmental hazards associated with these sites. Likewise, more research will be conducted if the District determines that the potential WQARF site, known as the Middle Gila River site, is within the project area and project alternatives are in the vicinity of this site. Otherwise, based on a search of the environmental regulatory records, the El Rio team should not be concerned with other hazardous material sites within or near the project area for planning purposes at this time.

As a final point, this report discusses known sites recognized by local, state, and federal environmental agencies; however, unknown hazardous sites potentially exist anywhere in the project area. Thus, a Phase I Environmental Site Assessment, which includes site inspections, will be done by the District for the final selected project alternatives and alignments prior to any property acquisition and project implementation.

Recommendation for management of hazardous materials:

- Avoid all sites with known history of hazardous materials
- Conduct site assessments to identify problem areas early in the planning process

Solid Waste Sites

Planning for the El Rio project includes consideration of unauthorized present and past solid waste disposal activity. The effort included compilation of an inventory of solid waste dumpsites in the El Rio project area. The dumpsites were identified during field reconnaissance. A GIS-compatible map showing areas of low, medium, and high solid waste densities was prepared from the inventory. A copy of the map is contained in Appendix D of this report.

Solid Waste appears to be ubiquitous in the El Rio project area. However, significant concentrations are limited to areas of easy and frequent public access. The areas of significant solid waste accumulation are west of the north end of the Estrella Parkway bridge crossing of the Gila River; within an abandoned sand and gravel mine located at the end of Miller Road adjacent to the Gila River floodway, south of the Town of Buckeye, and along a dirt road on the north bank of the Gila River between Miller Road and SR 85. An abandoned municipal solid waste landfill, formerly utilized by the Town of Buckeye, is located at the end of Miller Road. This landfill is considered to be significant because the waste was buried in-place when the facility was closed in the 1970s. The facility could be susceptible to exhumation by flooding.

Recommendations for solid waste considerations:

- Avoid sites with known history of solid waste disposal
- Remove and relocate solid wastes to legitimate landfill sites
- Conduct site assessments to identify problem areas early in the planning process
- Initiate a public education or enforcement program to eliminate illegal dumping

Cultural Resources

The El Rio project area contains numerous known significant cultural resources, as well as an unknown number of potentially significant cultural resources. If a flood control project will potentially impact any cultural resources, then measures would be taken to record and mitigate adverse effects to the cultural resources in the area. While well over 100 cultural resource sites are known to exist, only 10% of the project area has been surveyed. This limited cultural resources assessment identifies sites that should be protected, and also identifies numerous options for education, visitation and recreation as a means to achieve this protection.

Cultural resources recommendations:

- Avoid known cultural sites wherever possible
- Survey all potential disturbance areas for cultural resources
- Mitigate cultural resources where necessary
- Establish an interpretive center for educational purposes to show the rich cultural history of the area

Opportunities and Constraints

Certain types of land use and development may be constrained by the management goals of public agencies. Use and development of land within the project area for the purposes of the El Rio project will require coordination with these public agencies and private owners. It may be difficult to prevent certain uses and development on private land without the cooperation of the landowners and the assistance of county and municipal planning and zoning authorities.

Opportunities to implement components of the El Rio project may exist where the development goals of the project can be matched with those of the landowners. To the extent that the plans and development of the El Rio project can be successfully matched with existing conditions or plans of owners of public and private land in the project area, opportunities for environmental development or enhancement will be realized.

Recommendations for project implementation:

- Detailed recommendations from landowners and agencies that would apply to specific parcels are included in technical sections to this report

- Structural controls should be kept to a minimum and used only if non-structural controls are not an option
- Provide increased law enforcement presence if public access in increased
- The floodplain should be protected from encroachment from non-compatible uses

Environmental Aspects of the Five Objectives of El Rio Vision

The five objectives from the 1999 El Rio Vision are shown below. To aid in moving forward with the identification, evaluation, and implementation of alternatives for the El Rio Watercourse Master Plan, the goals for each of these five objectives are presented. These goals will become the specific environmental line items used in a matrix methodology to compare alternatives, as they are developed to achieve the El Rio project objectives. How each of these environmental aspects and goals will be advanced is the task of the next phase of the El Rio project: formulation and evaluation of alternatives for the El Rio WCMP.

1. Restore And Maintain The Natural Functions Within The River Corridor (As A) Riparian Habitat
    - Create diversity of vegetation
    - Restore disturbed areas
    - Control undesirable activities
    - Incorporate sand and gravel operations
    - Attain higher habitat value
    - Reintroduce historic landscape character to the river
    - Incorporate sediment transport and sand and gravel activity to maintain restoration
    - Identify a reference reach within the corridor
    - Identify potential demonstration projects
    - Coordinate with Tres Rios and Agua Fria Watercourse Master Plan projects
    - Consider aviation impacts to the Goodyear Airport
    - Convey flood flows
    - Provide open flow throughout the reach

2. Focus On Multi-Use Facilities And Functions
    - Emphasize community needs

- Educational-interpretive center
- Nature elements such as trails, bird watching, etc.
- Research site
- Develop compatible activities/policies
- Mixed use residential plan
- Link up with the Estrella Regional Park
- Identify entry points and vista points close to bridges
- Fishing opportunities to be developed
- Improve water quality
- Coordinate plans with transportation corridors
- Potable water supply
- Riverside scenic drive
- Integrate local access with regional network
- River walk
- Bike paths

3. Maintain Or Enhance Flood Control Elements Or Mitigate

    - Remove construction from the river
    - Consider over-bank storage (off-line basin, lakes, open space)
    - Increased capacity by dredging
    - Increase width of river
    - Minimize structural solutions
    - Protect and/or mitigate existing uses
    - Level of protection
    - Tributary flows
    - Enhance conveyance while also providing flood protection as well as riparian restoration

4. Focus On Public/Private Partnerships

    - Utilize/incorporate sand and gravel activities
    - Adopt-a-River program

- Ducks Unlimited
- Water brokering (AIC)
- Concessions
- Developer built features
- Provide incentives to promote participation by development community
- Attract grant funding
- Educational /research partners
- Offsite mitigation
- Sustainability
- Canal water features

5. Link Functional Compatibility Outside The Riparian Habitat Limits

   - Make canals/washes a linkage with developments
   - Link Estrella Parkway with River corridor
   - Loop 303 as access; strategy component
   - Help development focus towards the river
   - Collaborate with adjacent communities' land use plans
   - Consider law and order, security, crime control by local jurisdictions
   - Develop management framework for the project, implementation and maintenance
   - How to integrate/manage the planning/implementation/maintenance
   - Consider special districts
   - Consider marketing plan
   - Consider financial plan

Many of the goals above have significant environmental aspects. As each alternative technology or management approach is developed and evaluated for application in the El Rio Watercourse Master Plan, these goals can be rated. In a qualitative sense, the proposed project components will have either a beneficial, detrimental, or neutral affect on the ecosystems and functions of the riparian systems along the El Rio project area. In a quantitative sense, each proposed project component could have either a strong, light, or moderate level of affect. There are going to be cases where project components can have both positive and negative affects at different times, at different places, and on different resources. It is anticipated that a mitigation plan for balancing of project affects will be derived to generate a net positive affect on all resource values within the project area.

Recommendations of Environmental Resources Team

The recommendations for each of the individual disciplines are restated here to allow use in the development and evaluation of alternatives to implement the El Rio WCMP.

Surface Water Quantity Recommendations

- Surface water flows are adequate to restore and sustain diverse riparian communities
- Maintenance of surface water flows will be required to sustain desirable riparian communities
- Groundwater is currently shallow enough to allow economical pole planting techniques
- Stormwater runoff is not adequate, by itself, to allow sustainable riparian communities in the project area, and irrigation would be required outside of the shallow groundwater areas

Surface Water Quality Recommendations

- Water quality concerns are based on levels of pathogens, trace metals, pesticides, nutrients, and organic compounds
- Due to the nature of effluent dominated waters, full-body contact recreation or potable water uses are not advisable
- Consumption of aquatic fish and wildlife is not advisable at this time
- Development of recreational opportunities that encourage consumption of fish is not advisable
- Movement of water through the system is recommended to maintain dissolved oxygen and to prevent stagnation
- Dissolved solids levels will require occasional flushing or leaching of soils to prevent salt buildup

Wetland Community Recommendations

- Protect highest quality habitat types such as wetland marsh, cottonwood, willow, and other plant communities dominated by native species

- Restore and enhance higher quality habitat types such as native cottonwood and willow, through conversion of poor quality types such as salt cedar, where conditions are favorable
- Remove exotic species, replacing them with open water, wetland marsh, and native riparian in areas where conditions are favorable
- Enhance and upgrade lower quality upland habitat types where soil and water quality allow

Soil Recommendations

- Conduct agronomic testing on soils at proposed sites for active restoration of native vegetation
- Identify soil conditions that pose limitations for project facilities using site assessments
- Consider leachability of contaminants for soils in areas that may be developed as permanent open water areas.
- Consider soil banking or stockpiling from sand and gravel operations to provide high quality sources of fine materials for restoration and mitigation

Vector Control Recommendations

- Nuisance and vector species exist, sometimes in high numbers, and will require control
- Locate, design, and manage facilities with consideration of vectors
- Encourage biological control of vectors by optimizing conditions such as water depths and water levels for natural predators
- Larvicides and pesticides may be required elements of integrated management plans

Vegetation Community Recommendations

- The salt cedar/cottonwood/willow community presents the best opportunity for enhancement
- Restoration and enhancement projects must be self-sustaining
- Preserve the existing marsh habitat wherever possible
- Increase marsh habitat wherever possible
- Protect or enhance existing habitat types with willow as a component
- Increase all habitat types with cottonwood or willow as a component
- Reduce or eliminate salt cedar habitat in favor of all habitat types except cobble / strand
- Evaluate replacement of monotypic salt cedar habitat with native mesquite bosque

Recommendations for Endangered Species and Unique Wildlife Habitat

- Surveys for Yuma clapper rail, southwestern willow flycatcher, and yellow billed cuckoo should be conducted in areas of suitable habitat that may be impacted by project activity
- Restore or enhance all marsh habitat types to benefit the Yuma clapper rail
- Protect and enhance dense stands of vegetation along water where possible to benefit southwestern willow flycatcher
- Protect and enhance mature cottonwood and willow habitat type to benefit yellow billed cuckoo
- Temporal losses of habitat need to be considered when removing large expanses of any plant community
- Avoid the two known heron rookeries
- Avoid the known egret roosts
- Protect and avoid known nesting locations for all protected species
- Overspray from insecticide spraying in the agricultural areas should be kept away from the riparian areas of the river corridor
- Create or enhance suitable habitat types for protected species wherever possible
- Remove or reduce exotic species where encroachment into suitable habitat lessens its habitat value to protected species of wildlife
- Design flood control facilities to be compatible with beaver populations
- Develop a beaver management protocol
- Public access needs to be controlled and limited to non-motorized travel in sensitive areas or during sensitive breeding seasons
- Project activities should result in a net increase in either habitat values or total acreage; those activities not meeting this criterion must be mitigated

Recommendations for Open Surface Water Habitat

- Maintain or increase the amount of surface water available as aquatic habitat
- Restore or maintain adequate water quality for diverse fish and wildlife resources
- Reduce active waterfowl habitat near operating airports
- Maintain connections between surface water bodies to allow wildlife and fish migration
- Maintain continuous flows through the corridor to maintain dissolved oxygen levels
- Avoid stagnation and isolation of surface water
- Develop access for recreational fishing, while acknowledging challenges of health advisories for consumption of fish from the project area

- Improve water quality to allow removal of health advisories for consumption of fish
- Plan for beaver management and water level manipulation at selected open-water bodies

Recommendation for Management of Hazardous Material Sites

- Avoid all sites with known history of hazardous materials
- Conduct site assessments to identify problem areas early in the planning process

Recommendations for solid waste considerations:

- Avoid sites with known history of solid waste disposal
- Remove and relocate solid wastes to legitimate landfill sites
- Conduct site assessments to identify problem areas early in the planning process
- Initiate a public education or enforcement program to eliminate illegal dumping

Recommendations for Cultural Resources

- Avoid known cultural sites wherever possible
- Survey all potential disturbance areas for cultural resources
- Mitigate cultural resources where necessary
- Establish an interpretive center for educational purposes to show the rich cultural history of the area

Recommendations for project implementation:

- Detailed recommendations from landowners and agencies that would apply to specific parcels are included in technical sections to this report
- Structural controls should be kept to a minimum and used only if non-structural controls are not an option
- Increase conveyance capacity with vegetation maintenance
- Provide increased law enforcement presence if public access in increased
- The floodplain should be protected from encroachment from non-compatible uses

Concluding Statement of the Environmental Resources Report

The El Rio project area presents an unequalled opportunity for protection, enhancement, and restoration of valuable natural riparian habitat along the Gila River. This opportunity for optimizing multiple uses of the river can be balanced with the need for improved flood conveyance. The timing for the next flood is unknown, but based on a century of records there is an average of one significant flood each decade. It is unlikely that full implementation of the El Rio Watercourse Master Plan can be completed in time to handle the next significant flood event. However, the choices of rebuilding after the next flood event can be guided by the technical recommendations in this report, and the specific goals to be developed in the next phase of El Rio master planning.

The opportunity presented by the development of the El Rio Watercourse Master Plan also comes at a crossroads in time for vegetation and wildlife in the area. The encroachment of salt cedar into upstream riparian areas of the El Rio project area continues. This encroachment displaces and replaces native cottonwood and willow stands to the detriment of native plant species dependent on shallow groundwater, to the detriment of aquatic species dependent on open water, to the detriment of wildlife species dependent on diverse plant species for food, to the detriment of landowners dependent on flood control to protect their property from flooding, to the detriment of water resources in the southwest valley, and to the consternation of flood control agencies charged with simultaneously optimizing conditions for all of the above. The time to plan a course of action is before the salt cedar has moved upstream or become so entrenched that it literally preempts the ability to consider or implement creative alternatives to radical clearing and channelizing of the floodway.

The goals are clear, the benefits are compelling, and the timing is right for the process of developing and evaluating alternatives for timely implementation.

Contributors to the Environmental Resources Report

The individuals and organizations listed below conducted field and archival research, collected and analyzed data, prepared GIS maps, and otherwise contributed technical information to the environmental resources report.

Contribution	**Name**	**Organization**
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El Rio Watercourse Master Plan

EL RIO ENVIRONMENTAL RESOURCES

PREPARED FOR:

FLOOD CONTROL DISTRICT
of
Maricopa County

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July 2003

STANTEC CONSULTING Inc.
Project No. 8200240

Contract FCD 2001C024

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INTRODUCTION

For reporting purposes, environmental resources within the El Rio project area have been divided into three major areas, which include biological, anthropogenic (human-influenced), and physical resources. Each of these major resource areas presents both opportunities and constraints for development of flood management plans, practices and activities. The environmental resources report presents the most significant elements of these three major resource areas so that the development of flood management alternatives can achieve a suitable balance between what are sometimes seen as competing issues and values. Each of the three resource reports includes a combination of archival information and field data collected by the EL Rio team during the fall of 2002 and the spring of 2003.

Significant effort has been made in all three resources areas to allow for qualitative and quantitative analysis of the key resources. The information presented in the report includes the following:

- Habitat types and associated acreages
- Acres of surface water
- Current and historical locations and areas of surface water
- Locations of unique wildlife features and valuable habitat
- Locations of problem areas and densities of nuisance species and disease vectors
- Types and location of suitable habitat types for endangered species
- Overview of the known cultural resource sites in the project area
- Guidelines for the interpretive development of cultural resources
- Locations of solid waste disposal and hazardous waste sites
- Qualitative description of effluent, discharge, and recharge water sources
- Location of effluent, discharge, and recharge waters
- Locations and types of soils in the project area
- Specific issues related to wetland management

The inventory of environmental resources has identified a mix of valuable habitat types and components. The inventory has also identified that use of these valuable resources may not be optimized in some locations. Some resource uses may be in contradiction and conflict with each other. The environmental resources report provides the basis for developing flood management approaches that can minimize resource conflicts and that will optimize resource opportunities.

ENVIRONMENTAL RESOURCES REPORT ORGANIZATION

The environmental resources report is a compilation of an executive summary and three technical sections. The executive summary provides project background and reiterates important technical findings. Each technical section presents information on a different type of resource. The report sections are: physical and wetland resources, biological resources, and anthropogenic issues and resources.

The first section of the report is a presentation of the physical resources including water quantity, water quality, soils, and wetland management issues and opportunities in the project area. Also included in this section is a presentation of vector issues that need to be addressed in development of management alternatives and approaches

The second section is a presentation of inventory information on the natural biological resources of the El Rio project area. This biological inventory is presented in a narrative format, with supporting photographic record. The annotated photographs are to present a visual record of the vegetation types found in the project area surveys conduced in the fall of 2002 and spring of 2003. Particular emphasis is given to habitat considerations for special status, threatened, and endangered species in the area. The section includes an analysis of opportunity areas for preserving or enhancing the important biological habitat values of the El Rio project area.

The third section of the report is a presentation of resource issues that reflect human influence on the El Rio project area. The section presents the current and historical location and extent of surface water in the river, the locations of effluent and irrigation return water discharge points, the locations of solid and hazardous waste disposal sites, and locations of historic and prehistoric cultural resource sites. The section concludes with an analysis of how land ownership affects the applicability of environmental regulations, and how these regulations may affect the opportunities and constraints to alternatives for El Rio project area management.

El Rio Watercourse Master Plan

EL RIO ENVIRONMENTAL RESOURCES

SECTION 1
PHYSICAL AND WETLAND RESOURCES

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INTRODUCTION

This volume contains five chapters which discuss the water quantity, water quality, vegetation, soil type, and vector and nuisance insects in the El Rio Project area. Each chapter can be read as an independent document on the subject, however reading the entire volume provides a more complete picture of the physical resources in the project area. The objective this volume is to provide background conditions and discuss potential opportunities of the El Rio Project. The information will be significant in the next phase of the project as alternatives for the El Rio Project area are developed.

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Environmental Issues

WASS Gerke and Associates, Inc.

SURFACE WATER QUALITY

CHAPTER 1

BACKGROUND

Located within the 12,249 square mile (11% of Arizona's land area) Middle Gila Watershed, the surface water quality of the El Rio reach of the Gila River is influenced by surface water inputs and groundwater interactions (ADEQ, 2002). The El Rio project focuses on a reach of the Gila River bounded on the upstream by its confluence with the Agua Fria River and on the downstream by the SR 85 Bridge. This report focuses primarily upon the quality of surface water inputs to the system which are influenced by both natural processes and anthropogenic activities.

One example of natural processes affecting the water quality is the naturally occurring salt springs and mineral deposits within the watershed contribute to high salinity (as total dissolved solids (TDS)) measurements recorded immediately downstream of the El Rio reach. This condition is further exacerbated by the low rainfall and high evaporation rates characteristic of the project area.

Over 60% of the population of Arizona lives within the contributing watershed and their activities also have some effect on water quality within the El Rio project area (ADEQ, 2002). Constituents in discharges from municipal wastewater treatment plants, agricultural operations, developed lands, and in stormwater runoff may include a range of contaminants from inorganic trace elements to organic compounds.

Sometimes human activities magnify the impact of the naturally occurring contaminants on water quality. Consider the naturally occurring salt sources within the watershed, the use of water softeners, and wastewater treatment processes add to and concentrate respectively, salts in water discharged to the Project reach. Human activities and natural processes occurring within the watershed impact the characteristic the surface water quality in the El Rio project area through the introduction of contaminants, their subsequent concentration, and the lack of surface flows.

The Arizona Department of Environmental Quality (ADEQ) 2002 Assessment and Planning List encompasses the El Rio Project with two segments of the Gila River, Agua Fria River – Waterman Wash (AZ15070101-014) and Waterman Wash – Hassayampa River (AZ15070101-010). Designated Uses for both segments are identical and include: aquatic life and wildlife effluent dependent water (A&Wedw), partial body contact recreation (PBC), fish consumption (FC), agricultural irrigation (AgI), and agricultural livestock watering (AgL). As of 2002, attainment of those Designated Uses is considered "inconclusive" because of "Missing Core Parameters" and a lack of current water chemistry monitoring data. Both segments have been under a fish consumption advisory for DDT, toxaphene, dieldrin, and chlordane (ADEQ, 2002). The fish advisory was based on a 1985 report that described the organochorine pesticide levels as significant treat to fish, wildlife, and human health. (USFWS, 1997)

There are several key parameters that define the quality of a river system for the sustainability of native vegetation, protection of wildlife, and water resources. As previously stated, contaminants of surface water include naturally occurring and artificial substances introduced into the system by a variety of means. The contaminants most prevalent in the El Rio reach of Gila River can be categorized into the following groups:

- Dissolved Oxygen
- pH
- Electrical Conductivity/Salinity/TDS
- Nutrients (Nitrogen & Phosphorous)
- Trace Elements and Heavy Metals

- Pesticides
- Suspended Solids

Dissolved oxygen (DO) is necessary for many aquatic organisms including fish and macroinvertebrates to survive. Discharges of organic compounds (often measured as biological oxygen demand (BOD)) can lower dissolved oxygen levels to the extent that fish kills can occur. As an example, such discharges can occur into the El Rio reach from poorly treated wastewater, stormwater runoff, or unintentional discharges from animal feeding operations. Nutrient inputs from nonpoint sources such as septic tanks and agricultural runoff within the contributing watershed can contribute to algal blooms in existing aquatic areas. At night such blooms can depress DO concentrations via respiration to levels that are harmful to aquatic life. Finally, DO is important from the standpoint of quality of life in that as a rule of thumb, waters with higher DO levels are often less suitable for mosquito breeding.

The acidity of water is often measured and expressed as pH. A pH of 7.0 is considered neutral while a pH of 1 is very acidic and 14 is strongly alkaline. Nutrient availability for plant species and the mobility of select heavy-metals depend upon this parameter. In addition to the water "hardness", the solubility of metals is also largely controlled by pH. Generally, acidic water is able to dissolve far greater concentrations of metals than neutral water. In wetlands, however, circumneutral pH and the presence of low redox zones favor metal immobilization in wetlands. In this process metals entering wetlands precipitate with metal sulfides and the bound metals will be immobilized in the wetland substrate.

Salinity which is often reported as electrical conductivity (EC) or as total dissolved solids (TDS) is important with respect to both the survival of aquatic organisms and the fitness of vegetation. Salinity levels ultimately dictate the species of invertebrates and fish based upon their salt tolerance. A suite of ions contribute to the overall salinity and may include sulfate, chloride, fluoride, and many trace elements including boron. Boron, which is toxic to plants, and several other ions are found naturally within the Salt River, an important tributary to the El Rio. Wastewater treatment practices and runoff from agricultural fields that receive wastewater or biosolids are other sources of boron. In general, as salinity increases, one can expect a reduction in the size, number, and diversity of plants, aquatic invertebrates, and fish that can be established and sustained in a given area.

Nutrients, such as nitrogen and phosphorous, influence the character and overall fitness of aquatic resources. Ammonia, a nitrogen based compound, can be toxic to fish, while elevated nitrate-nitrogen and phosphorous concentrations can cause algal blooms and alter water quality. Excess nitrate (> 10 mg/L) is also harmful to human health because it can cause methanoglobinemia.

Trace elements and heavy-metals are another water quality concern for both plants and animals. While some elements boron (B), copper (Cu), iron (Fe), and zinc (Zn) in small concentrations are essential for plant growth, excessive concentrations of most trace elements might have toxic effects on plants. Bioaccumulation and biomagnification processes result in even low concentrations of certain heavy-metals such as Cu, becoming toxic to wildlife over time. As evidence of these phenomena, detectable concentrations of 11 potentially toxic heavy metals were detected in fish samples collected in the vicinity of the El Rio Project area (USFWS, 1997).

Pesticide use in the 25,000 square mile Gila watershed introduces another water quality issue for the El Rio Project area. Such use has been sustained and is marked by several pivotal events including the Pink Bollworm eradication program of the late 1950's and early 1960's. In the project reach 4 organochlorine pesticides (DDE, DDT, dieldrin, and chlordane) have historically been recorded at concentrations exceeding levels of concern.

Suspended solids are also a concern in the El Rio project area with respect to the physical and chemical properties. Physically, deposition of solids on the soil surfaces can clog the soil, thus reducing water infiltration and soil aeration. If the solids are organic compounds, their decomposition produces an oxygen sink which could hinder the movement of oxygen from the atmosphere to the root zone. Chemically, many important contaminants, such as heavy metals and pesticides, are associated with particulates because they attach of bind to the particulate. Particulates are transported to the river via stormwater runoff, agricultural tailwater discharges, and in municipal wastewater.

In summary, the general water quality in the El Rio Project reach of Gila River is poor in comparison to other regional water supplies for several reasons including salinity, nitrogen, heavy-metals, pesticides, and organic compounds. The salinity of surface and groundwater in the El Rio project reach is three to nine time higher than in Central Arizona Project (CAP) water and surface waters in the Salt, Verde, and Agua Fria Rivers. Nitrate levels often exceed the Environmental Protection Agency (EPA) maximum contamination limits (MCL) for drinking water of 10 mg/L which can also increase the rate of eutrophication in existing or proposed aquatic resources. The Arizona Department of Environmental Quality (ADEQ) has compiled information on previous investigations in the lower/middle Gila River from the 1960's through present time that point to five chemicals of concern: chlordane, DDT, dieldrin, toxaphene, and methylmercury. A summary of water quality at Gillespie Dam, which is located downstream about 20 miles from the project area, (eight events between 1995 and 1998), is shown in the Table 1.

Table 1

Gila River Water Quality at Gillespie Dam

Constituent	Average Level
TDS (mg/L)	2,396
Calcium (mg/L)	160
Magnesium (mg/L)	72
Sodium (mg/L)	590
Alkalinity (mg/L as $CaCO_3$)	242
Sulfate (mg/L)	524
Chloride (mg/L)	871
Fluoride (mg/L)	2
Nitrate (mg/L as N)	9
pH	8

Source: Maricopa Water District Files. (MAG, 2002)

The remainder of this report will delineate the available water quality data and characterize the quality of water from each of the sources into the project area. Characterization will be based on actual data when available; in the absence of site specific data, literature values will be reported.

SAMPLING LOCATIONS

The surface water quality sampling locations that are represented in the GIS surface water sources layer are listed in Table 2 (**Appendix A**). In most cases the data reported include the parameters listed below and collection efforts span the time period 1992 through 2000.

Sampling Parameters

- Dissolved Oxygen
- TDS
- Nitrate
- Nitrate and nitrite
- Beryllium, Total and Dissolved
- Bromide, Total and Dissolved
- Copper, Total and Dissolved
- Cyanide
- Mercury, Total
- Selenium, Total
- Thallium, Total
- Chloroform
- Lindane
- DDT
- DDD
- DDE
- Di-bromide
- Dieldrin
- Toxaphene

Table 2
Water Quality Sampling Locations

Location	Type of Water
Buckeye WWTP	Wastewater effluent
Estrella WWTP	Wastewater effluent
Salt Gila up from Buckeye Canal	Stream flow
Goodyear WWTP	Wastewater effluent
St. John's canal discharge	Agricultural return
Avondale WWTP	Wastewater effluent
Lockeed Martin Discharge	Industrial effluent
Drainage ditch 0.1 miles west of El Mirage Road	Agricultural return
El Mirage Road north bank	Stormwater
El Mirage Road south bank	Stormwater
Gila River and Salt River at 115th Avenue	Stream flow
115th Avenue Bridge NE	Stormwater
Salt River at 107th Avenue	Stream flow
Salt River ½ mile south of 91st Avenue discharge	Stream flow
Tolleson WWTP	Wastewater effluent
Discharge from gravel mine, south of Salt River near 85th to 91st Avenue	Industrial discharge
SRP canal west of 75th Avenue	Agricultural return
¾ mile east of 147th Avenue Bridge	Stormwater
Gila River upstream of confluence with Salt River	Stream flow/Stormwater
Salt River upstream of confluence with Gila River	Stream flow/Stormwater
67th Avenue bridge northwest corner	Stormwater
Maricopa drain at lateral 14 on Western Canal	Agricultural return
Laveen drain at Deadhorse Ditch	Agricultural return
½ mile east of 115th Avenue Crossing	Stormwater
Buckeye feeder canal and Lennox drain at head	Stormwater

The locations of fish captures for tissue analysis are depicted in **Appendix B**. Fish tissue analysis indicated a significant presence of organochlorides and metals, however decreases were detected between the 1985 and 1994-1995 sampling events. For example, geometric mean DDE levels in whole body fish analysis decreased significantly, 2.65 μg/g to 1.29 μg/g, between the 1985 and 1994-1995 sampling events. Carp samples indicated one-tenth the residual level of DDT, from 1985 to 1994-1995.

Metals analysis indicated the presence of 15 metals potentially toxic to fish. Arsenic levels (geometric mean = 0.4 mg/g) did not show a significant change from 1985 to 1994-1995. Copper analysis indicates steady or increasing levels in fish samples between the two events. Selenium concentrations in carp collected in 1994-95 (1.87 µg/g dry weight) were similar (P=0.1915) to those in carp collected in 1985 (1.60 µg/g).

SOURCE WATER CHARACTERIZATION

Potential sources of surface water supply to the El Rio project area include the following:

- Treated wastewater effluents
- Agricultural return-flows
- Stormwater run-off
- Industrial and Animal Feed Operations

Treated Wastewater Effluents

A primary source of surface water in the El Rio project area is effluent from regional wastewater treatment plants (WWTP). Five regional plants currently have permits to discharge to the Gila River or its tributaries. These include:

- City of Phoenix 91st Avenue WWTP
- City of Avondale WWTP
- City of Goodyear 157th Avenue WWTP
- Goodyear Estrella WWTP
- Town of Buckeye WWTP
- City of Tolleson WWTP

Wastewater effluent quality depends on the treatment process; however, discharge permits establish maximum levels allowable for each facility. The NPDES permit for the 91st Avenue WWTP limited the levels for carbonaceous biochemical oxygen demand (cBOD), suspended solids, fecal coliforms, settleable solids, and chlorine residual. In addition levels of trace metals such as cadmium, copper, lead, selenium, silver, cyanide, and zinc; and organics such as Di (2-ethylhexyl) phthalate, heptachlor-epoxide, and hexachlorocyclo-hexane gamma (Lindane) are also limited. As an example, the average discharge concentrations for parameters measured in the 91st Avenue WWTP discharge are provided in Table 3.

Table 3

91st Avenue Wastewater Treatment Plant
Effluent Quality

Parameter (units)	Average
Dissolved Oxygen (mg/L)	3.5
pH	6.8
COD (mg/L)	27
Nitrate (mg/L as N)	4
Nitrite (mg/L as N)	0.2
Phosphorus (mg/L)	2.7
TSS (mg/L)	3.4
Chloride (mg/L)	300
Arsenic (mg/L)	0.004
Boron (mg/L)	0.6
Cadmium (mg/L)	< 0.002
Chromium (mg/L)	< 0.005
Copper (mg/L)	< 0.01
Iron (mg/L)	0.2
Lead (mg/L)	< 0.02
Mercury (mg/L)	< 0.0002
Nickel (mg/L)	< 0.02
Selenium (mg/L)	0.002
Silver (mg/L)	< 0.001
Zinc (mg/L)	< 0.6
E. Coli (MPN/100 mL)	< 1

Dissolved oxygen, pH, and conductivity results are based on twice weekly sampling in 2001 and 2002. The remaining of the water quality results are based on monthly sampling efforts conducted during 2001 and 2002. Metals results are based on three sampling events in 2001.

Similar information is available in the GIS data base (WWTP and NPDES layers) for the existing wastewater treatment facilities located in Avondale, Goodyear, and Buckeye. Currently all of Tolleson WWTP effluent is piped directly to Palo Verde Nuclear Power Plant for reuse as cooling water. The Gila River Indian Community is primarily served by septic systems and due to the shallow groundwater table in this region, septic system malfunctioning can add to nutrient and pathogens in the shallow groundwater aquifer an ultimately contribute to water quality in the El Rio reach.

Agricultural Return-Flows and Dewatering Discharges

Historic agricultural use of the Lower Gila River Valley included extensive use of pesticides beginning in the 1950. From May 15th through July 19th of 1958 alone, the Pink Bollworm Eradication Program treated 65,000 acres of cotton with 500,000 pounds of DDT. Overall, between 1958 and 1960, 33,000 acres of the Buckeye-Avondale area were treated with 1.7 million pounds of DDT. Similar efforts have been undertaken in other agricultural areas of the Middle Gila Watershed and all have contributed to the pesticide contamination of the EL Rio reach of the Gila River through regional storm events and releases from upstream dams. Agricultural return flow drainage pipes and canals have carried much of that into the Gila River. In 1970 the Gila River was documented as one of the most DDT-burdened stream of 20 sampled in the western United States. (USFWS, 1997)

Today the primary agricultural non-point source pollution (NPS) pollutants are nutrients, sediments, animal wastes, salts, and pesticides. Nitrogen and phosphorus are the primary nutrients of concern; however, fertilizers often also contain potassium (K) and secondary nutrients. Commercial fertilizers contain trace metals as micronutrients to support crop growth, and municipal wastewater sludge applied as fertilizer often contain metals removed during the treatment process. Selenium is a natural element in soils, but in aquatic environments it enters the food chain, bioaccumulates and becomes toxic to higher organisms.

Municipal wastewater sludge also can contain bacteria and viruses that are human and wildlife pathogens. In Arizona, non-edible crops such as alfalfa, cotton, and wheat are grown with Class B biosolids, which have not been heat treated to kill pathogens. Biosolids applied to edible crops must be Class A biosolids, which are pathogen-free. Many of the agricultural fields on the northern banks of the project reach use biosolids as fertilizer. Run-off and return flows from field treated with Class B biosolids may have pathogens.

Groundwater from the shallow aquifer is pumped into agricultural canals and periodically discharged into the Gila River. Groundwater quality information is available for wells in the Buckeye Water Conservation and Drainage District (BWCDD). Table 4 contains the results of 27 wells sampled in the summer of 2000.

Groundwater samples indicate high levels of nitrate and total dissolved solids (TDS). Nitrate is typical of groundwater percolating through agricultural field with applied fertilizers. TDS levels are increasing in the valley as evaporation and evapotranspiration, condense the salts and minerals in the water.

Table 4

BWCDD Well Water Quality
Results of 27 wells sampled in 2000

Parameter (units)	Average	Max	Min
Alkalinity (mg/L as $CaCo_3$)	270	410	153
Arsenic (mg/L)	0.009	0.016	0.005
Barium (mg/L)	0.03	0.11	0.013
Cadmium (mg/L)	< 0.002	< 0.002	< 0.002
Calcium (mg/L)	267	438	187
Chloride (mg/L)	1105	1780	714
Chromium (mg/L)	< 0.01	0.01	< 0.01
Copper (mg/L)	0.02	0.05	0.01
Cyanide (mg/L)	< 0.01	< 0.01	< 0.01
Fluoride (mg/L)	3.0	6.8	0.3

Parameter (units)	Average	Max	Min
Iron (mg/L)	0.19	2.3	0.07
Lead (mg/L)	< 0.005	< 0.005	< 0.005
Magnesium (mg/L)	106	180	54
Manganese (mg/L)	< 0.01	0.05	< 0.01
Mercury (mg/L)	< 0.005	< 0.005	< 0.005
Nitrate (mg/L)	21.3	34.4	11
Nitrite (mg/L)	< 0.01	< 0.01	< 0.01
pH	7.4	7.7	7.0
Selenium (mg/L)	0.004	0.013	0.002
Silver (mg/L)	< 0.002	< 0.002	< 0.002
Sodium (mg/L)	862	1108	592
Sulfur (mg/L)	910	2110	718
Total Dissolved Solids (mg/L)	3446	4200	2160
Total Hardness (mg/L as $CaCO_3$)	993	1640	690
Zinc (mg/L)	< 0.01	< 0.01	< 0.01

Stormwater and Stream flow

The quality of stormwater runoff is a factor of the land use, frequency and intensity of the storm event occurring within the contributing watershed. In the late 1980's and early 1990's, the USGS and the Flood Control District of Maricopa County (FCDMC) conducted a study to characterize the water quality from mean-events in several land use types in Maricopa County.

In general, stormwater and stream flow typically have neutral pH with values between 6.3 and 9.0. Stormwater alkalinity ranges from 10 to 150 mg/L as $CaCO_3$ while stream flow has higher alkalinity of 10 to 228 mg/L as $CaCO_3$. Dissolved oxygen levels for both tend to be high; with levels from 3.8 to 10.2 mg/L.

At times, urban runoff in the valley can be black in color from oil, grease, particulates from ground-up tires, and other sources. Urban stormwater typically has less dissolved solids than other water sources. However, stormwater contains significant levels of oxygen demanding substances measured as COD and BOD, oil, grease, and fecal coliform bacteria. Undeveloped, but disturbed lands, like much of the region surrounding the El Rio Project area, can produce the largest suspended solids concentrations. Table 5 lists the mean-event concentrations, based on sampling events in Maricopa County

Table 5

Stormwater Quality
Mean-Event Constituent Concentration
Maricopa County, Arizona

Parameter (units)	**Mean –Event Concentration**
COD (mg/L)	239
BOD (mg/L)	109
Suspended Solids (mg./L)	227
Dissolved Solids (mg/L)	102
Nitrogen (mg/L as N)	3.26
Phosphorus (mg/L)	0.41
Cadmium (mg/L)	0.99
Copper (mg/L)	47.0
Lead (mg/L)	71.6
Zinc (mg/L)	204
Fecal coliform (colonies / 100 mL)	44,400
Fecal streptococci (colonies / 100 mL)	17,400

(USGS, 1995)

Concentrated Animal Feeding Operations (CAFO)

The EPA defines animal feeding operations that have the potential to discharge pollutants into surface water as a CAFO. Typical pollutants from CAFOs include nitrogen, nutrients, and pathogens.

The EPA recognizes four dairies, an animal feedlot, and an equestrian center as CAFOs located in the vicinity of the El Rio project area.

- Bales Feedyard – Beef cattle feedlot
- Butler Dairy – Dairy farm
- Lueck Dairies – Dairy farm
- Rainbow Dairy – Dairy farm
- Van Leeu Wen Dairy – Dairy farm
- Equestrian Center

Surface run-off and percolation through CAFO waste storage basins into the shallow groundwater are potential source of contaminants into the Gila River. Animal wastes test high in biological oxygen demand (BOD) and often contain pathogens that threaten human health. Two common pathogens found in polluted water are *Giardia* and *Cryptosporidium*. Microfiltration and chlorination are the only two acceptable methods from eliminating the risk of these parasitic pathogens in waters potentially impacted by CAFOs.

Industrial Waste Flows

Industrial waste flows can be high in salinity especially those discharged from industrial cooling towers because of the evaporative concentration of the ions. The project area is not known to have a significant industrial component discharging to the surface waters or shallow aquifer. The one main industry in the region is Lockheed Martin, located at Litchfield Road, north of the Gila River. The facility operates an industrial wastewater treatment facility, with a NPDES permit for discharge. NPDES discharge data from EPA is contained in the water quality WWTP NPDES GIS layer.

WATER QUALITY IMPROVEMENT USING CONSTRUCTED WETLANDS

Rivers and riparian corridors contain sensitive organisms that are easily impacted from contaminants. However, the chemistry and microorganism of wetlands are excellent environments for many water purification processes. Beavers have been credited as the first water quality engineers for improvements resulting from beaver dams. The dams impound water creating a wetland environment, which in turn provides a setting for the physical, chemical, and biological treatment of water. Constructed wetlands can be built in the project reach for habitat and source treatment for polishing agricultural return flows, dewatering flows, wastewater effluents, and stormwater flows after a thorough water quality characterization of a proposed water source has been conducted. Such a characterization is needed in order to identify the specific pollutants the wetland would be designed to attenuate, sequester, and/or remove and to assess the potential of creating a hazard if toxic compounds are identified in the source water.

Wetland Processes That Alter Water Quality

Wetlands can be defined as "land where the water surface is near the ground surface for long enough each year to maintain saturated conditions." Free-water-surface (FWS) constructed wetlands are systems designed to maintain water surface above the ground surface. (Reed, 1995) FWS constructed wetlands produce a range of effluent qualities, depending on the influent characteristics, constituent operational loading rates, climate, and aerial extent of the system. When designed and operated properly, constructed treatment wetlands have performed within predictable ranges of effluent values and meet their permit limitations. Wetlands accomplish this through a combination of physical, chemical and biological mechanisms.

Physical mechanisms that influence the water quality from a wetland include gas transfer, sedimentation, adsorption/desorption, filtration impaction, flocculation, photochemical reactions, and volatilization. Gas transfers involve the movement of gases such as O_2, N_2, CH_4, and sulfides across the air-water interface and to and from the bottom sediments. Sedimentation is an extremely important pollutant removal mechanism because many constituents, such as heavy metals are often associated with the particulate phase. In treatment wetlands sedimentation is also a primary removal mechanism for BOD, TSS, and heavy metals, while it provides a secondary mechanism for the removal of nitrogen and phosphorous. Adsorption and desorption can affect the parameters BOD, TSS, bacteria and viruses, and heavy metals either by increasing (desorption) or decreasing (adsorption) their concentrations in the water column. Filtration/Impaction refers to particulates being filtered mechanically as the water passes through substrates and plant materials, which contributes to the reduction of BOD, TSS and heavy metals (Stowell et al, 1980). Flocculation precedes and can enhance sedimentation thereby assisting in the removal of BOD, TSS, bacteria, and viruses. Photochemical reactions facilitate the degradation of organic compounds and contribute to bacteria and virus reduction. Volatilization is a physical mechanism that can contribute to the removal of ammonium and other pollutants with low partial pressures.

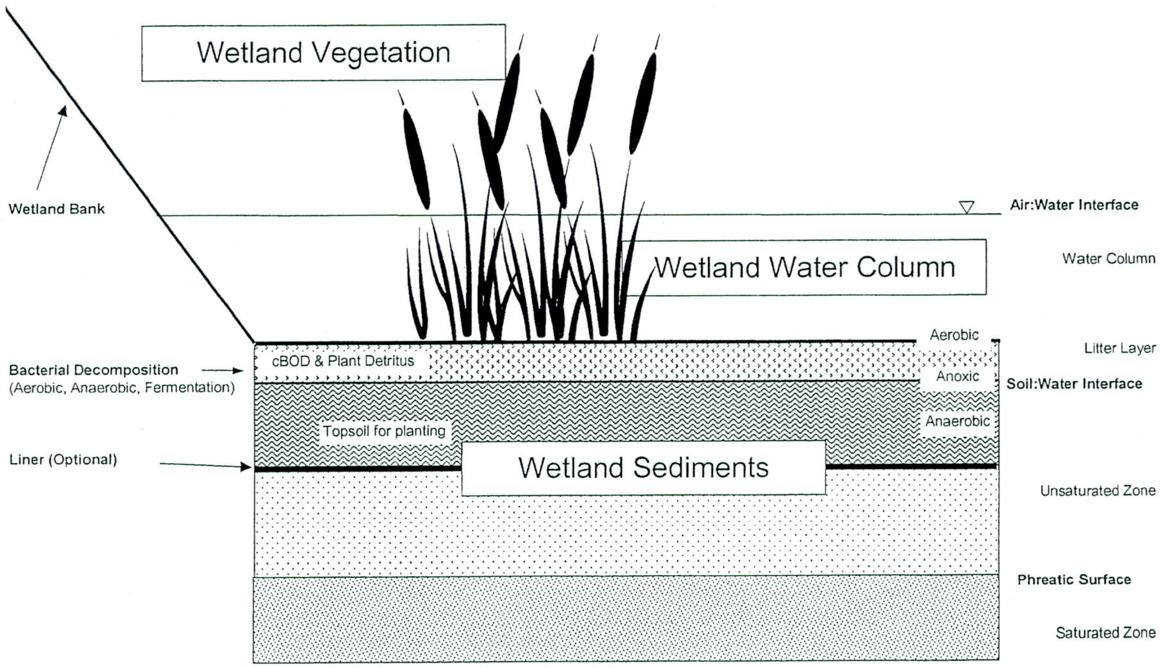


Figure 1. Treatment Wetland compartments that work together to alter water quality.

The previously mentioned physical mechanisms work in concert with the chemical processes in a wetland to further alter wetland water quality. The chemical mechanisms at work in a wetland include chemical adsorption, chelation, oxidation/reduction reactions, and chemical precipitation. Chemical adsorption onto surfaces within wetlands can result in water column reductions of phosphorous, bacteria and viruses, and heavy metals. Chelation reactions also affect phosphorous concentrations, but are a primary mechanism for heavy metal removal. Chemical oxidation/reduction (redox) reactions are a primary removal mechanism for BOD and heavy metals, and can also have an affect on TSS. Certain heavy metals can be bound as metal sulfides under appropriate redox conditions. If reducing conditions are maintained, these compounds can become buried and essentially immobile (USEPA ETI, 2000). Chemical precipitation reactions can be a primary removal mechanism for phosphorous.

The biological processes of wetland also influence water quality. Important biological mechanisms include algal synthesis, assimilation into higher plants, bacterial metabolism, and predation. Algal synthesis or incorporation of nutrients into cell tissue can influence nutrient concentration in the water column. If these algal cells are allowed to exit the wetland system, they will export nutrients and show up analytically as TSS. Assimilation, or the uptake and metabolism by plants can increase or decrease BOD, TSS, nutrients, dissolved oxygen, bacteria and viruses, and heavy metals depending on the lifecycle stage of the vegetation. Bacterial metabolism, both aerobic and anaerobic can have a profound effect on wetland water quality. Aerobic bacteria are responsible for nitrifying ammonia species to nitrite and nitrate, while anaerobic bacteria convert nitrate to dinitrogen (N_2) gas. Aerobic bacteria also reduce BOD and TSS concentrations. Aerobic bacteria may also depress dissolved oxygen concentration due to the use of O_2 in bacterially mediated reactions. Phosphorous concentrations are influenced by microorganisms as they uptake this nutrient for cell tissue growth and metabolic activities. Finally, zooplankton, aquatic insect larvae, and even small fish larva will feed upon suspended solids that can harbor bacteria and viruses.

These are all internal processes that potentially affect the quality of water exiting a wetland. It must be stressed that FWS wetlands are "open-systems" and as such are subject to various perturbations. Even though properly designed wetland systems perform in a predictable range of effluent values, a limitation to using FWS constructed wetlands as an agricultural or stormwater runoff treatment system is not only the variability in hydraulic and mass loadings, but also the background concentration of constituents produced by the external loading and the internal wetland processes.

Background concentrations of BOD, COD, turbidity, total phosphorus, total nitrogen, and total and fecal coliform can control the effluent quality achievable in a free water surface constructed wetland. The natural cycle of nutrients and the potential re-release of constituents incorporated in the wetland biomass must be considered in the effluent permit requirements for discharges from FWS constructed wetlands.

In summary, constructed wetlands can reduce BOD, nitrate, suspended solids, and metals. However, total dissolved solids, a sign of increasing salinity, is not improved by wetland systems. Salinity levels will continue to develop as a challenge to this project as well as many of the valley's water resource projects in the future.

DATA GAPS

Because water quality sampling data within the project area is limited, addition sampling would be recommended. Sampling should be considered determine the water quality parameter water bodies receiving surface and subsurface flows from:

- Agricultural return pipes and canals
- CAFOs
- Stormwater

In addition water quality sampling is recommended during selection of preferred restoration or enhancement locations. An accurate understanding of water quality will allow features to be designed for water quality improvements.

SUMMARY

The surface water quality of the El Rio reach of the Gila River is influenced by local and regional drainage. Regional flows occur in response to releases from upstream dams that can transport contaminants to the subject reach from throughout the contributing watershed. On a local basis, the major surface water sources of water in the project area are wastewater effluent, dewatering wells, agricultural return flows, and stormwater runoff.

The Gila River in the El Rio Project area is designated by ADEQ as an effluent dominated stream, fed primarily from the 91st Avenue WWTP effluent and agricultural return flows. Historically the quality of water in the river has been poor and residual pesticides and trace metals resulted in contaminated fish and a health advisory on fish and shellfish consumption. Because of these issues, planning and conceptual design restoration alternatives should include a complete characterization of the proposed water source to assess the need for pretreatment and to identify constituents that may contribute to the creation of an attractive hazard in the restored reach. A summary of water quality concerns from the various sources is shown in Table 6.

Table 6

Summary of Water Quality Concerns from Sources in the El Rio Project Area

	Dissolved Oxygen	pH	Nutrient	Pathogens	Metals	Organics
WWTP Effluent	X		X	X	X	X
Agricultural return flows	X		X	X	X	X
Dewatering flows		X	X			
Animal operations	X	X	X	X		X
Stormwater	X	X	X	X	X	X

REFERENCES

ADEQ, 2002. *Arizona's 305b Water Quality Assessment and 303(d) Listing Report*. Arizona Department of Environmental Quality, Phoenix, Arizona.

Reed, Sherwood C. *et al*. 1995. *Natural Systems for Waste Management and Treatment*. McGraw-Hill.

MAG, 2002. 208 Water Quality Management Plan Update. Prepared by Carollo Engineer.

Stowell, R., R. Ludwig, J. Colt, and G. Tchobanoglous. 1980. "Towards the Rational Design of Aquatic Treatment Systems." Presented at the American Society of Civil Engineers Spring Convention, Portland, OR. April 14-18, 1980. 43 p.

USEPA ETI, 2000. Free Water Surface Wetlands for Municipal Wastewater Treatment A Technology Assessment. R. Wass editor. Currently In Print.

USFWS, 1997. Environmental Contaminants in Fish and Wildlife of the Lower Gila River, Arizona. Kirk King, *et al*.

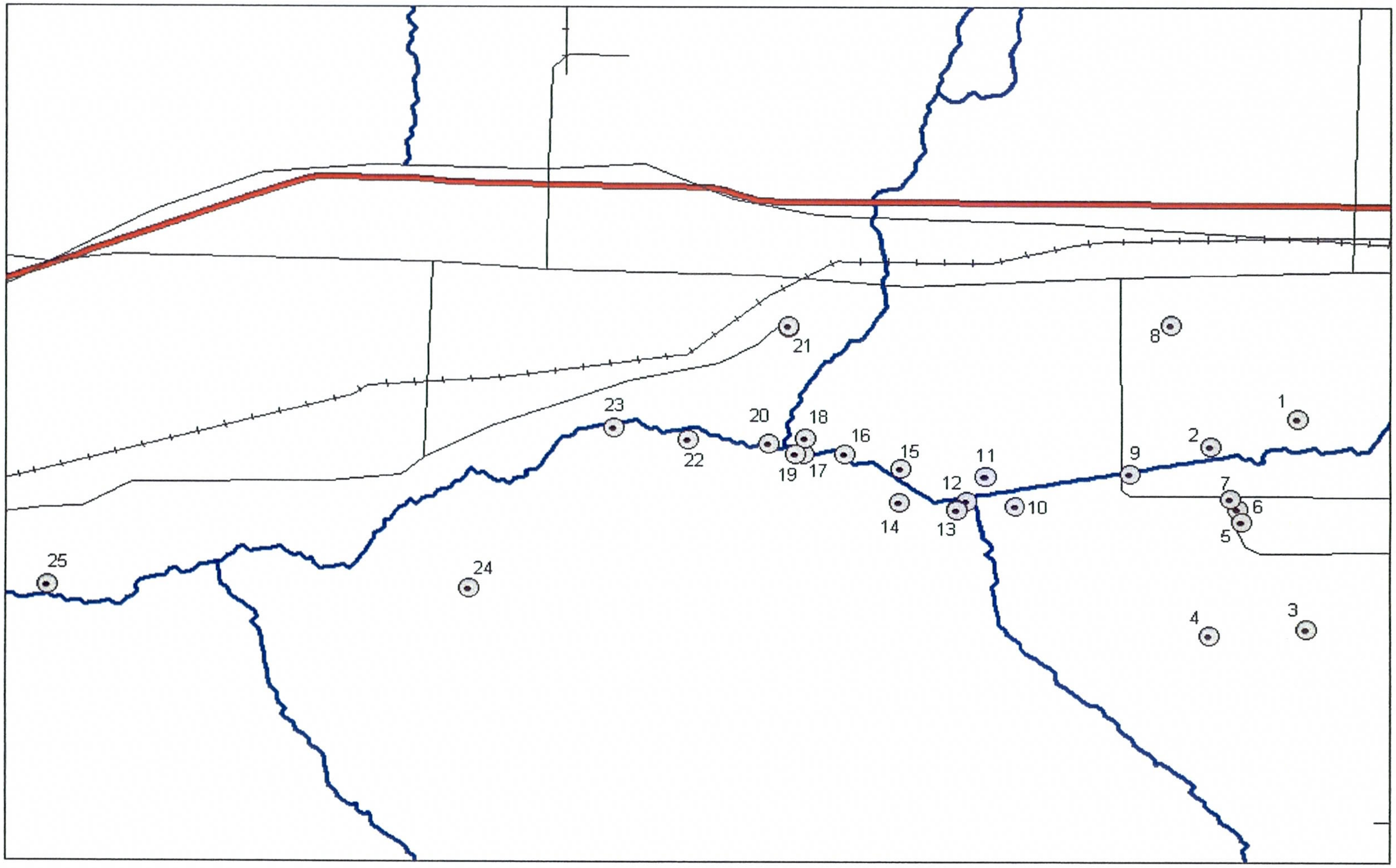
USGS, 1995. Statistical Summary of Select Physical, Chemical, and Microbial Characteristics, and Estimates of Constituent Loads in Urban Stormwater, Maricopa County. Thomas Lopes *et al.*

APPENDICES

APPENDIX A	Water Quality Sampling Locations
APPENDIX B	Fish Tissue Sampling Locations

APPENDIX A

Water Quality Sampling Locations



APPENDIX A

El Rio Project
Water Quality Sampling Locations

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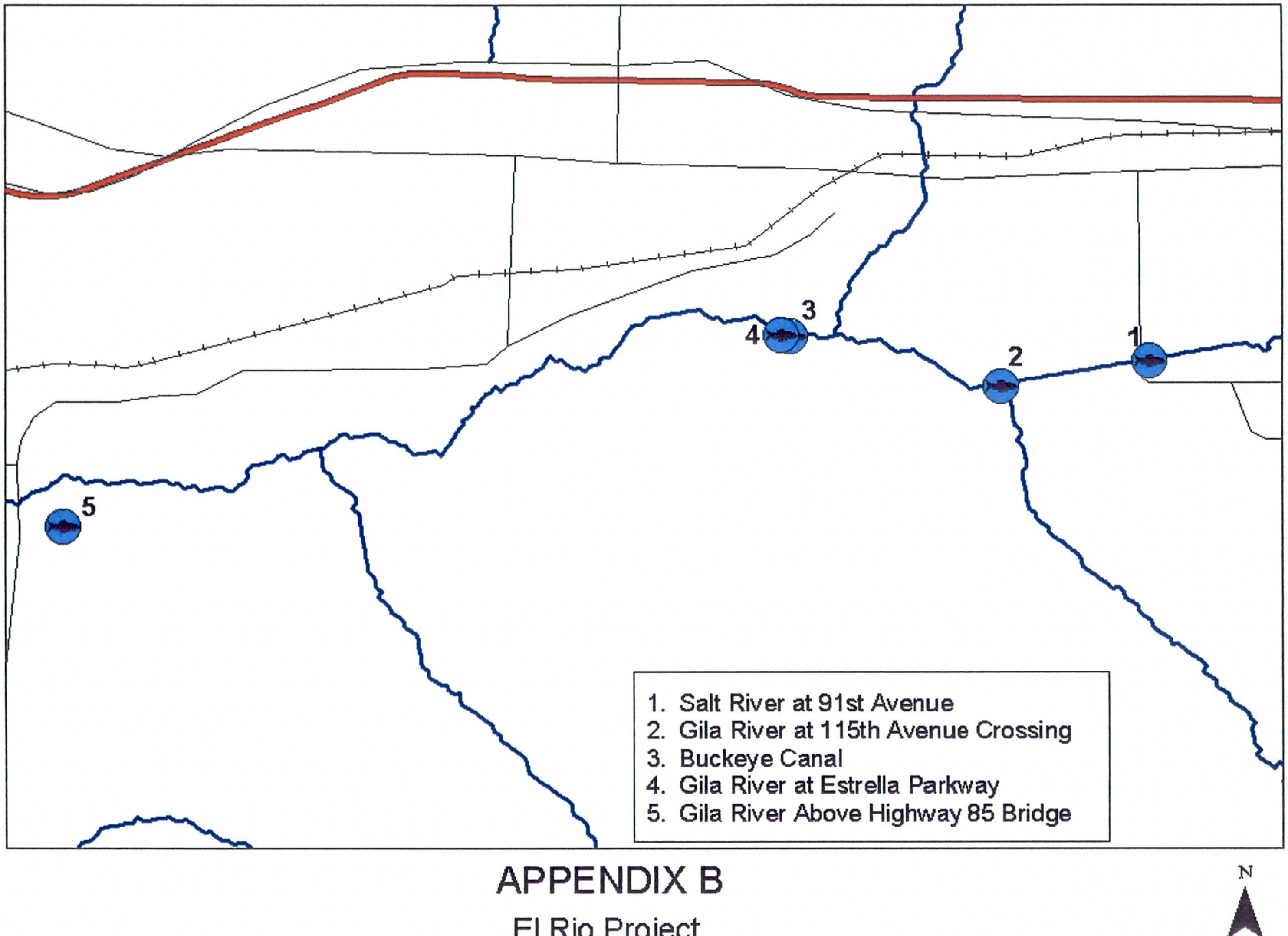
Water Quality Sampling Locations

	Location	Type of Water
1	67th Avenue bridge northwest corner	Stormwater
2	Salt River upstream of confluence with Gila River	Stream flow/Stormwater
3	Laveen drain at Deadhorse Ditch	Agricultural return
4	Discharge from gravel mine, south of Salt River near 85th to 91st Avenue	Industrial Discharge
5	Gila River upstream of confluence with Salt River	Stream flow/Stormwater
6	Maricopa drain at lateral 14 on Western Canal	Agricultural return
7	SRP canal west of 75th Avenue	Agricultural return
8	Tolleson WWTP	Wastewater effluent
9	Salt River ½ mile south of 91st Avenue discharge	Stream flow
10	Salt River at 107th Avenue	Stream flow
11	½ mile east of 115th Avenue crossing	Stormwater
12	115th Avenue Bridge NE	Stormwater
13	Gila River and Salt River at 115th Avenue	Stream flow
14	El Mirage Road south bank	Stormwater
15	El Mirage Road north bank	Stormwater
16	Drainage ditch 0.1 miles west of El Mirage Road	Agricultural return
17	Buckeye feeder canal and Lennox drain at head	Stormwater
18	Avondale WWTP	Wastewater effluent
19	St. John canal discharge	Agricultural return
20	¾ mile east of 147th Avenue Bridge	Stormwater
21	Lockheed Martin Discharge	Industiral effluent
22	Goodyear WWTP	Wastewater effluent
23	Salt Gila up from Buckeye canal	Stream flow
24	Estrella WWTP	Wastewater effluent
25	Buckeye WWTP	Wastewater effluent

APPENDIX B

Fish Tissue Sampling Locations



APPENDIX B

El Rio Project
Fish Tissue Sampling Locations

CHAPTER 2 – SURFACE WATER QUANTITY PAGE

SURFACE WATER QUANTITY

CHAPTER 2

Prior to the 1900's the Gila River was a dynamic river, influenced by flows from the San Pedro, Santa Cruz, Salt, and Agua Fria rivers. Today, the hydraulic regime of this dynamic river system has been altered by damming, groundwater pumping, and urban development. In order to implement a restoration program in this altered area, availability of water is critical for success. Restoration of lost habitat depends on the availability of water.

The quantity of surface water in the El Rio Project area is dependent upon numerous factors relating to climate, geology, land use, and urban and agricultural activities. This water quantity analysis considers the sources that bring surface water into the project area as well as the sources that remove water from the project area.

Although the Metropolitan Phoenix area is an arid desert, the confluence of the Salt, Agua Fria, and Gila Rivers has a history of perennial surface water. European explorers of the 17th and 18th centuries write about the abundance of the Gila River and its associated riparian community (Rea 1983). In 1884 Dr. John Griffin traveled the Gila and described the river at low flow as being 60 to 80 yards wide, on average 4 feet deep and moving fast (McNammee 1994). Although the perennial character of the Gila River is no longer apparent, today the region still hosts some important natural surface water bodies. Therefore, a unique economic opportunity exists to restore a sustainable ecosystem of xero-riparian, hydro-riparian and wetland habitats in the El Rio Project reach.

SOURCES OF SURFACE WATER

Sources of surface water in the area include precipitation, upstream and nearby wastewater treatment plants, agricultural drains and canal discharges. Annual precipitation is low (approximately seven inches/yr) and its occurrence is variable. Wastewater treatment plant discharges are likely the most consistent year around discharges of surface water to the system, while agricultural irrigation and dewatering water would be next. This memorandum discusses each source and the available data describing the potential quantity contributed to the project reach by each source.

Local Climate Conditions

Climatic sources include: precipitation, evaporation, and evapostranspiration.

Precipitation

In a typical year approximately seven inches of precipitation occurs from two distinct weather patterns: the summer monsoon (July through October) and the winter cold front (November through March). Approximately 40 percent of the annual rainfall occurs during the subtropical monsoon season which is typically short-duration, high-intensity thunderstorms. Conversely, the winter cold front storms account for approximately 50 percent of the annual precipitation and are typically long-duration, low-intensity events. The remaining 10 percent may occur as the result of either weather pattern (USGS, 1995). Historic and real time precipitation data is available from a USGS and Flood Control District of Maricopa County (FCDMC) flood warning network rain gauges located around the state. A summary of monthly average rainfall collected over the time period February 1, 1998 through January 31, 2003 from the Buckeye gauge station (February 1, 1998 to January 31, 2003) is provided in Table 1. The average annual rainfall for the time period was 6.8 inches, the minimum annual total was 5.6, and the maximum rainfall in any year was 8.5 inches.

Evaporation

Open water evaporation data from the Phoenix area indicate an average of 94.4 inches per year, based on data from 1896 to 2000. If such data are unavailable, open water body evaporation rates can be estimated as 0.7 to 0.8 of local pan evaporation data. The Arizona Meteorological Network, part of the Office of Arid Lands at the University of Arizona, provides local reference evapotranspiration values that can be used to estimate pan evaporation rates on a site specific basis. Evaporation is important with respect to concentrating salts, water availability, and other parameters which may lead to vegetation stress or even failure of restored habitats.

Table 1

Monthly Rainfall Data
From the Buckeye, Arizona Gage Station
(2/98 – 1/03)

Month	Average (inch)	Minimum (inch)	Maximum (inch)
January	0.3	0.0	0.9
February	1.1	0.0	4.0
March	0.7	0.0	1.8
April	0.3	0.0	1.3
May	0.0	0.0	0.0
June	0.1	0.0	0.4
July	1.6	0.0	3.1
August	0.7	0.0	1.4
September	0.6	0.0	1.5
October	0.7	0.0	2.5
November	0.1	0.0	0.3
December	0.2	0.0	0.4

Table 2
Monthly Evaporation Data
Phoenix, Arizona

Month	Average (inch)
January	3.03
February	4.02
March	6.11
April	8.64
May	11.33
June	12.67
July	13.10
August	11.87
September	9.69
October	6.81
November	4.15
December	2.96
Cumulative Total	*94.4*

Evapotranspiration

Evapotranspiration (ET) is a measure of the water loss from a vegetative surface considering the combined effects of soil evaporation and plant transpiration. Factors that affect evapotranspiration rate include: temperature, relative humidity, wind, soil moisture, plant type, and plant development. Evapotranspiration can be increased or decreased over that measured in open water bodies by the choice and aerial extent of vegetation (USBR 1993).

Reference evapotranspiration (ETo) is defined as the ET from a 3 to 6 inch tall cool season grass that completely covers the ground, and is supplied with adequate water. Historic reference evapotranspiration data is available from AZMET location around the state. The closest AZMET station is located on the Roosevelt Canal in Buckeye (Latitude 33° 24' N Longitude 112° 41' W). Monthly average ETo, developed from daily records for February 1, 1998 to January 31, 2003 are shown in Table 3.

Table 3

Monthly Evapotranspiration Data
Roosevelt Canal Station, Buckeye, Arizona

Month	**Average** (inch)	**Minimum** (inch)	**Maximum** (inch)
January	3.4	2.6	4.0
February	4.2	3.1	5.0
March	6.2	5.6	6.9
April	8.1	7.5	9.1
May	10.5	9.6	11.3
June	11.0	10.2	11.5
July	9.8	8.9	10.4
August	9.1	8.4	9.9
September	7.8	7.5	8.2
October	6.1	5.2	7.1
November	3.8	3.0	4.4
December	3.1	2.7	3.8
Annual Total	*81.8 (6.8 feet)*	*79.0 (6.6 feet)*	*86.5 (7.2 feet)*

Wastewater Effluent

Wastewater treatment plants (WWTP) and water reclamation facilities (WRF) may discharge treated wastewater effluent into the Gila River, tributaries to the Gila River, and irrigation districts serving the agricultural lands surrounding the El Rio project area, or recharge the upper groundwater aquifer beneath the El Rio project area. In all cases these discharges or recharges impact the quantity of water in the Gila River.

Several WWTPs and WRFs are located near the El Rio project area. In addition many more are planned to meet the need for wastewater treatment created by increasing populations. **Appendix A** contains a map illustrating the location of the 6 existing WWTP and WRFs and the 12 planned WWTP and WRFs.

A schedule for facility expansion and new construction was taken from the MAG 208 plan (October 2002). Table 4 lists the current and future capacity (anticipated by year 2020) in million gallons a day (mgd).

Table 4

Existing and Planned WWTP and WRF Capacity

Facility Name	Municipality	Current Capacity (mgd)	Capacity by 2020 (mgd)
City of Avondale WWTP	Avondale	3.5	6.4
Town of Buckeye WWTP	Buckeye	0.6	2
City of Goodyear 157th Avenue WWTP (future Cotton-Lane WRF)	Goodyear	3	4
Estrella WWTP (also known as Corgett Basin WRF)	Goodyear	0.8	2.2
Northside WRF (also known as North WRF)	Avondale	0	6
Blue Horizon WRF	Buckeye	0	2
Sundance WRF	Buckeye	0	3.6
Whitestone WRF (also known as Verrado WRF)	Buckeye	0	3.35
Palm Valley WRF	Goodyear	0	8.2
Rainbow Valley WRF	Goodyear	0	5.5
Waterman Basin WRF	Goodyear	0	7
Sarival WRF	Goodyear	0	8.2
TOTAL CAPACITY		**7.9**	**58.45**

Reuse, Recharge, and Discharge Options

Reuse permits are required by ADEQ for facilities accepting treated effluent. There are five facilities in the region that currently have reclaimed water permits. They include:

- City of Avondale WWTP
- City of Goodyear WWTP
- Goodyear Estrella WWTP
- City of Tolleson

- Phoenix 91st Avenue WWTP

Reuse of effluent limits the quantity of water discharged to the river. The primary reuses are irrigation of crops and turf, which have a seasonal patterns in water usage. The result is large discharges in winter months, and reduced or no discharge during the growing season.

Recharge and Recovery

The Underground Water Storage and Recovery Program was initiated by the Arizona Department of Water Resources (ADWR) in 1986. Since then, 15 Underground Storage Facility (USF) permits have been issued in Maricopa County for recharging effluent. Only one is known to exist in the El Rio project vicinity and it is managed by the City of Goodyear WWTP which has a USF permit for 3,360 acre-feet per year (MAG, 2002).

USF permits are typically used to operate aquifer storage and recovery (ASR) systems. The primary objective of ASR systems is the short term storage of water in times of excess for use in times of shortage. ASR systems require a large unsaturated zone to be effective and could potentially reduce or eliminate surface water discharges. Since the groundwater table is high in the project area, it is unlikely that WRP will opt to develop large-scale ASR project for seasonal storage.

The Aquifer Protection Permit (APP) program was introduced by ADEQ in 1989, to permit discharges to groundwater. Current Aquifer Protection Permits (APP) for the following facilities:

- City of Avondale WWTP
- Town of Buckeye WWTP
- City of Goodyear, Recharge Project/SAT Facilities

Currently six facilities in the region have National Pollution Discharge Elimination System (NPDES) permits for discharge of treated effluent. Table 5 lists the facilities with NPDES permits and the permitted receiving water.

Table 5

Permitted Receiving Waters
WWTP and WRF

Facility Type	Name	Receiving Water
Municipal WWTP	Avondale WWTP	Gila River
Municipal WWTP	Buckeye WWTP	Arlington Canal
Municipal WWTP	Goodyear 157th Avenue WWTP	Gila River
Municipal WWTP	Goodyear Estella WWTP	Corgett Wash – tributary to Gila River
Industrial WWTP	Lockheed Martin	Unnamed ditches – tributary to BID
Municipal WWTP	Phoenix 91st Avenue WWTP	Salt River
Municipal WWTP	Tolleson WWTP	Salt River

(MAG 208 Plan, 2002)

Agricultural Discharges

The Buckeye Water Conservation and Drainage District (BWCDD) operates the Buckeye Canal, the South Extension Canal, and the Arlington Canal to transport water for agricultural uses on the north bank of the project area. The water supplies are reclaimed water from the 91st Avenue WWTP and the Buckeye WWTP as well as groundwater from more than 30 irrigation and dewatering wells. The amounts of water discharged to the El Rio reach of the Gila River from agricultural activities is variable and depend upon climate and crop choice in a given field for a given time-period.

Tail water

The BWCDD also maintains surface drainage canals which carry agricultural tail water from the service area to the river. Tail water runoff is the unused irrigation water or rain water that is collected at the base or at the end of an irrigation system or field in a ditch or other impoundment. This water may be reused again for irrigation purposes, left to evaporate, percolate into the ground, treated, and/or discharged to surface bodies of water. Discharge points are located in the Gila River at the following road alignments:

- Jackrabbit Road
- Between Dean and Airport Roads
- Watson Road (end of South Extension Canal)
- Miller Road
- Between Rooks and Miller Roads
- Between Wilson and Turner Roads
- Between Bruner and Verde Roads

A map of the BWCDD canal system and discharge points is included in **Appendix B**. The discharge from the BWCDD can be estimated as 14,000 AF/yr, which represents 40 % of the water 35,000 AF/yr supplied.

In addition to canals discharges, fields adjacent to the river also contain culverts that drain directly into the Gila River. Field inspection found tail water entering the Gila River as shown in the photo in **Appendix C**.

Dewatering Wells

A high ground water table in the Buckeye area, impacts the productivity of farms. Dewatering wells are operated to control water levels in many fields. This results in excess groundwater which is put into canals and drained to the Gila River.

Stormwater Runoff

Stormwater collection systems in the project area are limited in extent as is the amount of impervious area. As development occurs in the region it is likely that agricultural land will be transferred into residential and commercial land uses. Although this will likely increase the amount of stormwater runoff, on-site retention requirements of new developments will likely attenuate those flows collecting them in detention facilities and allowing the water to evaporate or percolate into the groundwater. Consideration could be given to developing drainage pathways that treat, convey, and discharge runoff from new developments to discharge into the Gila River. As such until the region develops further and stormwater collection systems evolve that would route flows to the river, it is not anticipated that stormwater is or will be a reliable source of water for restoration purposes in the project area.

Concentrated Animal Feeding Operations (CAFOs)

CAFO's are not permitted to have surface run-off due to the high level of nutrients, BOD, and pathogens associated with animal waste. For this reason, CAFOs are not considered a significant source of flow into the project area.

RESTORATION OPPORTUNITIES

The presence and availability of excess water in the El Rio project area allows great opportunities for restoration. Existing water bodies in the eastern portion of the site are thought to be supported primarily by effluent from the 91st Avenue WWTP and a high groundwater table. The middle region of the project area contains water bodies that exist seasonally, typically following significant rainfall events in the contributing watershed. The western region of the project area contains many water bodies, throughout the year. These water bodies are likely sustained by a combination of groundwater and agricultural tail-water.

DATA GAPS

Although the number and type of surface water inputs to the El Rio project reach have been identified and located, some critical information is still lacking. Measurement or estimates will need to be conducted to assess the quantity of surface water discharges from agricultural activities. Ideally, these would be done immediately after potential restoration areas have been identified.

SUMMARY

Although the perennial character of the Gila River is no longer apparent, today the El Rio Project reach provides significant and existing, natural surface water bodies. This provides a great opportunity to develop a sustainable ecosystem restoration project with xero-riparian, hydro-riparian and wetland habitats.

Sources of surface water in the area include precipitation, upstream and nearby wastewater treatment plant discharges, agricultural drains and canal discharges. Also important is the geological setting which is characterized by relatively shallow depth to groundwater (See Groundwater Technical Memorandum). The shallow groundwater setting and multiple surface water inputs, albeit of differing quality, provide flexibility in approaching ecosystem restoration in the El Rio reach. For instance, the shallow groundwater table facilitates the establishment of dominant riparian species by pole-planting, a simple and economical technique. The shallow depth to groundwater and surface water inputs will also likely reduce the cost of establishing or enhancing wetland and aquatic habitat features. Finally, vegetation management achieved through the replacement of terrestrial species with wetland plants or open water aquatic areas via excavation will also be more cost effective because of the reduced amount of material to be removed.

Because annual precipitation is low (approximately 7 inches/yr) and its occurrence is variable, restoration efforts should probably not rely upon runoff as a primary source, but could be used to augment systems in appropriate locations. Wastewater treatment plant discharges are likely the most consistent year around discharges of surface water to the system, while agricultural irrigation and dewatering water would be next. Combined with the groundwater character, the surface water sources appear sufficient to assist restoration efforts.

REFERENCES

MAG, 2002. 208 Water Quality Management Plan Update. Prepared by Carollo Engineer.

McNamee, Gregory 1994. *Gila The Life and Death of an American River.* University of New Mexico Press, Albuquerque, NM.

USBR, 1993. *Review of Wetland Evapotranspiration Literature*. Prepared by the Environmental Resources Engineering Department, Humboldt State University, Bureau of Reclamation Contract No. 1-PG-30-12790, May 1993.

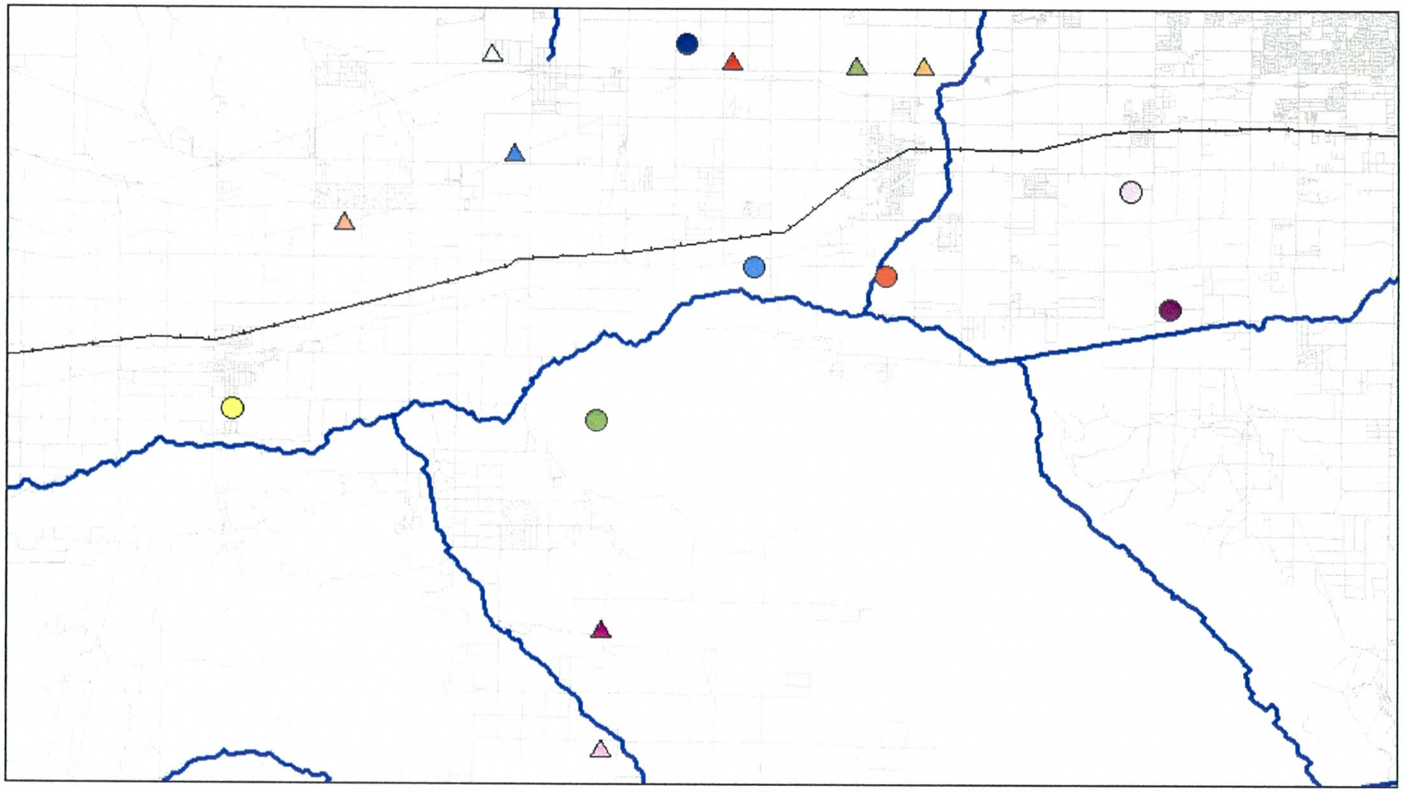
USGS, 1995. Statistical Summary of Select Physical, Chemical, and Microbial Characteristics, and Estimates of Constituent Loads in Urban Stormwater, Maricopa County. Thomas Lopes *et al.*

APPENDICES

APPENDIX A	Figure of WWTP and WRF
APPENDIX B	Figure of BWCDD Tail Water Discharges
APPENDIX C	Photo

APPENDIX A

Figure of WWTP and WRF



APPENDIX A

El Rio Project Wastewater Treatment Plants and Water Reclamation Facilities

Existing Facilities

- Avondale WWTP
- Buckeye WWTP
- Goodyear Estrella WWTP (Corget WRF)
- Goodyear 157th Avenue WWTP
- Lockheed Martin WWTP
- Phoenix 91st Avenue WWTP
- Tolleson WWTP

Planned Facilities

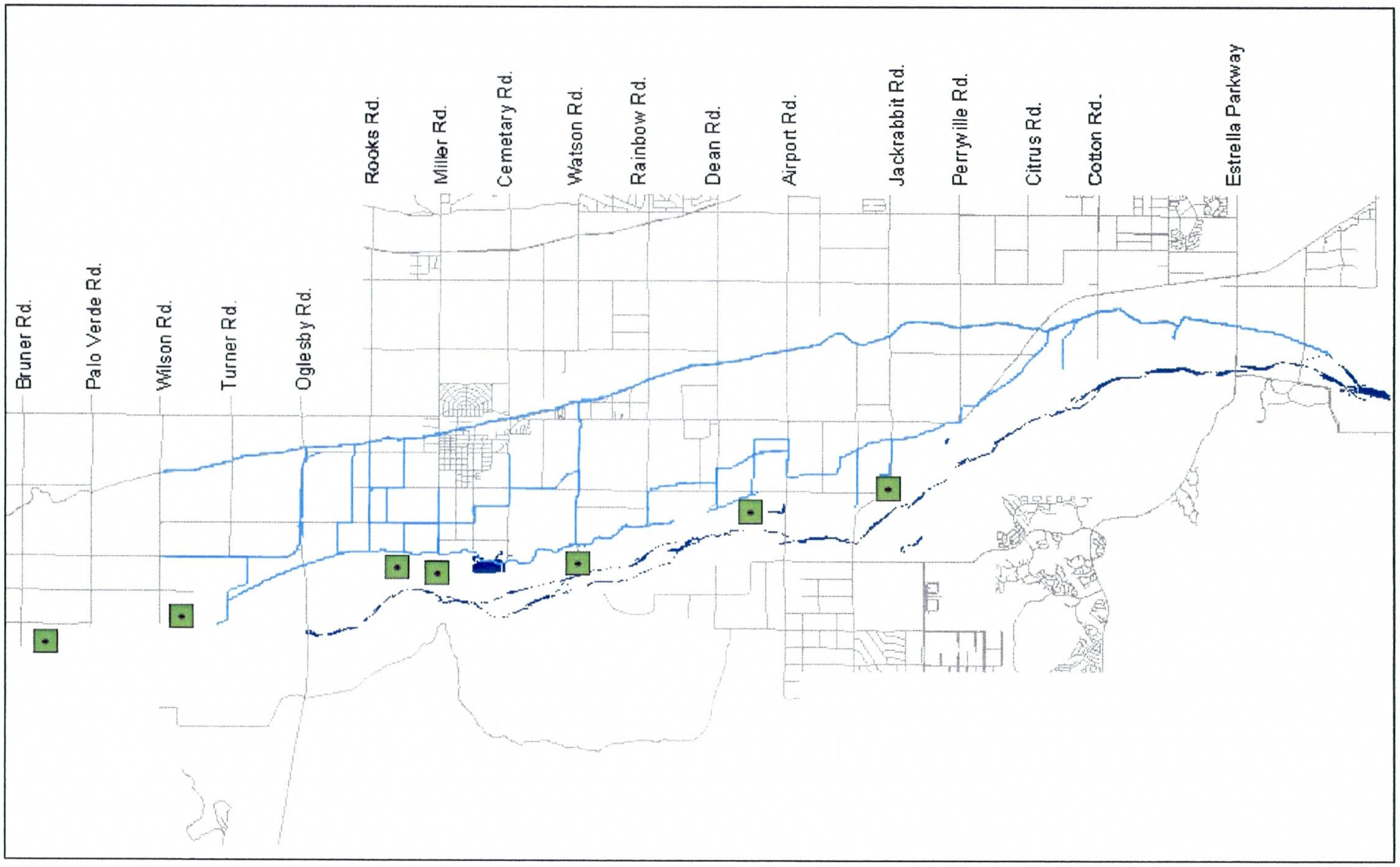
- Avondale North WRF
- Buckeye Blue Horizon WRF
- Buckeye Sundance WRF
- Buckeye Whitestone WRF
- Goodyear Palm Valley WRF
- Goodyear Rainbow Valley WRF
- Goodyear Sarival WRF
- Goodyear Waterman Basin WRF

0 2 4 6 Miles

N

APPENDIX B

Figure of BWCDD Tail Water Discharges



APPENDIX B

Tailwater Discharge Points along the El Rio Project Area

Legend

- Tailwater Discharge Points
- River Channel
- Canals
- Roads

N

APPENDIX C

Photo

APPENDIX C

Figure 1: Pipe draining agricultural field directly in to floodway of Gila River.

CHAPTER 3 – REVEGETATION POTENTIAL PAGE

REVEGETATION POTENTIAL

CHAPTER 3

BACKGROUND

The following reports on the vegetative cover types delineated in the El Ro Project reach of the Gila River by Ecoplan and Associates Inc. The format of this memorandum will consist of presenting the vegetation cover types, treatment mechanisms, resistance to flow, and potential for restoration. For this report, restoration alternatives include protection of high quality and desirable habitat, enhancement of marginal habitat, and creation of new habitat for aesthetics, mitigation water quality improvements, or buffering sensitive areas from adjacent land use or other activities.

VEGETATION COVER TYPES

In the El Rio Project Reach 12 vegetation cover types were identified and defined.

- Sonoran Desert Scrub (SDS)
- Cobble/Strand (CS)
- Arrow weed/Salt Cedar/Willow (AWS)
- Arrow weed/Willow (AW)
- Salt Cedar (SC)
- Salt Cedar/Cottonwood/Willow (SCW)

- Salt Bush/Quail Brush (ATX)
- Cottonwood/Willow (CW)
- Willow/Salt Cedar (WS)
- Agriculture (AG)
- Marsh (M_)
- Marsh Type 1 (M1)
- Marsh Type 2 (M2)

Table 1

El Rio Vegetative Cover Types and Pre-Project Acreages

Cover Type	Symbol	Acreage	% of Total
Arrow-weed/Willow/Salt Cedar	AWS	49	0.6 %
Arrow-weed/Willow	AW	32	0.4 %
Saltbush/Quail brush	ATX	179	2.2 %
Cobble Strand	CS	3,049	38 %
Cottonwood/Willow	CW	100	1.3 %
Marsh 2	M2	17	0.2 %
Salt Cedar	SC	4,349	55 %
Salt Cedar/Cottonwood/Willow	SCW	33	0.4 %
Willow/Salt Cedar	WS	168	2.1 %
Total		7,975	100.0 %

WETLAND VEGETATION TREATMENT

Wetlands are complex systems, where physical components facilitate chemical reactions and biological processes to remove and/or transform pollutants. Vegetation type plays a major role in the removal mechanism. For the purposes of improving water quality, wetland vegetation can be grouped into four categories: emergent vegetation, submerged aquatic species, floating/spreading aquatic species, and transitional plants.

Emergent Vegetation

Emergent aquatic macrophytes are rooted in the bottom muds, and typically grow in saturated soils to water depths of approximately one meter. Treatment wetlands generally include, but are certainly not limited to *typha sp.* and s*choenoplectus sp.* (formerly known as *scirpus*). Some species can tolerate complete saturation on a year-round basis, but others may require a disturbance e.g., drying, burning, or some means of re-aerating soils. In the past, monocultures have been extensively used but the current trend is towards the use of a diverse assemblage to meet water quality goals while providing greater habitat value. A diverse assemblage of macrophytes is also more sustainable habitat compared to monocultures.

Emergent wetland vegetation established in dense stands allows for mechanical removal of particulate matter and the pollutants associated with it. The dense stands slow water velocity which aids in settling solids and permit interception and impaction of particulate matter. The submerged portions of the plants and litter-fall serve as surfaces for the attachment of biological films. Upon plant senescence and subsequent decay, plant material can release nutrients that can sometimes be detected as seasonal pulses in the wetland discharge. Carbon is also released and can be used by microbial communities to satisfy metabolic needs and is important for microbial mediated nutrient transformations and removals. Carbon compounds resulting from the decay of wetland plants and microbial communities will also likely show up in the wetland effluent and can be measured as Biochemical Oxygen Demand (BOD) or Carbon Oxygen Demand (COD). The decaying emergent vegetation provides a "litter-zone" where labile carbon is formed and subsequently used by bacteria for metabolic requirements, such as denitrification.

Emergent plants can also influence the water quality by shading the water surface, thus dampening temperature and wind-induced turbulence. Live and dead emergent shoots exchange gases between the bottom sediments, water column, and atmosphere. Oxygen can be transported through stem structures to the roots and rhizomes where some may "leak" out. This sets up an oxidizing zone immediately adjacent to an anoxic or anaerobic zone which are very important for nutrient transformations, degradation of organic compounds, and if sufficient sulfur is present in the system, heavy-metal removal as metal-sulfide complexes.

Submerged aquatic plants

Submerged aquatic plants can persist in water depths deeper than one meter. Submerged aquatic plants are established such that they "fill" the water column of internal deep zones. They will be typically rooted in the bottom and thrive if sufficient light penetrates the water column. Submerged plants such as *Ceratophyllum demursum*, provide surface in the water column for the attachment of microbes that do the brunt of the nutrient removal/transformations and can help in the assimilation of BOD produced from the natural decay of plant biomass. In some cases, submerged aquatic species have been used in areas too deep to sustain emergent macrophytes. Submerged plants alter water quality by exchanging gases with the water column, (O_2 during daylight hours, CO_2 at night), and can provide substantial surface area within the water column for the attachment of algae and bacteria, providing an ideal "nursery" for zooplankton growth. They mediate water temperatures and provide refuge and forage for wildlife. A good algal cover or even duckweed covers can preclude light transmission and make it difficult to sustain these plants over time unless nutrients are managed in emergent vegetation zones and retention times in open-water areas are minimized.

Spreading and Floating Plants

Spreading and floating plants are species that root in moist substrates (shoreline or banks of islands) and the spread out over the water surface. Floating aquatic plants, such as *Hydrocotyle*, *Ludwegia*, and *Potamogeton* facilitate the uptake of pollutants (generally nutrients, but perhaps dissolved constituents as well) by floating plants during growth and development. Floating vegetation systems for treatment, with true pollutant removal, require harvesting plants. The floating plants tend to have dangling root structures that facilitate the uptake of dissolved constituents, permit gas exchange with the water column, and provide an environment suitable for zooplankton communities to establish within. Floating aquatic vegetation establishes in the banks and spreads across the water surface minimizing algal production in the open water. These plants can provide numerous benefits to wildlife and other wetland vegetation.

Hydrocotyle (pennywort), for example, has been used in several operating treatment wetlands to:

1) protect emergent macrophytes from predation during the spring re-growth periods. In essence emergent species are grown through the pennywort cover. Muskrats consume the pennywort thereby allowing the bulrush to mature;

2) shading the water surface and providing nursery habitat for zooplankton, fish, and amphibians; and

3) providing forage for waterfowl.

Transitional plants

Transitional plants are the plants that grow by the banks of a wetland, in the zone between two inches of water and the moist soils above the water's surface. Species include *eleocharis*, *equisetum*, and *juncus*. In addition *salix* (willow) trees prefer growing in this zone. Although these do not have a direct impact on water quality, they are essential for bank stabilization and habitat value of the wetland environment.

RESISTANCE DUE TO VEGETATION

The stage-discharge relationship for a river system is influenced by the vegetation in the channel and overbank. The presence of plant communities can increase or decrease the effective flow resistance; thereby impacting the velocity, sedimentation, and depth of water. The resistance of river flow as a result of vegetation in the flow path can be estimated described based on the area and type of vegetation. The resistance is calculated by the characteristic area of vegetation (Av), the bulk drag coefficient (Cd), and is a function of river velocity. Drag is the force created when a fluid moves through vegetation. This force creates velocity gradients, eddies, and loss of momentum.

Both the Av and Cd are challenging to quantify for a particular stretch of river. The surface area estimated and used in defining Av for a particular vegetation community is most commonly the frontal area, but relationships have also been calculated with the wetted area. The frontal area is described as the area of the object, on a plane normal to the flow direction. Bulk drag coefficient is an estimate of the resistance force caused by a particular object. Cd values are derived in wind tunnels or field data and can be correlated for water applications. Deciduous vegetation Cd values depend on the leaf development.

Alternate Method to Calculate the N-value

Historically the resistance of a river was described merely by roughness values, n, in Manning's equation. Manning's n value ranges exist for most cover types from cobble to vegetated communities. However, available roughness values vary greatly within a cover type. To better estimate resistance roughness of vegetation in an un-submerged channel, the following equation can be used:

$$n = K_n R^{2/3} \left[\frac{C_d A_d}{2g} \right]^{1/2}$$

This relationship is used to describe Manning's roughness as a factor of a unit correction factor (Kn), the hydraulic radius of the channel (R), drag coefficient (Cd), Area (Ad), and gravitational force (g). (Fischenich, 2000)

An equation for larger woody plants is as follows:

$$n = n_o + \sqrt{1.0 + \left(\frac{C_d \sum A_i}{2gAL} \right) \left(\frac{K_n}{n_o} \right)^2 \left(\frac{A}{P} \right)^{4/3}}$$

Here, n_o is the total boundary roughness, and $C_d \Sigma A_i/(AL)$ is the expression for the vegetation in the floodplain, and P is the wetted perimeter. (Freeman, 2000)

Finding/Summary

Manning roughness values, n, for a common wetland reed (bulrush) range from 0.27 to 0.70. Values were found to decrease with increasing velocities (WRP, 1994). "Few data are available from which drag coefficients can be computed for vegetation immersed in flowing water" (Fischenich and Dudley, 2000). One of the largest recently published studies was conducted through the US Army Corps of Engineers, Engineering Research and Development Center, entitled "Determination of Resistance Due to Shrubs and Woody Vegetation," published in October 2000. The study included 20 different plant species and 220 experiments. Unfortunately most of the riparian species in the Gila River were not included in this study. Salt cedar, however, was included in the study, and results of the experiments showed roughness values of between 0.048 to 0.072 (Freeman, 2000). **Appendix A** contains the list of resistance for the 20 species studied.

VEGETATION RESTORATION POTENTIAL

The sustainability of a restoration project will be dependent of providing the proper soil and water condition for plant survival. Table 2 lists the depth to groundwater and salinity requirements (measured in electrical conductivity) for plant species in the El Rio study area.

Table 2

Depth to Groundwater and Salinity Requirement of Vegetation

Common Name	Scientific Name	Depth to Groundwater (m)	Salinity as EC (dS/m)
Foothill paloverde	*Cercidium microphylum*	<10	< 5.0
Triangle-leaf bursage	*Ambrosia deltoidea*	< 10	ND
Fremont Cottonwood	*Populus fremontii*	3	< 3.0
Velvet mesquite	*Prosopis velutinia*	< 10	4 - 10
Willow	*Salix gooddingii*	0 – 3	< 4.0

Table 2 Cont.

Brittlebush	*Encelia farinosa*	N/A	ND
Arrow weed	*Tessaria sericea*	< 10	ND
Salt cedar	*Tamarix spp.*	10	18.5
Four-wing saltbush	*Atriplex canescens*	10	6 - 10
Cattail	*Typhia latifolia*	Standing water to 0.5	< 4.0
Coyote Willow	*Salix exigua*	1 - 3	6 - 10
Seep-Willow	*Baccharis glutinosa*	1 - 3	10

N/A = Not Applicable
ND = No Data

Sonoran Desert Scrub (SDS)

Preserve and protect existing Sonoran Desert Scrub. There is a potential to plant this cover type in converting selected areas of salt cedar where soil salinities are too high (> 3-5 mmhos/cm) for hydro-riparian species and where depth to groundwater exceeds approximately 10-feet below ground surface.

Cobble/Strand (CS):

Cobble/Strand open space should be considered for protection. It is also a candidate cover type for enhancing shallow drainages or for areas where the vegetation density, such as monotypical stands of Salt Cedar, needs to be reduced.

Arrow weed/Salt Cedar/Willow (AWS)

This cover type may be protected in place or enhanced by removing the salt cedar especially when located immediately adjacent to open water areas. Augmentation with cottonwood and willow species should also be considered when soil moisture and salinity are within appropriate ranges.

Arrow weed/Willow (AW)

This cover type should be considered valuable and protected within the El Rio project reach.

Salt Cedar (SC)

Protection could be considered in areas where this cover type is located immediately adjacent to persistent open water, since it is currently considered as potentially suitable habitat for Southwest Willow Flycatcher. Replacement of this cover type should be considered in all other areas. If soil and moisture conditions permit, replacement of this cover type could be with native hydro-riparian species. In other areas where soil salinity may too high, consideration should be give to replacement with open water through excavation, salt tolerant tree species such as velvet and screw bean mesquite, or a salt bush/ quail brush complex. Final decisions regarding replacement should be made after specific locations have been identified and among other things, site specific soil and water quality information is available.

Salt Cedar/Cottonwood/Willow (SCW)

The SCW cover type is a candidate for protection/preservation depending upon its location within the El Rio project reach. Enhancement/augmentation of the native species in this complex is recommended where removal of exotics will not result in degradation of the existing habitat afforded by this cover type. Enhancement would likely entail select removal of exotics and replacement with appropriate ground cover, mid and dominant canopy species.

Salt Bush/Quail Brush (ATX)

Protect and preserve in place. This cover type may be used to replace exotic vegetation in areas where soil salinity and moisture levels do not permit other native species to become established.

Cottonwood/Willow (CW)

CW cover should be considered extremely valuable and where it occurs in the El Rio project reach it should be protected and preserved in place. If water sources are available certain areas may be enhanced through pole-plantings, containerized stock, or provision of appropriate soil areas and moisture conditions downwind of existing CW areas to encourage recruitment of additional stock from existing seed sources. Creation of CW areas should also be considered at appropriate location within the El Rio reach.

Willow/Salt Cedar (WS)

WS is another relatively desirable cover type and in most cases it should be considered for preservation. Possible enhancement in these areas would include selective replacement of salt cedar located immediately adjacent to shorelines with true willows (*Salix sp.*) or seep-willow.

Agriculture (AG)

Preservation of agricultural fields in the El Rio project reach should be an objective as agricultural lands can serve as a buffer for flood conveyance. Agriculture can also buffer incompatible land uses such as urban development and wildlife habitat. Besides serving as potential forage and refuge areas for wildlife, agricultural activities provide surface water and groundwater inputs to the river in this reach.

Marsh

Existing marshes should be considered valuable vegetative cover and protected. Because of high habitat value and potential to improve water quality, the creation of both wetland marshes and subsurface flow wetlands should be considered. Wetland marsh creation should be used to replace dense stands of salt cedar and thereby improve flood conveyance within the reach at selected areas while at the same time providing additional high quality habitat. For surface water discharges to the river that may be high in nitrate or toxic compounds, subsurface flow systems should be used to prevent contact with a free water surface by humans and wildlife. Subsurface flow systems also can be used in areas where mosquito breeding is potentially problematic.

SUMMARY

Twelve vegetative cover types were identified in the El Rio Project area. These areas are typified by communities with varying tolerance to salinity and moisture. The opportunity exists to preserve and possibly enhance existing high quality and even marginal habitat types. This can be ultimately be achieved through selective removal of exotic species and replacement with open water, wetland marsh, native-riparian and upland vegetative communities. Creation of additional high quality native vegetation is also possible within the El Rio reach subject to appropriate soil conditions and available water. Restored habitat can improve water quality in the region, by reducing solids, organics, trace metals, pesticides, and oxygen demanding compounds. In addition replacement of particular habitat types such as salt cedar with native reeds or open water can reduce the resistance in the cross section, and minimize the impact of flood flows.

REFERENCES

Fischenich, Craig, and Sydni Dudley, 2000. Determining Drag Coefficients and Area for Vegetation. Technical Note EMRRP SR-08

Fischenich, Craig, 2000. Resistance Due to Vegetation. EDRC TN-EMRRP- SR-07

Freeman, Gary et. al., 2000. Determination of Resistance Due to Shrubs and Woody Vegetation. Prepared for US Army Corps of Engineers. Engineer Research and Development Center. ERDC/DHL-TR-00-25.

WRP, 1994. Effects of Vegetation on Hydraulic Roughness and Sedimentation in Wetlands. WRP Technical Note SD-CP-2.2.

APPENDIX A Resistance of Plant Species

APPENDIX A

Resistance of Plant Species

Table 3
Summary of Large Flume Results with Homogeneous Groupings (SI Units)

Run	Plant	Plant Height H, m	Plant Density M, 1/m^2	Water Depth Y_o, M	Mean Velocity V, m/sec	Energy Slope S	Average n	Bed Hydraulic Radius m	Bed V^*/V	Bed Manning's n
II 0-1	none			0.718	0.388	0.00013		0.562	0.069	0.0200
II 0-2	none			1.321	0.209	0.00002	0.016	0.884	0.064	0.0200
II 0-3	none			1.459	0.591	0.00015	0.016	1.011	0.069	0.0220
I 1-1	Yellow Twig Dogwood	0.51	5.360	1.271	0.366	0.00053	0.046	1.202	0.216	0.0710
I 1-2	Yellow Twig Dogwood	0.51	5.360	1.256	0.610	0.00124	0.042	1.184	0.198	0.0650
I 1-3	Yellow Twig Dogwood	0.51	5.360	1.122	0.750	0.00184	0.040	1.059	0.185	0.0590
I 1-4	Yellow Twig Dogwood	0.51	5.360	0.942	0.482	0.00119	0.047	0.902	0.213	0.0670
I 1-5	Yellow Twig Dogwood	0.51	5.360	1.021	0.588	0.00140	0.043	0.971	0.196	0.0620
I 1-6	Yellow Twig Dogwood	0.51	5.360	1.049	0.689	0.00163	0.040	0.991	0.183	0.0580
I 1-7	Yellow Twig Dogwood	0.51	5.360	0.536	0.878	0.00582	0.048	0.521	0.197	0.0560
I 1-8	Yellow Twig Dogwood	0.51	5.360	0.716	0.991	0.00477	0.041	0.688	0.181	0.0540
I 1-9	Yellow Twig Dogwood	0.51	5.360	0.887	1.091	0.00418	0.038	0.843	0.170	0.0530
I 2-1	Yellow Twig Dogwood	0.51	2.379	1.356	0.765	0.00102	0.031	1.232	0.145	0.0480
I 2-2	Yellow Twig Dogwood	0.51	2.379	1.149	0.924	0.00165	0.031	1.056	0.142	0.0460
I 2-3	Yellow Twig Dogwood	0.51	2.379	0.515	1.058	0.00693	0.040	0.499	0.174	0.0500
I 2-4	Yellow Twig Dogwood	0.51	2.379	0.396	0.750	0.00496	0.042	0.421	0.191	0.0530
I 3-1	Berried Elderberry	0.71	2.691	1.207	0.294	0.00030	0.042	1.134	0.195	0.0640
I 3-2	Berried Elderberry	0.71	2.691	0.983	0.479	0.00063	0.035	0.918	0.157	0.0500
I 3-3	Berried Elderberry	0.71	2.691	1.064	0.589	0.00085	0.034	0.989	0.154	0.0490
I 3-4	Berried Elderberry	0.71	2.691	0.953	0.304	0.00043	0.045	0.908	0.204	0.0640
I 3-5	Berried Elderberry	0.71	2.691	0.706	0.518	0.00125	0.040	0.676	0.176	0.0530
I 3-6	Berried Elderberry	0.71	2.691	0.782	0.614	0.00110	0.033	0.735	0.145	0.0440
I 3-7	Berried Elderberry	0.71	2.691	0.849	0.692	0.00123	0.032	0.793	0.141	0.0430
I 3-8	Berried Elderberry	0.71	2.691	0.816	0.769	0.00167	0.033	0.767	0.146	0.0450
I 3-9	Berried Elderberry	0.71	2.691	0.748	0.862	0.00199	0.031	0.702	0.136	0.0410
I 3-10	Berried Elderberry	0.71	2.691	0.915	0.945	0.00191	0.030	0.849	0.133	0.0410
I 4-1	Purpleleaf Euonymus	0.20	12.809	1.182	0.319	0.00041	0.045	1.120	0.209	0.0680
I 4-2	Purpleleaf Euonymus	0.20	12.809	1.195	0.420	0.00055	0.040	1.122	0.186	0.0600
I 4-3	Purpleleaf Euonymus	0.20	12.809	1.120	0.669	0.00159	0.042	1.063	0.195	0.0630

(Sheet 1 of 3)

Table 3 (Continued)

Run	Plant	Plant Height H, m	Plant Density M, 1/m^2	Water Depth Y_0, M	Mean Velocity V, m/sec	Energy Slope S	Average n	Bed Hydraulic Radius m	Bed V^*/V	Bed Manning's n
I 4-4	Purpleleaf Euonymus	0.20	12.809	0.842	0.662	0.00225	0.045	0.810	0.202	0.0620
I 4-5	Purpleleaf Euonymus	0.20	12.809	0.887	0.766	0.00251	0.042	0.849	0.189	0.0590
I 4-6	Purpleleaf Euonymus	0.20	12.809	0.781	0.974	0.00408	0.041	0.751	0.178	0.0560
I 4-7	Purpleleaf Euonymus	0.20	12.809	0.491	0.817	0.00477	0.042	0.477	0.183	0.0520
I 5-1	Purpleleaf Euonymus	0.20	5.694	1.032	0.411	0.00053	0.038	0.968	0.172	0.0550
I 5-2	Purpleleaf Euonymus	0.20	5.694	1.034	0.632	0.00106	0.035	0.967	0.159	0.0500
I 5-3	Purpleleaf Euonymus	0.20	5.694	0.707	0.963	0.00436	0.040	0.680	0.177	0.0530
I 6-1	Red Twig Dogwood	0.97	1.216	1.263	0.323	0.00110	0.075	1.233	0.357	0.1190
I 6-2	Red Twig Dogwood	0.97	1.216	1.264	0.479	0.00213	0.070	1.233	0.336	0.1110
I 6-3	Red Twig Dogwood	0.97	1.216	1.296	0.611	0.00266	0.062	1.259	0.297	0.0990
I 6-4	Red Twig Dogwood	0.97	1.216	0.940	0.347	0.00204	0.085	0.925	0.390	0.1230
I 6-5	Red Twig Dogwood	0.97	1.216	0.757	0.609	0.00508	0.070	0.744	0.313	0.0950
I 6-6	Red Twig Dogwood	0.97	1.216	0.829	0.953	0.00582		0.804	0.225	0.0693
I 6-7	Red Twig Dogwood	0.97	1.216	0.537	0.683	0.00833	0.070	0.530	0.308	0.0890
I 6-8	Red Twig Dogwood	0.97	1.216	0.934	0.962	0.00540	0.050	0.905	0.227	0.0720
I 7-1	Red Twig Dogwood	0.97	0.527	1.184	0.348	0.00117	0.070	1.155	0.330	0.1080
I 7-2	Red Twig Dogwood	0.97	0.527	0.818	0.504	0.00322	0.070	0.803	0.316	0.0973
II 1-1	Service Berry	0.71	0.538	0.690	0.350	0.00145	0.063	0.676	0.280	0.0840
II 1-2	Service Berry	0.71	0.538	0.967	0.562	0.00180	0.050	0.933	0.228	0.0720
II 1-3	Service Berry	0.71	0.538	0.803	0.685	0.00229	0.043	0.771	0.192	0.0590
II 1-4	Service Berry	0.71	0.538	0.933	0.903	0.00276	0.038	0.886	0.171	0.0540
II 1-5	Service Berry	0.71	0.538	1.154	0.513	0.00132	0.050	1.108	0.234	0.0760
II 1-6	Service Berry	0.71	0.538	1.275	0.688	0.00157	0.042	1.206	0.198	0.0650
II 4-1	Yellow Twig Dogwood		1.830	1.358	0.145	0.00019	0.071	1.316	0.344	0.1150
II 4-2	Yellow Twig Dogwood		1.830	1.389	0.343	0.00059	0.053	1.330	0.254	0.0850
II 4-3	Yellow Twig Dogwood		1.830	1.261	0.608	0.00112	0.040	1.186	0.189	0.0620
II 4-4	Yellow Twig Dogwood		1.830	1.081	0.967	0.00201	0.032	1.003	0.144	0.0460
II 6-1	Mulefat	0.97	0.646	1.423	0.408	0.00040	0.037	1.314	0.177	0.0590
II 6-2	Mulefat	0.97	0.646	1.265	0.643	0.00095	0.035	1.173	0.162	0.0530
II 6-3	Mulefat	0.97	0.646	1.364	0.724	0.00103	0.033	1.252	0.154	0.0510

(Sheet 2 of 3)

Table 3 (Concluded)

Run	Plant	Plant Height H, m	Plant Density M, 1/m^2	Water Depth Y_0, M	Mean Velocity V, m/sec	Energy Slope S	Average n	Bed Hydraulic Radius m	Bed V^*/V	Bed Manning's n
II 6-4	Mulefat	0.97	0.646	1.072	0.791	0.00119	0.030	0.984	0.135	0.0430
II 9-1	Vally Elberberry	0.97	1.722	1.366	0.282	0.00099	0.083	1.337	0.418	0.1350
II 9-2	Vally Elberberry	0.97	1.722	1.330	0.427	0.00163	0.070	1.296	0.339	0.1130
II 9-3	Vally Elberberry	0.97	1.722	1.071	0.522	0.00267	0.068	1.047	0.317	0.1020
II 9-4	Vally Elberberry	0.97	1.722	0.914	0.621	0.00475	0.072	0.897	0.329	0.1030
II 10-1	Salt Cedar	1.52	0.624	1.430	0.416	0.00156	0.072	1.394	0.352	0.1190
II 10-2	Salt Cedar	1.52	0.624	1.378	0.580	0.00238	0.063	1.338	0.305	0.1020
II 10-3	Salt Cedar	1.52	0.624	1.116	0.716	0.00380	0.060	1.085	0.281	0.0910
II 10-4	Salt Cedar	1.52	0.624	0.933	0.685	0.00369	0.058	0.909	0.264	0.0830
II 10-5	Salt Cedar	1.52	0.624	0.844	0.750	0.00513	0.060	0.824	0.272	0.0840
II 10-6	Salt Cedar	1.52	0.624	0.827	0.935	0.00517	0.048	0.801	0.215	0.0660
II	Black Willow	1.22	2.293	1.416	0.313	0.00084		1.090	0.303	0.0980
II	Black Willow	1.22	2.293	1.426	0.551	0.00113		1.337	0.221	0.0740
II	Black Willow	1.22	2.293	1.388	0.763	0.00210		1.312	0.216	0.0720
II	Black Willow	1.22	2.293	0.680	0.688	0.00175		0.637	0.152	0.0450
II	Black Willow	1.22	2.293	0.906	0.910	0.00333		0.874	0.186	0.0580
II	Black Willow	1.22	2.293	0.821	0.789	0.00326		0.794	0.202	0.0620
II	Black Willow	1.22	2.293	0.776	0.726	0.00228		0.743	0.178	0.0540
II 13-1	Mountain Willow	1.52	4.844	0.678	0.628	0.00323	0.052	0.661	0.231	0.0690
II 13-2	Mountain Willow	1.52	4.844	0.605	0.704	0.00414	0.050	0.590	0.219	0.0640
II 13-3	Mountain Willow	1.52	4.844	0.747	0.651	0.00666	0.075	0.736	0.336	0.1020
II 13-4	Mountain Willow	1.52	4.844	0.818	0.609	0.00616	0.080	0.806	0.363	0.1120
II 13-5	Mountain Willow	1.52	4.844	0.934	0.610	0.00584	0.082	0.919	0.378	0.1190
II 13-6	Mountain Willow	1.52	4.844	1.092	0.521	0.00459	0.090	1.076	0.421	0.1360
II 13-7	Mountain Willow	1.52	4.844	1.251	0.446	0.00306	0.090	1.230	0.432	0.1430
II 13-8	Mountain Willow	1.52	4.844	1.326	0.447	0.00283	0.088	1.303	0.428	0.1420
II 13-9	Mountain Willow	1.52	4.844	1.414	0.526	0.00335	0.083	1.387	0.406	0.1370
II 13-10	Mountain Willow	1.52	4.844	1.278	0.600	0.00432	0.080	1.254	0.383	0.1270
II 13-11	Mountain Willow	1.52	4.844	1.382	0.895	0.00549	0.062	1.343	0.301	0.1010
II 14-1	Mt Willow w/o leaves	1.52	4.844	0.874	0.595	0.00379	0.066	0.856	0.299	0.0930
II 14-2	Mt Willow w/o leaves	1.52	4.844	1.376	0.368	0.00136	0.075	1.343	0.364	0.1220

(Sheet 3 of 3)

Table 4
Summary of Large Flume Results with Homogeneous Groupings (Non-SI Units)

Run	Plant	Plant Height H, ft	Plant Density M, 1/ft^2	Water Depth Y_o, ft	Mean Velocity V, ft/s	Energy Slope S	Average n	Bed Hydraulic Radius ft	Bed V^*/V	Bed Manning's n
II 0-1	none		0.000	2.355	1.274	0.00013		1.844	0.069	0.0200
II 0-2	none		0.000	4.334	0.687	0.00002	0.016	2.901	0.064	0.0200
II 0-3	none		0.000	4.788	1.940	0.00015	0.016	3.318	0.069	0.0220
I 1-1	Yellow Twig Dogwood	1.67	0.498	4.170	1.200	0.00053	0.046	3.944	0.216	0.0710
I 1-2	Yellow Twig Dogwood	1.67	0.498	4.120	2.000	0.00124	0.042	3.885	0.198	0.0650
I 1-3	Yellow Twig Dogwood	1.67	0.498	3.680	2.460	0.00184	0.040	3.474	0.185	0.0590
I 1-4	Yellow Twig Dogwood	1.67	0.498	3.090	1.580	0.00119	0.047	2.959	0.213	0.0670
I 1-5	Yellow Twig Dogwood	1.67	0.498	3.350	1.930	0.00140	0.043	3.185	0.196	0.0620
I 1-6	Yellow Twig Dogwood	1.67	0.498	3.440	2.260	0.00163	0.040	3.252	0.183	0.0580
I 1-7	Yellow Twig Dogwood	1.67	0.498	1.760	2.880	0.00582	0.048	1.710	0.197	0.0560
I 1-8	Yellow Twig Dogwood	1.67	0.498	2.350	3.250	0.00477	0.041	2.258	0.181	0.0540
I 1-9	Yellow Twig Dogwood	1.67	0.498	2.910	3.580	0.00418	0.038	2.766	0.170	0.0530
I 2-1	Yellow Twig Dogwood	1.67	0.221	4.450	2.510	0.00102	0.031	4.041	0.145	0.0480
I 2-2	Yellow Twig Dogwood	1.67	0.221	3.770	3.030	0.00165	0.031	3.463	0.142	0.0460
I 2-3	Yellow Twig Dogwood	1.67	0.221	1.690	3.470	0.00693	0.040	1.636	0.174	0.0500
I 2-4	Yellow Twig Dogwood	1.67	0.221	1.300	2.460	0.00496	0.042	1.382	0.191	0.0530
I 3-1	Berried Elderberry	2.33	0.250	3.959	0.963	0.00030	0.042	3.720	0.195	0.0640
I 3-2	Berried Elderberry	2.33	0.250	3.225	1.570	0.00063	0.035	3.011	0.157	0.0500
I 3-3	Berried Elderberry	2.33	0.250	3.490	1.934	0.00085	0.034	3.244	0.154	0.0490
I 3-4	Berried Elderberry	2.33	0.250	3.125	0.996	0.00043	0.045	2.979	0.204	0.0640
I 3-5	Berried Elderberry	2.33	0.250	2.317	1.699	0.00125	0.040	2.219	0.176	0.0530
I 3-6	Berried Elderberry	2.33	0.250	2.565	2.013	0.00110	0.033	2.410	0.145	0.0440
I 3-7	Berried Elderberry	2.33	0.250	2.787	2.270	0.00123	0.032	2.603	0.141	0.0430
I 3-8	Berried Elderberry	2.33	0.250	2.676	2.522	0.00167	0.033	2.516	0.146	0.0450
I 3-9	Berried Elderberry	2.33	0.250	2.454	2.827	0.00199	0.031	2.303	0.136	0.0410
I 3-10	Berried Elderberry	2.33	0.250	3.002	3.102	0.00191	0.030	2.784	0.133	0.0410
I 4-1	Purpleleaf Euonymus	0.67	1.190	3.878	1.048	0.00041	0.045	3.674	0.209	0.0680
I 4-2	Purpleleaf Euonymus	0.67	1.190	3.921	1.377	0.00055	0.040	3.681	0.186	0.0600
I 4-3	Purpleleaf Euonymus	0.67	1.190	3.673	2.195	0.00159	0.042	3.489	0.195	0.0630
I 4-4	Purpleleaf Euonymus	0.67	1.190	2.762	2.172	0.00225	0.045	2.655	0.202	0.0620
I 4-5	Purpleleaf Euonymus	0.67	1.190	2.911	2.512	0.00251	0.042	2.767	0.189	0.0590

(Sheet 1 of 3)

Table 4 (Concluded)

Run	Plant	Plant Height H, ft	Plant Density M, 1/ft^2	Water Depth Y_0, ft	Mean Velocity V, ft/s	Energy Slope S	Average n	Bed Hydraulic Radius ft	Bed V^*/V	Bed Manning's n
II 9-3	Vally Elberberry	3.17	0.160	3.515	1.714	0.00267	0.068	3.434	0.317	0.1020
II 9-4	Vally Elberberry	3.17	0.160	2.999	2.038	0.00475	0.072	2.944	0.329	0.1030
II 10-1	Salt Cedar	5.00	0.058	4.692	1.364	0.00156	0.072	4.573	0.352	0.1190
II 10-2	Salt Cedar	5.00	0.058	4.522	1.902	0.00238	0.063	4.389	0.305	0.1020
II 10-3	Salt Cedar	5.00	0.058	3.660	2.350	0.00380	0.060	3.560	0.281	0.0910
II 10-4	Salt Cedar	5.00	0.058	3.062	2.246	0.00369	0.058	2.981	0.264	0.0830
II 10-5	Salt Cedar	5.00	0.058	2.768	2.462	0.00513	0.060	2.704	0.272	0.0840
II 10-6	Salt Cedar	5.00	0.058	2.714	3.067	0.00517	0.048	2.629	0.215	0.0660
II	Black Willow	4.00	0.213	4.646	1.028	0.00084		3.578	0.303	0.0980
II	Black Willow	4.00	0.213	4.677	1.809	0.00113		4.387	0.221	0.0740
II	Black Willow	4.00	0.213	4.554	2.503	0.00210		4.305	0.216	0.0720
II	Black Willow	4.00	0.213	2.232	2.257	0.00175		2.088	0.152	0.0450
II	Black Willow	4.00	0.213	2.974	2.984	0.00333		2.867	0.186	0.0580
II	Black Willow	4.00	0.213	2.693	2.590	0.00326		2.604	0.202	0.0620
II	Black Willow	4.00	0.213	2.547	2.381	0.00228		2.439	0.178	0.0540
II 13-1	Mountain Willow	5.00	0.450	2.226	2.061	0.00323	0.052	2.168	0.231	0.0690
II 13-2	Mountain Willow	5.00	0.450	1.986	2.309	0.00414	0.050	1.937	0.219	0.0640
II 13-3	Mountain Willow	5.00	0.450	2.451	2.137	0.00666	0.075	2.414	0.336	0.1020
II 13-4	Mountain Willow	5.00	0.450	2.683	1.999	0.00616	0.080	2.644	0.363	0.1120
II 13-5	Mountain Willow	5.00	0.450	3.063	2.000	0.00584	0.082	3.016	0.378	0.1190
II 13-6	Mountain Willow	5.00	0.450	3.582	1.710	0.00459	0.090	3.530	0.421	0.1360
II 13-7	Mountain Willow	5.00	0.450	4.104	1.462	0.00306	0.090	4.037	0.432	0.1430
II 13-8	Mountain Willow	5.00	0.450	4.351	1.465	0.00283	0.088	4.275	0.428	0.1420
II 13-9	Mountain Willow	5.00	0.450	4.639	1.725	0.00335	0.083	4.549	0.406	0.1370
II 13-10	Mountain Willow	5.00	0.450	4.194	1.967	0.00432	0.080	4.114	0.383	0.1270
II 13-11	Mountain Willow	5.00	0.450	4.534	2.936	0.00549	0.062	4.406	0.301	0.1010
II 14-1	Mt Willow w/o leaves	5.00	0.450	2.869	1.952	0.00379	0.066	2.809	0.299	0.0930
II 14-2	Mt Willow w/o leaves	5.00	0.450	4.515	1.207	0.00136	0.075	4.407	0.364	0.1220

(Sheet 3 of 3)

Table 5
Summary of Large Flume Results with Mixed Plant Groupings (SI Units)

Run	Plants	Plant Density M, 1/m^2	Water Depth Yo, M	Mean Velocity V, m/sec	Energy Slope S	Average n	Hydraulic Radius R_h (bed), m	Shear Ratio V^*/V (bed)	Manning's n (bed)
2-1	20 Service Berry, 68 Yellow Twig Dogwood, 68 Euonymus	4.20	1.414	0.353	0.00084	0.062	1.366	0.300	0.101
2-2	20 Service Berry, 68 Yellow Twig Dogwood, 68 Euonymus	4.20	1.398	0.486	0.00122	0.054	1.343	0.259	0.087
2-3	20 Service Berry, 68 Yellow Twig Dogwood, 68 Euonymus	4.20	1.287	0.659	0.00219	0.052	1.238	0.248	0.082
2-4	20 Service Berry, 68 Yellow Twig Dogwood, 68 Euonymus	4.20	0.908	0.742	0.00398	0.055	0.883	0.249	0.078
2-5	20 Service Berry, 68 Yellow Twig Dogwood, 68 Euonymus	4.20	0.944	0.560	0.00253	0.059	0.919	0.270	0.085
2-6	20 Service Berry, 68 Yellow Twig Dogwood, 68 Euonymus	4.20	0.685	0.779	0.00551	0.055	0.670	0.244	0.073
3-1	68 Yellow Twig Dogwood, 68 Euonymus	3.66	1.410	0.360	0.00069	0.055	1.353	0.265	0.089
3-2	68 Yellow Twig Dogwood, 68 Euonymus	3.66	1.266	0.537	0.00125	0.048	1.209	0.228	0.075
3-3	68 Yellow Twig Dogwood, 68 Euonymus	3.66	0.728	0.638	0.00290	0.050	0.707	0.222	0.067
3-4	68 Yellow Twig Dogwood, 68 Euonymus	3.66	0.982	0.473	0.00126	0.050	0.946	0.228	0.072
7-1	22 Mulefat, 70 Alders	2.48	1.332	0.366	0.00107	0.066	1.293	0.318	0.106
7-2	22 Mulefat, 70 Alders	2.48	1.344	0.456	0.00102	0.052	1.288	0.249	0.083
7-3	22 Mulefat, 70 Alders	2.48	1.148	0.624	0.00173	0.047	1.099	0.219	0.071
7-4	22 Mulefat, 70 Alders	2.48	1.006	0.845	0.00395	0.050	0.972	0.230	0.073
8-1	22 Mulefat, 70 Alders, 66 Valley Elderberry	4.20	1.373	0.488	0.00228	0.073	1.341	0.355	0.119
8-2	22 Mulefat, 70 Alders, 66 Valley Elderberry	4.20	1.340	0.572	0.00292	0.070	1.308	0.338	0.113
8-3	22 Mulefat, 70 Alders, 66 Valley Elderberry	4.20	1.377	0.751	0.00427	0.065	1.340	0.316	0.106
8-4	22 Mulefat, 70 Alders, 66 Valley Elderberry	4.20	1.189	0.533	0.00315	0.075	1.164	0.354	0.116
8-5	22 Mulefat, 70 Alders, 66 Valley Elderberry	4.20	1.113	0.567	0.00372	0.075	1.091	0.352	0.114
8-6	22 Mulefat, 70 Alders, 66 Valley Elderberry	4.20	1.166	0.678	0.00390	0.065	1.137	0.306	0.100
11-1	23 Salt Cedar, 83 Black Willows, 50 Red Willows	4.20	1.433	0.658	0.00290	0.062	1.390	0.302	0.102
11-2	23 Salt Cedar, 83 Black Willows, 50 Red Willows	4.20	1.320	0.794	0.00445	0.062	1.283	0.297	0.099
11-3	23 Salt Cedar, 83 Black Willows, 50 Red Willows	4.20	1.437	0.401	0.00158	0.075	1.403	0.367	0.124
11-4	23 Salt Cedar, 83 Black Willows, 50 Red Willows	4.20	0.955	0.528	0.00314	0.070	0.935	0.323	0.102
11-5	23 Salt Cedar, 83 Black Willows, 50 Red Willows	4.20	0.787	0.646	0.00471	0.065	0.772	0.291	0.089
11-6	23 Salt Cedar, 83 Black Willows, 50 Red Willows	4.20	0.814	0.959	0.00834	0.059	0.796	0.267	0.082
11-7	23 Salt Cedar, 83 Black Willows, 50 Red Willows	4.20	0.665	0.726	0.00456	0.053	0.649	0.236	0.070
12-1	83 Black Willows, 50 Red Willows	3.58	1.416	0.354	0.00079	0.060	1.366	0.291	0.098

(Continued)

Table 4 (Continued)

Run	Plant	Plant Height H, ft	Plant Density M, 1/ft^2	Water Depth Y_o, ft	Mean Velocity V, ft/s	Energy Slope S	Average n	Bed Hydraulic Radius ft	Bed V^*/V	Bed Manning's n
I 4-6	Purpleleaf Euonymus	0.67	1.190	2.563	3.195	0.00408	0.041	2.463	0.178	0.0560
I 4-7	Purpleleaf Euonymus	0.67	1.190	1.610	2.679	0.00477	0.042	1.565	0.183	0.0520
I 5-1	Purpleleaf Euonymus	0.67	0.529	3.385	1.348	0.00053	0.038	3.177	0.172	0.0550
I 5-2	Purpleleaf Euonymus	0.67	0.529	3.394	2.074	0.00106	0.035	3.172	0.159	0.0500
I 5-3	Purpleleaf Euonymus	0.67	0.529	2.320	3.158	0.00436	0.040	2.231	0.177	0.0530
I 6-1	Red Twig Dogwood	3.17	0.113	4.143	1.059	0.00110	0.075	4.046	0.357	0.1190
I 6-2	Red Twig Dogwood	3.17	0.113	4.148	1.573	0.00213	0.070	4.046	0.336	0.1110
I 6-3	Red Twig Dogwood	3.17	0.113	4.252	2.005	0.00266	0.062	4.129	0.297	0.0990
I 6-4	Red Twig Dogwood	3.17	0.113	3.085	1.139	0.00204	0.085	3.036	0.390	0.1230
I 6-5	Red Twig Dogwood	3.17	0.113	2.485	1.997	0.00508	0.070	2.442	0.313	0.0950
I 6-6	Red Twig Dogwood	3.17	0.113	2.719	3.127	0.00582		2.639	0.225	0.0693
I 6-7	Red Twig Dogwood	3.17	0.113	1.762	2.241	0.00833	0.070	1.739	0.308	0.0890
I 6-8	Red Twig Dogwood	3.17	0.113	3.065	3.157	0.00540	0.050	2.968	0.227	0.0720
I 7-1	Red Twig Dogwood	3.17	0.049	3.885	1.142	0.00117	0.070	3.788	0.330	0.1080
I 7-2	Red Twig Dogwood	3.17	0.049	2.685	1.653	0.00322	0.070	2.635	0.316	0.0973
II 1-1	Service Berry	2.33	0.050	2.265	1.148	0.00145	0.063	2.217	0.280	0.0840
II 1-2	Service Berry	2.33	0.050	3.173	1.844	0.00180	0.050	3.060	0.228	0.0720
II 1-3	Service Berry	2.33	0.050	2.634	2.249	0.00229	0.043	2.531	0.192	0.0590
II 1-4	Service Berry	2.33	0.050	3.062	2.964	0.00276	0.038	2.908	0.171	0.0540
II 1-5	Service Berry	2.33	0.050	3.786	1.684	0.00132	0.050	3.634	0.234	0.0760
II 1-6	Service Berry	2.33	0.050	4.182	2.257	0.00157	0.042	3.958	0.198	0.0650
II 4-1	Yellow Twig Dogwood		0.170	4.455	0.477	0.00019	0.071	4.319	0.344	0.1150
II 4-2	Yellow Twig Dogwood		0.170	4.558	1.124	0.00059	0.053	4.362	0.254	0.0850
II 4-3	Yellow Twig Dogwood		0.170	4.136	1.994	0.00112	0.040	3.892	0.189	0.0620
II 4-4	Yellow Twig Dogwood		0.170	3.546	3.173	0.00201	0.032	3.290	0.144	0.0460
II 6-1	Mulefat	3.17	0.060	4.668	1.339	0.00040	0.037	4.311	0.177	0.0590
II 6-2	Mulefat	3.17	0.060	4.151	2.108	0.00095	0.035	3.848	0.162	0.0530
II 6-3	Mulefat	3.17	0.060	4.474	2.375	0.00103	0.033	4.107	0.154	0.0510
II 6-4	Mulefat	3.17	0.060	3.518	2.594	0.00119	0.030	3.228	0.135	0.0430
II 9-1	Vally Elberberry	3.17	0.160	4.482	0.926	0.00099	0.083	4.387	0.418	0.1350
II 9-2	Vally Elberberry	3.17	0.160	4.365	1.400	0.00163	0.070	4.253	0.339	0.1130

(Sheet 2 of 3)

Table 5 (Concluded)

Run	Plants	Plant Density M, 1/m^2	Water Depth Y_o, m	Mean Velocity V, m/sec	Energy Slope S	Average n	Hydraulic Radius R_b (bed), m	Shear Ratio V_*/V (bed)	Manning's n (bed)
12-2	83 Black Willows, 50 Red Willows	3.58	1.426	0.551	0.00113	0.046	1.353	0.220	0.074
12-3	83 Black Willows, 50 Red Willows	3.58	1.388	0.763	0.00210	0.045	1.320	0.215	0.072
12-4	83 Black Willows, 50 Red Willows	3.58	0.906	0.910	0.00333	0.041	0.867	0.186	0.058
12-5	83 Black Willows, 50 Red Willows	3.58	0.821	0.789	0.00326	0.045	0.791	0.202	0.062
12-6	83 Black Willows, 50 Red Willows	3.58	0.776	0.726	0.00228	0.040	0.743	0.178	0.054
12-7	83 Black Willows, 50 Red Willows	3.58	0.680	0.688	0.00175	0.035	0.647	0.151	0.045

Table 6
Summary of Large Flume Results with Mixed Plant Groupings (Non-SI Units)

Run	Plants	Plant Density M, 1/ft^2	Water Depth Yo, ft	Mean Velocity V, ft/s	Energy Slope S	Average n	Hydraulic Radius R_h (bed), ft	Shear Ratio V^*/V (bed)	Manning's n (bed)
2-1	20 Service Berry, 68 Yellow Twig Dogwood, 68 Euonymus	0.39	4.638	1.159	0.00084	0.062	4.483	0.300	0.101
2-2	20 Service Berry, 68 Yellow Twig Dogwood, 68 Euonymus	0.39	4.588	1.594	0.00122	0.054	4.407	0.259	0.087
2-3	20 Service Berry, 68 Yellow Twig Dogwood, 68 Euonymus	0.39	4.222	2.161	0.00219	0.052	4.061	0.248	0.082
2-4	20 Service Berry, 68 Yellow Twig Dogwood, 68 Euonymus	0.39	2.979	2.434	0.00398	0.055	2.896	0.249	0.078
2-5	20 Service Berry, 68 Yellow Twig Dogwood, 68 Euonymus	0.39	3.096	1.837	0.00253	0.059	3.014	0.270	0.085
2-6	20 Service Berry, 68 Yellow Twig Dogwood, 68 Euonymus	0.39	2.249	2.557	0.00551	0.055	2.197	0.244	0.073
3-1	68 Yellow Twig Dogwood, 68 Euonymus	0.34	4.627	1.181	0.00069	0.055	4.439	0.265	0.089
3-2	68 Yellow Twig Dogwood, 68 Euonymus	0.34	4.152	1.761	0.00125	0.048	3.966	0.228	0.075
3-3	68 Yellow Twig Dogwood, 68 Euonymus	0.34	2.388	2.094	0.00290	0.050	2.319	0.222	0.067
3-4	68 Yellow Twig Dogwood, 68 Euonymus	0.34	3.222	1.552	0.00126	0.050	3.103	0.228	0.072
7-1	22 Mulefat, 70 Alders	0.23	4.370	1.201	0.00107	0.066	4.243	0.318	0.106
7-2	22 Mulefat, 70 Alders	0.23	4.411	1.496	0.00102	0.052	4.227	0.249	0.083
7-3	22 Mulefat, 70 Alders	0.23	3.766	2.048	0.00173	0.047	3.605	0.219	0.071
7-4	22 Mulefat, 70 Alders	0.23	3.301	2.772	0.00395	0.050	3.189	0.230	0.073
8-1	22 Mulefat, 70 Alders, 66 Valley Elderberry	0.39	4.506	1.601	0.00228	0.073	4.399	0.355	0.119
8-2	22 Mulefat, 70 Alders, 66 Valley Elderberry	0.39	4.397	1.876	0.00292	0.070	4.290	0.338	0.113
8-3	22 Mulefat, 70 Alders, 66 Valley Elderberry	0.39	4.517	2.463	0.00427	0.065	4.396	0.316	0.106
8-4	22 Mulefat, 70 Alders, 66 Valley Elderberry	0.39	3.901	1.750	0.00315	0.075	3.820	0.354	0.116
8-5	22 Mulefat, 70 Alders, 66 Valley Elderberry	0.39	3.650	1.860	0.00372	0.075	3.578	0.352	0.114
8-6	22 Mulefat, 70 Alders, 66 Valley Elderberry	0.39	3.826	2.225	0.00390	0.065	3.731	0.306	0.100
11-1	23 Salt Cedar, 83 Black Willows, 50 Red Willows	0.39	4.702	2.159	0.00290	0.062	4.560	0.302	0.102
11-2	23 Salt Cedar, 83 Black Willows, 50 Red Willows	0.39	4.330	2.604	0.00445	0.062	4.209	0.297	0.099
11-3	23 Salt Cedar, 83 Black Willows, 50 Red Willows	0.39	4.716	1.317	0.00158	0.075	4.602	0.367	0.124
11-4	23 Salt Cedar, 83 Black Willows, 50 Red Willows	0.39	3.133	1.731	0.00314	0.070	3.069	0.323	0.102
11-5	23 Salt Cedar, 83 Black Willows, 50 Red Willows	0.39	2.583	2.120	0.00471	0.065	2.532	0.291	0.089
11-6	23 Salt Cedar, 83 Black Willows, 50 Red Willows	0.39	2.669	3.147	0.00834	0.059	2.610	0.267	0.082
11-7	23 Salt Cedar, 83 Black Willows, 50 Red Willows	0.39	2.182	2.383	0.00456	0.053	2.130	0.236	0.070
12-1	83 Black Willows, 50 Red Willows	0.333	4.646	1.162	0.00079	0.060	4.482	0.291	0.098

(Continued)

Table 6 (Concluded)									
Run	Plants	Plant Density M, 1/ft^2	Water Depth Y_o, ft	Mean Velocity V, ft/s	Energy Slope S	Average n	Hydraulic Radius R_h (bed), ft	Shear Ratio V^*/V (bed)	Manning's n (bed)
12-2	83 Black Willows, 50 Red Willows	0.333	4.677	1.809	0.00113	0.046	4.440	0.220	0.074
12-3	83 Black Willows, 50 Red Willows	0.333	4.554	2.503	0.00210	0.045	4.330	0.215	0.072
12-4	83 Black Willows, 50 Red Willows	0.333	2.974	2.984	0.00333	0.041	2.845	0.186	0.058
12-5	83 Black Willows, 50 Red Willows	0.333	2.693	2.590	0.00326	0.045	2.596	0.202	0.062
12-6	83 Black Willows, 50 Red Willows	0.333	2.547	2.381	0.00228	0.040	2.438	0.178	0.054
12-7	83 Black Willows, 50 Red Willows	0.333	2.232	2.257	0.00175	0.035	2.123	0.151	0.045

CHAPTER 4 – SOIL

PAGE

SOIL

CHAPTER 4

BACKGROUND

Soils and sediments serve as a substrate for wetland, riparian, and terrestrial vegetation. Soil properties such as mineral content, permeability, and moisture holding capacity can influence the species of vegetation. Further, the quantity and quality of the water used to "irrigate" vegetation will influence the soil salinity and structure of the soils. Source water high in TDS will likely increase the salinity of the soil which in turn will reduce the number of vegetative species capable of surviving.

Select contaminants may also partition onto the surfaces of soil particles. Contaminated particles are then transported via runoff to the receiving water bodies where they can influence water quality and impact both flora and fauna. Historically, sediment sampling and quality analysis has been conducted in the El Rio project reach. These data were collected from the late 1960's through the early 1990's and are presented and discussed in the Lower/Middle Gila River Study and Painted Rocks Lake Phase I, but have not as yet been incorporated into the GIS sediment layer. Given the age of the data and transient nature of sediment transport, it is recommended that once locations are selected for potential restoration activities, near surface and deep sediment sampling and testing should be conducted that at a minimum include percent clay, percent silt, percent sand, soil EC and moisture status.

The remainder of this technical memorandum provides the regional soil classifications located in the overall El Rio Project reach. The general soil classifications are then subdivided and the soil coverage as shown on the GIS soils layer are discussed with respect to there locations within the project, composition, and hydrologic properties.

Regional Soil Character

Soil Classification information was obtained from the *Soil Survey of Maricopa County, Arizona, Central Part,* published in 1977 by the USDA Soil Conservation Service.

There are eight general soil classifications occurring in project area.

- Gilman-Estrella-Avondale association is characterized by nearly level loams and clay loams on valley plains and low stream terraces.
- Carrizo-Brios association nearly level to gently sloping gravelly sandy loams and sandy loams in stream channels and on low stream terraces.
- Laveen-Coolidge association is characterized by nearly level sandy loams, loams, and clay loams on old alluvial fans and valley plains.
- Ebon-Pinamt-Tremant association is characterized by nearly level to gently sloping gravelly loams, very cobbly loams, and gravelly clay loams on old alluvial fans at the base of mountains.
- Casa Grande-Harqua association is characterized by nearly level to sloping, saline-alkali loams, sandy loams, and gravelly clay loams on valley plains.
- Cherioni-Rock outcrop association is characterized by gently sloping to very steep very gravelly loams and Rock outcrop on mountains, buttes, and low hills.
- Torrifluvents association is characterized by nearly level sloping soils that are gravelly, cobbly, and stony throughout; on recent alluvial fans at the base of mountains.
- Antho-Valencia association is characterized by nearly level sandy loams on recent alluvial fans and valley plains.

Project Soil Coverage

Soil coverage GIS maps of the project area are included in **Appendix A.** **Tables 1**, **2**, **3**, and **4** summarize the types of soil, location, and prevalence in four areas of the project.

The Upper reach of the El Rio Project area begins at the confluence of the Agua Fria River. The Agua Fria is a perennial wash, composed primarily of loose sand and gravel material. Table 1 summarizes the types of soil, location, and distribution, near the confluence of the Gila and Agua Fria Rivers.

Table 1

Confluence of Gila River and Agua Fria

Location	Distribution	Percent	Symbol	Classification
Agua Fria River Channel	Dominant	95%	CF	Carrizo and Brios soils
Agua Fria River Channel	Significant	3%	Cb	Carrizo gravelly sandy loam
Agua Fria River Channel	Significant	2%	Bs	Brios sandy loam
Agua Fria River Channel Banks	Scattered	<1%	Br	Brios loamy sand
Agua Fria River Channel Banks	Scattered	<1%	Bt	Brios loam
Agua Fria River Channel Banks	Scattered	<1%	Vg	Vint loamy fine sand
Agua Fria River Channel Banks	Significant	2%	Vh	Vint fine sandy loam
Agua Fria River Channel Banks	Scattered	<1%	Vk	Vint loam
North Bank Gila River	Scattered	4%	Ge	Gilman fine sandy loam, saline-alkali
North Bank Gila River	Scattered	<1%	Gh	Gilman loam, saline-alkali
North Bank Gila River	Scattered	<1%	Aa	Agualt loam
South Bank Gila River	Scattered	<1%	Gh	Gilman loam, saline-alkali
South Bank Gila River	Significant	4%	Rs	Rock outcrop - Cheriono complex
South Bank Gila River	Dominant	22%	Gga	Gilman loam, 0-1% slope
South Bank Gila River	Scattered	<1%	Ge	Gilman fine sandy loam
South Bank Gila River	Scattered	<1%	Vh	Vint fine sandy loam
South Bank Gila River	Scattered	<1%	Bs	Brios sandy loam
South Bank Gila River	Scattered	<1%	Bt	Brios loam

The Upper reach of the El Rio Project area, is composed primarily of a gravelly, sandy loam channel. Table 2 summarizes the types of soil, location, and distribution in the reach between Agua Fria and Waterman Wash.

Table 2

Upper Reach of Gila River between Confluence of Agua Fria and Waterman Wash

Location	Distribution	Percent	Symbol	Classification
River Channel	Dominant	89%	CF	Carrizo and Brios soils
River Channel	Significant	5%	Br	Brios loamy sand
North Bank	Dominant	8%	Br	Brios loamy sand
North Bank	Significant	3%	Bs	Brios sandy loam
North Bank	Scattered	<1%	Bt	Brios loam
North Bank	Scattered	<1%	Vh	Vint fine sandy loam
North Bank	Scattered	<1%	Cn	Cashion clay, saline-alkali
North Bank	Dominant	22%	Gga	Gilman loam, 0-1% slope
North Bank	Scattered	<1%	Aa	Agualt loam
South Bank	Scattered	<1%	Go3	Gilman, Antho, and Glenbar soils
South Bank	Scattered	<1%	Ld	Laveen loam, saline-alkali
South Bank	Scattered	<1%	Aa	Agualt loam
South Bank	Scattered	<1%	Ge	Gilman fine sandy loam
South Bank	Scattered	<1%	Al	Antho association
South Bank	Scattered	<1%	Rs	Rock outcrop - Cheriono complex

Waterman Wash is composed primarily of stratified sediments, recently deposited by the intermittent stream flows. Table 3 summarizes the types of soil, location, and distribution in the reach near Waterman Wash.

Table 3

Gila River at Confluence with Waterman Wash

Location	Distribution	Percent	Symbol	Classification
Waterman Wash Main Channel	Dominant	87%	Td	Torripsamment and Torrifluvents, frequently flood
Waterman Wash Banks	Scattered	<1%	Afa	Antho-Carrizo complex
Waterman Wash Banks	Scattered	<1%	Vg	Vint loamy fine sand

Table 3 Cont.

Location	Distribution	Percent	Symbol	Classification
Waterman Wash Banks	Scattered	2%	Vh	Vint fine sandy loam
Waterman Wash Banks	Scattered	3%	Bt	Brios loam
Waterman Wash Banks	Scattered	<1%	Br	Brios loamy sand
Waterman Wash Banks	Scattered		Go3	Gilman, Antho, and Glenbar soils
Waterman Wash Banks and Confluence	Significant	30%	Gh	Gilman loam, saline-alkali
North Bank across from Waterman Wash	Scattered	<1%	Aa	Agualt loam
North Bank across from Waterman Wash	Significant	5%	Br	Brios loamy sand
North Bank across from Waterman Wash	Significant	11%	Gga	Gilman loam, 0-1% slope
North Bank across from Waterman Wash	Scattered	>1%	Ggb	Gilman loam, 1-3% slope
North Bank across from Waterman Wash	Scattered	>1%	GPI	Gravel Pit
North Bank across from Waterman Wash	Scattered	>1%	Bt	Brios loam

The Lower reach of the El Rio Project area, is composed primarily of a gravelly, sandy loam channel. Downstream of Waterman Wash, the south bank of the Gila River is dominated by rock outcrops. Table 4 summarizes the types of soil, location, and distribution between Waterman Wash and S.R. 85.

Table 4

Lower Reach between Confluence of Waterman Wash and State Route 85 Bridge

Location	Distribution	Percent	Symbol	Classification
River Channel	Dominant	98%	CF	Carrizo and Brios soils
Unnamed wash at Miller Road	Scattered	>1%	Afa	Antho-Carrizo complex
Unnamed wash at Miller Road	Scattered	>1%	Ac	Antho sandy loam, saline alkali
Unnamed wash at Miller Road	Scattered	>1%	Bs	Brios sandy loam
North Bank Gila River	Dominant	22%	Gf	Gilman fine loam, saline alkali
North Bank Gila River	Significant	16%	Gh	Gilman loam, saline alkali
North Bank Gila River	Scattered	>1%	GPI	Gravel Pit
North Bank Gila River	Scattered	2%	Vh	Vint fine sandy loam

Table 4 Cont.

Location	Distribution	Percent	Symbol	Classification
North Bank Gila River	Scattered	>1%	Ap	Avondale clay, loam, saline alkali
North Bank Gila River	Scattered	>1%	Vk	Vint loam
South Bank Gila River	Dominant	31%	Co	Cheriono-Rock outcrop complex
South Bank Gila River (near SR 85)	Dominant	8%	Vh	Vint fine sandy loam
South Bank Gila River	Scattered	>1%	Gh	Gilman loam, saline alkali
South Bank Gila River	Scattered	3%	Gf	Gilman fine loam, saline alkali

HYDROLOGIC PROPERTIES

Hydrologic properties of each soil type depend on the composition and formation. The composition of each of the six soil major soil associations are list below:

- Gilman-Estrella-Avondale association is derived from a wide variety of rock, including granite-gneiss, schist, andesite, rhyolite, basalt, and quartzite.
- Carrizo-Brios association was formed in recent alluvium, and derived from a wide mixture of acid and basic igneous and metamorphic rocks. This region is subject to occasional flooding.
- Laveen-Coolidge association was formed in alluvium derived from granite-gneiss, schist, limestone, andesite, rhyolite and basalt.
- Ebon-Pinamt-Tremant association was formed in old gravelly alluvium that was derived from a wide mixture of granite, granite-gneiss, schist, andesite, rhyolite, and quartzite.
- Casa Grande-Harqua association was formed in old gravelly alluvium that was derived from a wide mixture of granite, gneiss, schist, rhyolite, tuff and limestone.

- Cherioni-Rock outcrop association are soils formed over granite-gneiss, schist, andesite, basalt, and tuff bedrock.

Soils can be measured and characterized by permeability. Table 5 lists the range of permeability of each soil series within our project reach.

Table 5

Permeability of Project Area Soils by Series

Series	Symbols	Permeability (in/hr)
Agualt	Aa	0.6-2.0
Antho	Ac, Afa, Al, Ap	2 – 6
Avondale	Ao	0.2 – 2
Brios	Br, Bs, Bt	2 – 20
Carrizo	Cb, CF	2 – 20
Cashion	Cn	0.06 – 0.2
Cherioni	CO	0.6 – 2
Gilman	Ge, GgA, GgB, Gf, Gh, Go3	0.2 – 2
Laveen	Ld	0.6 – 2
Rock out crop	RS	-
Torripsamments	TD	-
Tremant	Te,	0.2 – 2
Vint	Vg, Vh, Vk,	2 – 6

(**Note:** No value estimates reported for Rock Outcrop and Torripsamments.)

AGRONOMIC PROPERTIES

Vegetation types supported by each of the soil classifications include the following:

- Gilman-Estrella-Avondale association supports native vegetation such as creosotebush, cactus, annual weeds and grasses, and scattered mesquite and paloverde trees.

- Carrizo-Brios association supports vegetation complexes of saltcedar, arrowweed, creosotebush, and saltbush.

- Laveen-Coolidge association supports native vegetation such as creosotebush and scattered mesquite and paloverde trees.

- Ebon-Pinamt-Tremant association supports vegetation complexes of creosotebush, bursage, cactus, and scattered mesquite and paloverde trees.

- Casa Grande-Harqua association supports vegetation complexes of saltbush, creosote, cactus, and scattered mesquite and paloverde trees.

- Cherioni-Rock outcrop association supports minimal vegetation in cracks that have collected silts. Vegetation includes creosotebush, bursage, cactus, and scattered mesquite and paloverde trees.

Soil Salinity

The El Rio reach of the Gila River is historically an area of increased salinity because of the large contributing watershed and the arid conditions characteristic of the El Rio project area. Native Riparian trees species such as Freemont Cottonwood (*Populus freemontii*) and Gooding's Willow (*Salix gooddingii*) require relatively low soil EC values for sustainable growth (Anderson 1995). Data developed by Jackson et al (1990) was used to select soil salinity threshold values, measured as electrical conductivity (EC), for sampling cottonwood and willow of 3.0 mmhos/cm. Similar data support soil EC threshold values for honey mesquite (*Prosopis glandulosa*) and screwbean mesquite (*Prosopis pubescens*) were 8.0 and 9.4 mmhos/cm respectively. In comparison, the threshold for salt cedar was approximately18.5 mmhos/cm.

SOIL DATA

Limited soil analysis of the project area has been preformed to date. As previously mentioned, ADEQ has completed historical sediment sampling in the El Rio Project reach, primarily at or near the Buckeye Canal. Also noted is the preliminary soil investigation for the Town of Buckeye Lake Project (URS/BRW 2001). The proposed project site is located south of Miller Road in the 100-year flood plan of the Gila River. Four bore holes were drilled to a depth of approximately 40 feet. Drilling reached the groundwater table at between 7 to 8.5 feet in all wells. The surficial layer was between 1 to 3 feet below grade, and contained silty sands, sandy silts, and silty gravel. Below this layer was a 10 to 20 foot thick layer of predominately sandy and silty moist clay. Details on this soil analysis are included in **Appendix B**.

RESTORATION CONSIDERATIONS

Soil texture (i.e. percent clay, percent sand, and percent silt), soil moisture holding capacity, and soil EC (salinity) are major factors in the success of revegetation efforts. In general, the project area soil types are moderately draining, sandy loams. Such soils will likely support a variety of wetland, riparian, and desert riparian scrub-shrub species as long as soil EC values are at or below soil EC threshold values.

DATA GAPS

Soil testing should be performed at all locations being considered for vegetation restoration or enhancement. This is important because of the lack of current soil data, due in part to the age of existing soil data sets, the variability in the quality of source water(s), past and present anthropogenic activities occurring within the regional and local contributing watersheds, and the existing dominant vegetative cover in the El Rio project reach. Sampling should consist of test pits as well as soil borings. Agronomic testing should consider the following parameters:

- pH
- Soil EC
- Free Lime
- % Organic Matter
- Nitrate – N
- Available Nitrogen

- Bicarbonate Phosphorous
- Potassium
- Magnesium
- Calcium
- Sodium
- Sodium Adsorption Ratio
- Copper
- Iron
- Manganese
- Zinc
- Boron
- Sulfate Sulfur
- Pesticides
- Herbicides

SUMMARY

There are two primary concerns with respect to soils related to the establishment and maintenance of native riparian and wetland plant species in the El Rio reach of the Gila River. First is the salinity content of the soils. Although soil data are lacking in the project reach, vegetation character and the appearance of salt deposits on the soil surface imply that soil EC values probably increase in the direction of river flow. This is logical as the El Rio reach of the Gila River is historically an area of increased salinity since its is located near the downstream end of the large contributing watershed and the arid conditions characteristic of the El Rio project area. In addition, the presence of salt tolerant vegetation indicate that the existing soil conditions of the El Rio project reach is probably on the saline side of the scale. Native riparian trees such as Freemont Cottonwood (*Populus freemontii*) and Goodings Willow (*Salix goodingii*) tolerate relatively low soil EC values for sustainable growth (Anderson 1995). Data developed by Jackson et al (1990) was used to select soil EC threshold values for sapling cottonwood and willow of 3.0 mmhos/cm. Similar data support soil EC threshold values for honey and screwbean mesquite of 8.0 and 9.4 mmhos/cm respectively. In comparison, the threshold for salt cedar was approximately 18.5 mmhos/cm.

Select contaminants such as heavy metals and hydrophobic pesticides and herbicides may also partition onto the surfaces of soil particles. Contaminated particles are then transported via runoff to the receiving water bodies where they can influence water quality and impact both flora and faunal fitness. Historically, sediment sampling and quality analysis has been conducted in the El Rio project reach but it is dated and likely of a resolution that is insufficient to make prudent restoration decisions. The existing data does indicate the potential for extreme soil EC values and contamination from organic compounds and heavy metals to occur in the project reach. As such, and due to cost considerations, it is recommended that the agronomic testing presented above be conducted on soils at sites where active restoration is proposed to take place.

REFERENCES

Anderson, Bertin W. 1995. *Salt Cedar, Revegetation and Riparian Ecosystems in the Southwest*. Symposium Proceedings of the California Exotic Pest Plant Council, pp 1-13.

URS/BRW 2001. *Buckeye Town Lake Engineering Feasibility Study*. Town of Buckeye, Arizona Project Number 789907.

SCS 1977. *Soil Survey of Maricopa County, Central Part*. United States Department of Agriculture Soil Conservation Service in Cooperation with University of Arizona Agricultural Experiment Station.

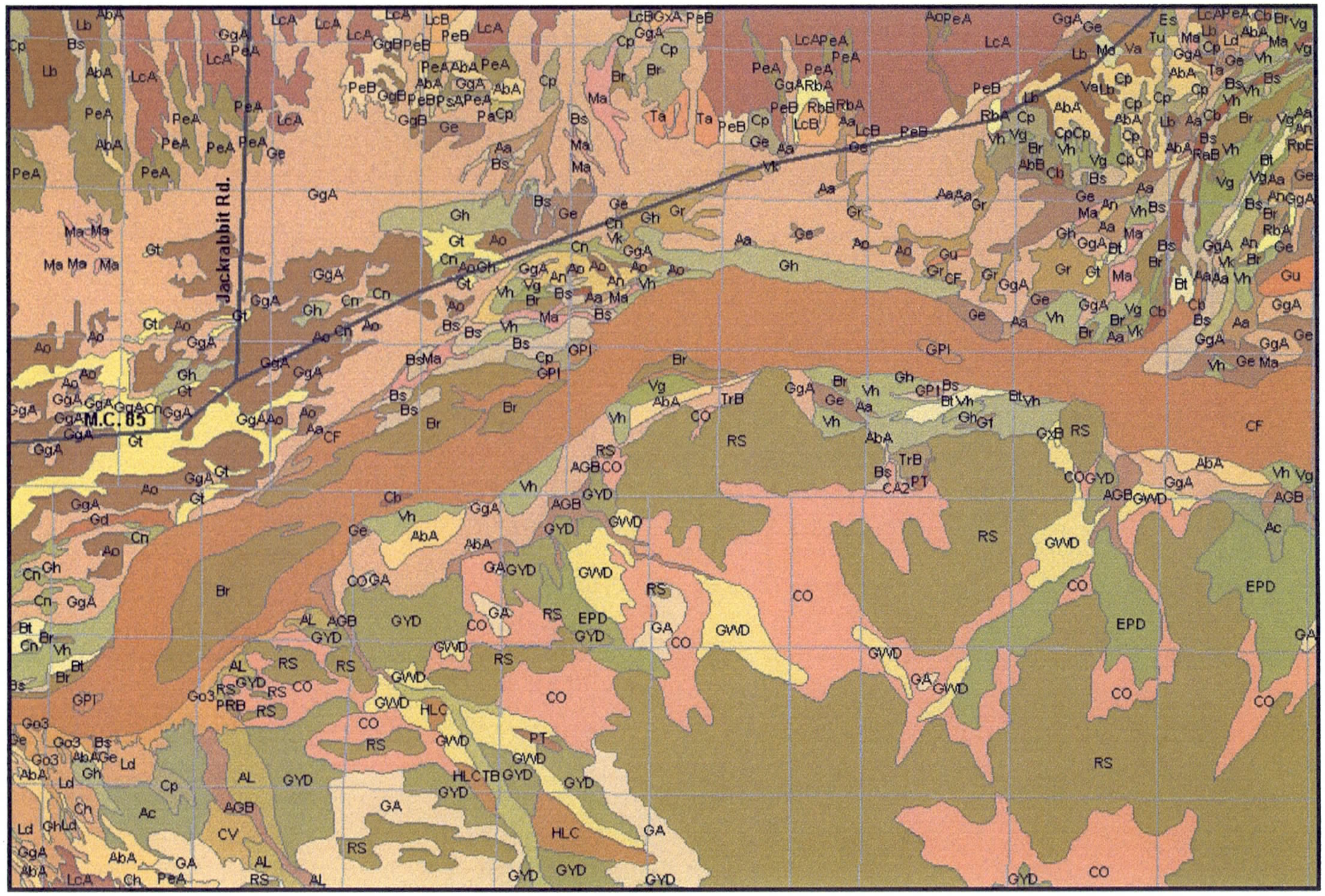
APPENDICES

APPENDIX A – Soil Coverage Maps

APPENDIX B – Buckeye Lake Soil Analysis

APPENDIX A

Soil Coverage Maps



APPENDIX A

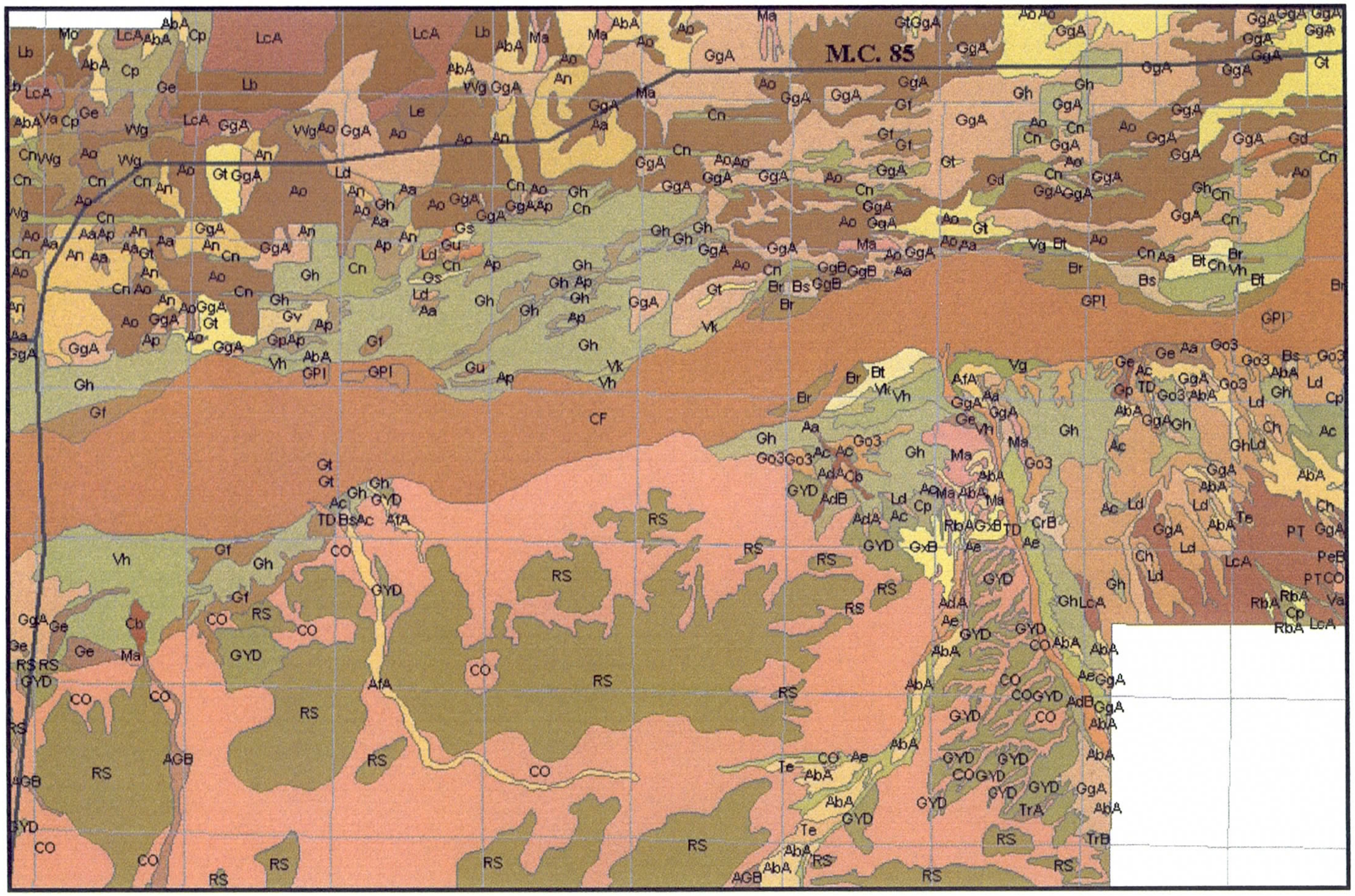
El Rio Project

Soil Types

Gila River - Upper Reach

0 4,000 8,000 12,000 Feet

N



APPENDIX A

El Rio Project

Soil Types

Gila River - Lower Reach

0 4,000 8,000 12,000 Feet

N

APPENDIX B

Buckeye Lake Soil Analysis

BORING LOG

BORING LOG: B-1
SHEET
PROJECT #: E1-47093001.00
CONTRACTOR: Envior-Drill, Inc.
DRILLER: J. Sutton
INSPECTOR: Jeff Heyman

PROJECT: Buckeye Town Lake
LOCATION: NE corner of Hazen & Miller Rds.
CLIENT: Town of Buckeye

DEPTH BELOW	WATER LEVEL	USCS	GRAPHIC	TYPE	NUMBER	SYMBOL	DEPTH (FT) FROM	DEPTH (FT) TO	MOISTURE, %	DRY DENSITY	SOIL (Blows/6 in.) 0/6	6/12	12/18	N	REC.	VISUAL MATERIAL CLASSIFICATION	SAMPLES
		SM		S	7		25	26.5			10	20	30	50	100		
																SILTY SAND, fine to coarse grained, subangular, trace fine to coarse angular gravel, dense, wet, light brown	
30		SM		S	8		30	31.5			20	30	50-3"	80 9"	50	Few cobbles, becomes very dense below 31 feet	
35				S	9		35	36.5	17		25	23	25	48	100		
		CL														SANDY CLAY, trace silt, low to medium plasticity, stiff, wet, brown	
40				S	10		40	41.5			8	4	5	9	100		
45																Auger stopped at 40'. Sampler stopped at 41.5'. Groundwater encountered at approximately 7'. Boring backfilled with grout from bottom to upper 2 feet and with soil from 2 feet to surface.	
50																	

BORING LOG

BORING LOG: B-2

PROJECT: Buckeye Town Lake
LOCATION: NE corner of Hazen & Miller Rds.
CLIENT: Town of Buckeye
CONTRACTOR: Envior-Drill, Inc.
DRILLER: J. Sutton
INSPECTOR: Jeff Heyman

PROJECT #: E1-47093001.00
HOLE LOCATION: NW corner of 4th & Sunrise Rds..
COORDINATES. N: N/A
E: N/A

RIG TYPE: CME-75
DRILLING METHOD: Hollow Stem Auger, 8" O.D.
HAMMER TYPE: Automatic

REF. ALIGNMENT: N/A
STATION: N/A
OFFSET: N/A

COMMENTS:

SURFACE ELEV.: N/A
DATUM: N/A
START DATE: 7/02/01 START TIME: 8:50
END DATE: 7/02/01 END TIME: 10:25

	Casing	Split Spoon	Shelby Tube	Piston	Ring Sample	Core Barrel
Type/Symbol		S	U	P	R	C
I.D.		1.375"			2.50"	
O.D.		2"			3.25"	
Length		24"			12"	
Hammer Wt.	140 lbs		Drill Rod Size		AW	
Hammer Fall	30"		I.D. (O.D.)		2" (8")	

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Casing Depth (ft)	Hole Depth (ft)
7/02/01	10:25	8.5	N/A	40

DEPTH BELOW	WATER LEVEL	USCS	GRAPHIC	TYPE	NUMBER	SYMBOL	DEPTH (FT) FROM	DEPTH (FT) TO	MOISTURE, %	DRY DENSITY	0/6	6/12	12/18	N	REC.	VISUAL MATERIAL CLASSIFICATION	SAMPLES
		ML		S	1		0	1.5			5	5	4	9	30	SANDY SILT, non-plastic, loose, dry to moist, brown	
				S	2		2.5	4	12		2	3	3	6	30	SANDY CLAY, little silt, low to medium plasticity, medium stiff, moist, brown	
5		CL		S	3		5	6.5			3	3	5	8	100		
	▼															SILTY SAND, predominantly fine to medium, subangular, loose, with clay seams of low plasticity, brown, moist to wet	
10				S	4		10	11.5			3	2	5	7	100		
		SM															
15				S	5		15	16.5			27	20	23	43	100		
																POORLY GRADED SAND, fine to coarse grained, subangular to angular, few gravels and cobbles, non-plastic, dense, light brown, wet.	
20		SP		S	6		20	21.5	NP		6	14	20	34	100		
25																	

BORING LOG

PROJECT: Buckeye Town Lake	BORING LOG: B-2
LOCATION: NE corner of Hazen & Miller Rds.	SHEET
CLIENT: Town of Buckeye	PROJECT #: E1-47093001.00
	CONTRACTOR: Envior-Drill, Inc.
	DRILLER: J. Sutton
	INSPECTOR: Jeff Heyman

DEPTH BELOW	WATER LEVEL	SAMPLE: USCS	GRAPHIC	TYPE	NUMBER	SYMBOL	DEPTH (FT) FROM	TO	MOISTURE, %	DRY DENSITY	SOIL (Blows/6 in.) 0/6	6/12	12/18	N	REC.	VISUAL MATERIAL CLASSIFICATION	SAMPLES
		SP		S	7		25	26.5			18	14	14	28	30	Becomes medium dense at 25 feet.	
30		SP		S	8		30	31.5			12	9	10	19	40		
		GM														**SILTY GRAVEL with SAND,** fine to coarse sub-angular to angular gravel and sand, few cobbles, non-plastic, very dense, wet, light brown	
35		GM		S	9		35	36.5	NP		18	25	40	65	50		
		CL														**SANDY CLAY,** trace silt, low to medium plasticity, very stiff, wet, brown	
40		CL		S	10		40	41.5			12	17	21	38	100		
45																	
50																	

Auger stopped at 40'. Sampler stopped at 41.5'. Groundwater encountered at approximately 8.5'. Boring backfilled with grout from bottom to upper 2 feet and with soil from 2 feet to surface.

BORING LOG

BORING LOG: B-3

PROJECT #: E1-47093001.00

PROJECT: Buckeye Town Lake
LOCATION: NE corner of Hazen & Miller Rds.
CLIENT: Town of Buckeye
CONTRACTOR: Envior-Drill, Inc.
DRILLER: J. Sutton
INSPECTOR: Jeff Heyman

HOLE LOCATION: SW corner of Sunrise & Norton
COORDINATES. N: N/A
E: N/A

RIG TYPE: CME-75
DRILLING METHOD: Hollow Stem Auger, 8" O.D.
HAMMER TYPE: Automatic

REF. ALIGNMENT: N/A
STATION: N/A
OFFSET: N/A

COMMENTS:

SURFACE ELEV.: N/A
DATUM: N/A
START DATE: 7/02/01 **START TIME:** 10:45
END DATE: 7/02/01 **END TIME:** 12:45

	Casing	Split Spoon	Shelby Tube	Piston	Ring Sample	Core Barrel
Type/Symbol		S	U	P	R	C
I.D.		1.375"			2.50"	
O.D.		2"			3.25"	
Length		24"			12"	
Hammer Wt.	140 lbs		Drill Rod Size		AW	
Hammer Fall	30"		I.D. (O.D.)		2" (8")	

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Casing Depth (ft)	Hole Depth (ft)
7/02/01	12:45	8.5	N/A	40

DEPTH BELOW	WATER LEVEL	USCS	TYPE	NUMBER	DEPTH FROM (FT)	DEPTH TO (FT)	MOISTURE, %	DRY DENSITY	0/6	6/12	12/18	N	REC.	VISUAL MATERIAL CLASSIFICATION
		ML	S	1	0	1.5			2	3	2	5	90	SANDY SILT, non-plastic, loose, dry to moist, brown
			S	2	2.5	4	13		3	3	4	7	100	SANDY CLAY, little silt, low to medium plasticity, medium stiff, brown
5		CL	S	3	5	6.5			3	4	6	10	100	Becomes stiff at 5 feet
	▼ (8.5)													
10		SM	S	4	10	11.5			3	5	5	10	100	SILTY SAND, predominantly fine to medium grained, subangular, loose, with seams of low plasticity clay, moist to wet, light brown.
15			S	5	15	16.5			22	50-5"		50-5"	40	POORLY GRADED GRAVELS, with silt and sand, fine to coarse, subangular to angular gravel, non-plastic, wet, very dense.
20		GP - GM	S	6	20	21.5			33	50-5"		50-5"	50	
25														

BORING LOG

BORING LOG: B-3
SHEET
PROJECT #: E1-47093001.00
CONTRACTOR: Envior-Drill, Inc.
DRILLER: J. Sutton
INSPECTOR: Jeff Heyman

PROJECT: Buckeye Town Lake
LOCATION: NE corner of Hazen & Miller Rds.
CLIENT: Town of Buckeye

DEPTH BELOW	WATER LEVEL	USCS	GRAPHIC	TYPE	NUMBER	SYMBOL	DEPTH (FT) FROM	DEPTH (FT) TO	MOISTURE, %	DRY DENSITY	0/6	6/12	12/18	N	REC.	VISUAL MATERIAL CLASSIFICATION	SAMPLES
				S	7		25	26.5			15	20	23	43	40		
																Becomes dense	
30				S	8		30	31.5			22	25	18	43	30		
		GM GP -															
35																Becomes medium dense	
				S	9		35	36.5			12	10	8	18	100		
40		CL		S	10		40	41.5			12	13	9	22	100	SANDY CLAY, trace silt, low to medium plasticity, very stiff, wet, brown	
45																Auger stopped at 40'. Sampler stopped at 41.5'. Groundwater encountered at approximately 8.5'. Boring backfilled with grout from bottom to upper 2 feet and with soil from 2 feet to surface.	
50																	

SOIL (Blows/6 in.)

BORING LOG

BORING LOG: B-4

PROJECT #: E1-47093001.00

PROJECT: Buckeye Town Lake	CONTRACTOR: Envior-Drill, Inc.
LOCATION: NE corner of Hazen & Miller Rds.	DRILLER: J. Sutton
CLIENT: Town of Buckeye	INSPECTOR: Jeff Heyman

HOLE LOCATION: NW corner of Hazen & 4th
COORDINATES. N: N/A
E: N/A

RIG TYPE: CME-75
DRILLING METHOD: Hollow Stem Auger, 8" O.D.
HAMMER TYPE: Automatic

REF. ALIGNMENT: N/A
STATION: N/A
OFFSET: N/A

COMMENTS:

SURFACE ELEV.: N/A
DATUM: N/A
START DATE: 7/03/01 START TIME: 7:00
END DATE: 7/03/01 END TIME: 9:45

	Casing	Split Spoon	Shelby Tube	Piston	Ring Sample	Core Barrel
Type/Symbol		S	U	P	R	C
I.D.		1.375"			2.50"	
O.D.		2"			3.25"	
Length		24"			12"	
Hammer Wt.	140 lbs		Drill Rod Size		AW	
Hammer Fall	30"		I.D. (O.D.)		2" (8")	

GROUNDWATER DATA

Date	Time	Water Depth (ft)	Casing Depth (ft)	Hole Depth (ft)
7/03/01	9:45	8.0	N/A	40

DEPTH BELOW	WATER LEVEL	USCS	TYPE	NUMBER	DEPTH FROM (FT)	DEPTH TO (FT)	MOISTURE, %	DRY DENSITY	0/6	6/12	12/18	N	REC.	VISUAL MATERIAL CLASSIFICATION
		GP	S	1	0	1.5			10	5	3	8	50	**SANDY GRAVEL,** with silt, moist, light brown
		CL	S	2	2.5	4	10		1	2	2	4	100	**SANDY CLAY,** little silt, low to medium plasticity, soft, moist, brown
5			S	3	5	6.5			3	5	8	13	100	
	▼													
10		SM	S	4	10	11.5			4	8	12	20	30	**SILTY SAND,** predominantly fine to medium grained, subangular, few fine to coarse gravels, non-plastic, medium dense, wet, brown
15			S	5	15	16.5			50-6"			50-6"	30	**POORLY GRADED GRAVEL,** with silt and sand, fine to coarse angular gravel with fine to medium sub-angular sand, few cobbles, non-plastic, very dense, wet, brown
20		GP - GM	S	6	20	21.5			7	14	19	33	100	Becomes dense
25														

BORING LOG

BORING LOG: B-4
SHEET
PROJECT #: E1-47093001.00
CONTRACTOR: Envior-Drill, Inc.
DRILLER: J. Sutton
INSPECTOR: Jeff Heyman

PROJECT: Buckeye Town Lake
LOCATION: NE corner of Hazen & Miller Rds.
CLIENT: Town of Buckeye

DEPTH BELOW	WATER LEVEL	USCS	GRAPHIC	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE SYMBOL	DEPTH (FT) FROM	DEPTH (FT) TO	MOISTURE, %	DRY DENSITY	SOIL (Blows/6 in.) 0/6	6/12	12/18	N	REC.	VISUAL MATERIAL CLASSIFICATION	SAMPLES
				S	7		25	26.5			12	14	13	27	30		
30				S	8		30	31.5	NP		8	11	15	26	100	Trace silt below 30 feet..	
35		GP - GM		S	9		35	36.5			17	14	18	32	100		
40				S	10		40	41.5			12	5	6	11	100		
45																Auger stopped at 40'. Sampler stopped at 41.5'. Groundwater encountered at approximately 8'. Boring backfilled with grout from bottom to upper 2 feet and with soil from 2 feet to surface.	
50																	

Summary of Laboratory Test Results
Preliminary Geotechnical Assessment
Proposed Buckeye Town Lake

BORING	DEPTH (feet)	MINUS # 200	ATTERBERG LIMITS			USCS Symbol
			Liquid Limit	Plastic Limit	Plasticity Index	
B-1	5	66	34	21	13	CL
B-1	35	38	38	21	17	CL
B-2	2.5	62	29	17	12	CL
B-2	20	1	NV	NV	NP	SP
B-2	35	29	NV	NV	NP	GM
B-3	2.5	71	29	16	13	CL
B-3	20	6	NV	NV	NP	GP-GM
B-4	2.5	73	29	19	10	CL
B-4	30	3	NV	NV	NP	GP-GM

CHAPTER 5 – VECTOR AND NUISANCE INSECTS

El Rio Watercourse Master Plan and Area Drainage Master Plan

Investigations and Development of Existing Conditions Model
Environmental Issues

AQUATIC CONSULTING & TESTING, INC.

VECTOR AND NUISANCE INSECT POTENTIAL

CHAPTER 5

INTRODUCTION

Biology of Aquatic Systems

Freshwater aquatic systems include assemblages of aquatic plants and animals that function as an ecological system. The terrestrial environment, especially marginal plants and animals, exerts a strong influence on adjacent aquatic system functions. Aquatic plants range from microscopic algae to macroscopic submerged, emergent, or floating weeds. Similarly, aquatic animals include microscopic free-swimming (planktonic) or benthic invertebrates, larger invertebrates as aquatic worms and insect larvae, and fish. These organisms provide the basis of predator-prey relations and the aquatic food web (USEPA 1990, Cooke *et al.* 1993, McComas 1993).

Insects of Concern

When a balanced aquatic food web is maintained, few aesthetic or public health problems are encountered in an aquatic system regardless of whether it is a pool, lake, or stream. However, autochthonous (internal) or allocthonous (external) forces can cause disruption of the food web and an imbalance in species composition. An internal mechanism such as redistribution of nutrients from the sediment during thermal turnover can cause overabundance of plant species, loss of oxygen in deep waters, changes in predator composition, and increases in anoxia-tolerant benthic species. An external input such as stormwater runoff can cause a similar situation.

Several organisms that normally play a beneficial role in aquatic systems can become problems when the food web is unbalanced and their numbers dramatically increase. The primary aquatic organisms that may become a concern in the El Rio project area are mosquitoes and midgeflies.

Vector Versus Nuisance Insects

Both mosquitoes and midgeflies can fall into the nuisance category and both are involved in human, domesticated animal, and wildlife health issues.

Vectors are considered organisms that transmit disease. Fortunately in Arizona the absence of biting midges precludes their involvement in disease transmission. However, numerous species of mosquitoes found in central Arizona can transmit serious diseases to human and other animal populations.

Nuisance insects are those that interfere with normal daily activities: work, recreation, aesthetic enjoyment, and relaxation. Several mosquito species that are not involved in disease transmission are voracious biters. Some attack during the day, while others are more active at night. They can have a significant impact on working or recreating outdoors. Although they do not bite, midge flies can be quite bothersome because of their swarming behavior. Adult flies can fly into mouths and eyes of humans or animals that inadvertently cross their path. When adult midges die, they leave sticky, hard to clean messes that result in increased property maintenance. Allergic reactions to midgefly contact have been reported in hypersensitive individuals.

Creating and maintaining a balanced aquatic ecosystem and minimizing external adverse influences on species composition will be important components of plan development for the El Rio watercourse. In order to accomplish this task, basic knowledge of mosquito and midge biology, anticipated species, habitat preferences and availability, and management options need to be understood and evaluated in context of project goals.

MOSQUITO BIOLOGY

Mosquitoes are winged insects belonging to the order Diptera and the family Culicidae. The have a narrow abdomen, a long and slender proboscis, and have scales on the wing margins and veins. Males have feather like antennae and mouthparts that are not adapted for piercing.

Females have long slender antennae and a set of needle like organs in the proboscis for piercing skin of animals and obtaining blood.

Mosquitoes may be divided into two groups: floodwater and stagnant water. Floodwater species lay their eggs on soil that will be flooded at a later time, while stagnant water species lay their eggs directly on the surface of water. Eggs may be deposited singly or as groups called rafts. When the eggs hatch, larvae swim to the surface to breathe through a structure called the siphon. The larvae go through several developmental stages before emerging from the water as winged-adults. Many species can over-winter in the egg or mature larval stages. Some species are of importance because of their ability to transmit disease, while others are problematic because of their aggressive biting.

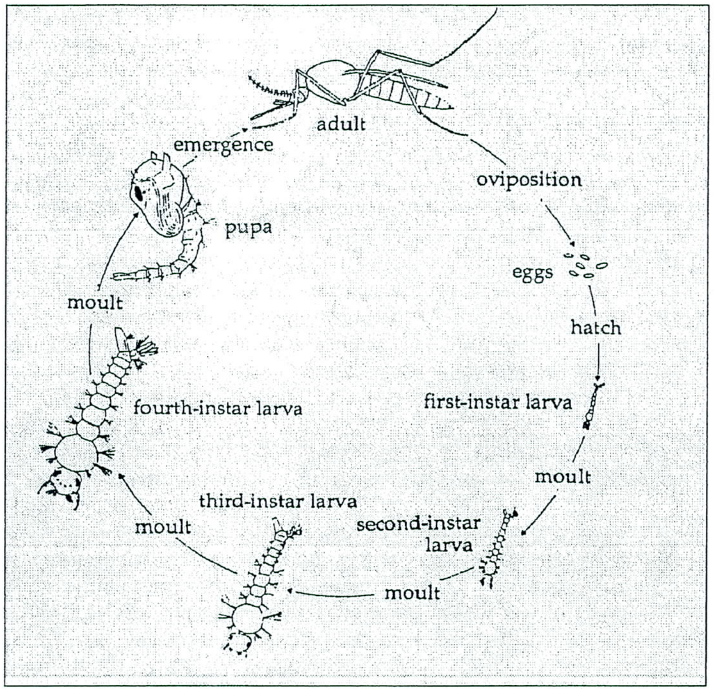
Some mosquito basics include:

- Mosquitoes must have water to complete their life cycle.
- As few as seven days are required to complete some life cycles during warm weather.
- Mosquitoes do not develop in grass or shrubs, although they may rest in these locations during the day. Note: improperly irrigated turf, where stagnant water remains for several days, can be a breeding site.
- Only female mosquitoes bite to obtain a blood meal. Male mosquitoes live on plant nectar.
- The female mosquito can live for as long as three weeks during the summer or many months over the winter in order to lay her eggs the following spring.
- Female mosquitoes, while in search of a blood meal, are attracted to carbon dioxide which is a signal that an animal is near. They are also secondarily attracted to lights.

Mosquito Life Cycle

The life cycle of the mosquito, depicted in Figure 1, has four basic stages: egg, larva, pupa, and adult. Most mosquitoes lay eggs singularly or in rafts on the surface of the water. The rafts can contain between 100 and 400 eggs. Other mosquitoes (flood water forms) lay eggs on rocks and vegetation in wait of submergence by rainfall or flooding. Eggs usually hatch within two to three days of being laid or submerged by water.

Figure 1: Mosquito Life Cycle



Upon hatching, small wiggling larvae swim to the surface of the water to begin breathing through their siphon. They feed on minute organic particulate matter and bacteria. The larvae go through four molts (skin-shedding) to accommodate growth during the next two to 16 days, depending on species. The organism during each of these stages is called an instar.

Following the fourth instar, the mosquito develops into a pupa. The pupa does not eat. Within the pupa the mosquito develops over the next two days. When fully developed, the pupa skin splits and the adult fly emerges.

The adult generally rests on the surface of the water until it is strong enough to fly away. The mature adult males will feed on nectar while the females will search for blood meals to nourish their eggs. Adults may fly from a few hundred yards to 14 miles in a night. Adults may live from two to nine weeks, depending upon species, and some females may produce up to three batches of eggs.

Mosquito Habitats

In general, mosquitoes prefer shallow, stagnant water with vegetative cover (indirect sunlight). Oviposition (laying of eggs) can occur in a variety of habitats from temporary to semi-permanent bodies of shallow water to stagnant water in artificial containers (cans, tires, bird baths, flower pots, etc.). Some species prefer dark colored containers or environments (e.g., tree holes) or organically rich water. Species-specific habitat preferences are described under the species descriptions.

Running Waters

Few species breed in running waters. *Anopheles quadrimaculatus* and *Culex territans* have been found in streams, but prefer other habitats.

Transient Waters

Transient waters, such as flooded areas, pools, and ditches are breeding grounds for mosquitoes (typically *Aedes* and *Psorophora* species) that produce eggs that are resistant to desiccation. The life cycles of these mosquitoes require alternating periods of wet and dry. Opportunist forms such as *Culex* can also utilize transient waters during an extended wet period.

Permanent Waters

Permanent waters are present for an extended period of time and are usually associated with aquatic vegetation such as rushes, sedges, or cattails. The vegetation provides refuge from predators for the larvae. Typical mosquito genera found in these areas include *Anopheles*, *Culex*, and *Culiseta*. These mosquitoes produce eggs that are not resistant to desiccation and that must be laid directly on the water surface to survive. Seasonal changes in vegetation influence the succession of mosquito species in the area (New Jersey Mosquito Control Association 2003).

MIDGE BIOLOGY

Aquatic midges are mosquito-like insects of the family Chironomidae. The adults are small (1-10 mm in length), and unlike mosquitoes, lack scales and have no proboscis. They may be gray, brown or green in color. Midge flies are considered aquatic because their immature (larval) stages are spent in water. They are one of the most common and abundant aquatic insects in natural and man-made water systems. They are a food source for many bottom-feeding fishes and other aquatic animals. Larval densities as great as 10,000 per square meter of lake bottom have been recorded in Arizona urban reservoirs. Midges do not bite, suck blood, or carry disease. They are important to man only when they exist and emerge in such large numbers as to create a nuisance. The importance of midge flies has increased in recent years because of a number of factors, including: (a) creation of new midge producing habitats close to residential areas, (b) deteriorating water quality which is more conducive to midge breeding, and (c) emergence of high numbers of midges cause humans to cease outdoor activities because they can be inhaled or fly into the mouth, nose, or eyes.

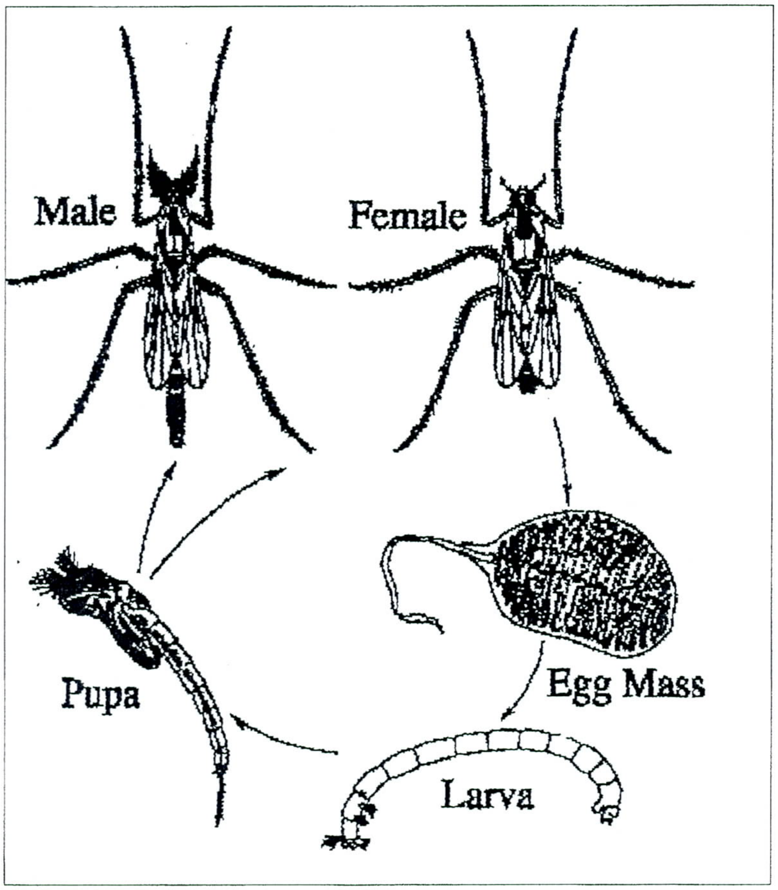
Adult midges form aerial aggregations or swarms consisting of 10 to 20 individuals up to millions of adult flies. The behavior typically occurs between spring and autumn and reaches its highest development in the mating dances of the males. Swarms may form at four altitudes: (a) very near the ground, (b) 4-14 meters above high shrubs and between tree tops, (c) above the top of trees, and (d) very high in the open air. In urban areas, swarms may be associated with buildings. Swarming is linked with diurnal change of illumination and/or temperature that divides Chironomids into daylight and twilight swarmers, the latter divided into preference for dusk or dawn swarmers. The swarm is initiated by males and provides an efficient means of female insemination.

Wind and light influence dispersion of adults from the site of emergence. Midges rarely fly in excess of one-quarter mile from their breeding sites. Attraction to light causes nuisance to humans; massed midge emergence can be attracted to artificial lights and result in infestation of houses and business premises. In more natural situations, distribution is more strongly influenced by wind and temperature. These factors control ambient humidity, which is important because the adult midge must avoid dehydration. The adult life span is relatively short at 4 to 10 days.

Midge Life Cycle

The midge fly life cycle (Figure 2) is composed of four stages: egg, larva, pupa, and adult. Most fertile females settle on the water's edge and deposit a dark gelatinous mass consisting of eggs within a thin mucilage. The egg mass is protruded until it touches the water. After the entire egg mass is passed out, it is secured to some fixed object close to the water's edge. In lentic habitats, eggs may detach and sink to the bottom or drift and later re-attach to a firm substrate such as a plant or stone. The egg mass of freshwater species may contain from 20 to 2000 eggs depending on the species. Hatching occurs in 2 to 4 days, but is highly dependent upon ambient temperature. Upon hatching, larvae of some species may take on a planktonic habit, swimming and consuming small detritus particles. Upon encountering suitable substrate, the larvae burrow

Figure 2. Midge fly life cycle



into the mud and construct a tube. The larvae collect and gather food (algae and detritus) by undulating and extending their head and anterior body outside of the tube. Emergence as an adult fly can occur in as little as 10 and usually averaging around 28 days, but emergence is strongly influenced by water temperature, photoperiod, and food supply (Armitage *et al.* 1995; Ogg 1994; Day 1996; Koehler 1999, LACWVC 2000).

After the first molt (growth stage), the larvae begin to develop their characteristic red color. The color is produce by hemoglobin that increases the organism's ability to take use oxygen in anoxic sediments. At this stage, the larvae are often called bloodworms. As they larva grows, it gradually expands the tube to accommodate its size. The larval stage generally lasts from 2 to 7 weeks depending upon the species and the water temperature. The larva transforms into the pupa while in its tube. The pupal stage lasts about three days. During this period rudimentary wings begin to develop. The pupa eventually leaves the tube and begins to swim to the surface of the water just before emerging as an adult fly.

The adult lives for three to five days, during which it does not feed, but mates in swarms at dusk and dawn. During the day, adult midges generally seek cool, shady places such as bushes, trees, and eaves of buildings. The entire life cycle can be completed in as little as two weeks under optimum conditions. Thus adult midges are short-lived, functioning only to swarm, mate, and lay eggs.

Midge Habitats

Midge flies can be found in streams, rivers, ponds, and lakes. They may also develop in oxidation ponds, irrigation and storm water channels, settling ponds, and sludge beds. In Arizona, they generally prefer water three to 14 feet in depth. Midge fly larvae are often found in polluted waters or at least in organically rich waters. Organic sediments provide optimum habitat, although they can develop in gravelly-bottom ponds. Algae-laden water ultimately produces the organic debris for burrowing and an unlimited food source for the larvae in the form of decaying algae and detritus. Some species are found associated with aquatic vegetation, including milfoil and parrot feather (*Myriophyllum*), cattail (*Typha*), and algae mats. The adult midge flies seek shade and moisture during hot days. Bushes, tress, eaves of buildings, and indoors (when the opportunity exists) are common resting-places. At night, adult midges are attracted to lights of residences and businesses. Mating flights are generally limited to areas proximal to the water, but wind can carry adults some distance from the breeding site.

HEALTH AND QUALITY OF LIFE ISSUES RELATED TO MOSQUITOES

Mosquitoes are known to transmit several important diseases of man and animals (Carpenter *et al.* 1946, Siverly 1972, Snow 1990). Brief descriptions of the diseases are provided below with reference to observed occurrence of potential vectors in Arizona.

Mosquito-Transmitted Diseases

Human Malaria

Malaria is an acute and chronic disease caused by the invasions of red blood cells by a protozoan transmitted by the *Anopheles* mosquito. The primary human vector in the southern states is *A. maculipennis.* Only a few cases are reported each year. Imported malaria, contracted abroad, is more common. Malaria is an infectious disease characterized by chills, shaking, and bouts of severe fevers. Malaria is caused by single celled parasites called *Plasmodium.* Plasmodium can be transmitted from person to person by the bite of the female *Anopheles* mosquito. Malaria was once widespread in North America and other temperate regions with the last major outbreak of malaria occurred in the 1880's. Today the disease occurs mostly in tropical and subtropical countries particularly Africa and Southeast Asia. In recent years malaria has made a comeback in regions where it had been nearly eradicated because the mosquitoes have become resistant to the pesticides used to control them and malaria parasites have become resistant to drugs used to treat them (Nayar 1991, MSN 2003).

Bird Malaria

This disease is caused by an infection with one or more species of blood-inhabiting protozoa of the genus *Plasmodium* and is transmitted by various mosquitoes. Mosquitoes belonging to the genera *Aedes, Anopheles, Culex, and Culiseta* may be vectors. *Culex pipiens* is considered an important vector and this species and is commonly found in low numbers in central Arizona collections.

Filariasis (Elephantiasis)

This disease of man is cause by the presence of a nematode worm transmitted by the bite of mosquitoes. The disease is restricted to the warm, moist regions of the world from 36 degrees N to 25 degrees S latitude.

Dog Heartworm

Dog Heartworm is caused by the nematode *Dirofilaria immitis*. Mosquitoes belonging to the genera *Aedes, Culex*, and *Anopheles* may transmit a parasitic nematode found in dogs, cats and wild carnivores. The worm invades the heart and pulmonary artery of the host. The Heartworm parasite requires two hosts to complete its development. The nematodes develop within the mosquito. When the mosquito feeds upon a dog the larvae of the nematode is transferred into the dog's blood stream. Heartworm disease occurs worldwide but mostly in subtropical and tropical regions. In the U. S. heartworm is found in all 50 states. The danger of heartworm is greatest in the summer months, but in the southern U.S. the treat can be year-round. This disease has been reported in all counties in the state of Arizona.

Symptoms of heartworm may not develop up to one year after initial infection. Dogs with typical heartworm may show signs of fatigue, cough, and appear rough and not thriving. Blood and worms may be coughed up. Possible blockage of blood vessels can cause the dog to collapse and suddenly die (Nayar 1998).

Arboviruses and Encephalitides

Arboviruses have complex lifecycles that depend on both arthropods and other hosts such as birds. The viruses can be transmitted accidentally to humans by mosquito bites. The viruses cause an inflammation of the central nervous system (encephalitis) in horses and humans. The principle encephalitides are Western Equine Encephalitis (WEE), St. Louis Encephalitis (SLE), and West Nile Virus (WNV). Arboviruses are generally at a dead end host if they reach humans, but Dengue Fever and Yellow Fever can be transmitted from one person to another via mosquitoes (O'Meara and Getman 1997, Green 2003).

Yellow Fever: This disease is transmitted via a virus carried primarily by *Aedes aegypti*. Yellow fever is a disease that produces mild symptoms to severe illness and death. The symptoms of the disease include two different phases. The first acute phase includes fever, muscle pain, backache, headache, shivers, loss of appetite, nausea and vomiting. Up to fifteen percent can enter into a second phase referred to as the toxic phase. In the toxic phase the patient often develops sever vomiting, abdominal pain and jaundice. Bleeding can occur from the patient's mouth and it can appear in vomit or feces. Up to half of the patients that go into the second "toxic phase" die within 10-14 days. There is no specific treatment for Yellow Fever. Yellow Fever gets its name from jaundice, which afflicts some patients. Wild rodents, marsupials, and primates serve as a source of infection to susceptible mosquitoes. Many mosquito species belonging to genera observed in central Arizona (*Aedes, Culex*, and *Psorophora)* have been reported in the literature to be naturally infected or have been shown experimentally to harbor and transmit the disease. However, the illness rarely occurs in the United States (WHO 2001).

Dengue Fever: Dengue (breakbone fever) is an acute infection caused by a virus transmitted via *Aedes aegypti* or *Ae. albopictus*. *Ae. aegypti* is an urban mosquito that resides in and near human populations. Rapid rises in urban growth are bringing people into more contact with this vector (CDC 2003). Dengue is restricted to tropical and subtropical regions. A. *aegypti* has been collected in Central Arizona; populations have been identified in Tucson and Tempe and a northern migration appears to be occurring. Dengue fever is often found in urban areas. Four closely related viruses transmitted from mosquito to human cause dengue. The prevalence of Dengue has grown over the past few decades. It is now endemic in more than 100 countries in Africa, the Americas, the Eastern Mediterranean, Southeast Asia, and the Western Pacific. Prior to 1970 nine countries had dengue outbreaks, but since then it has increased by more than-four fold. 2.5 billion people are currently at risk from dengue (WHO 2002).

Infection from Dengue viruses produces severe flu-like illness that can affect children, adults, and the elderly. Its common clinical features include non-specific febrile illness with rashes in children. In adults the symptoms include mild febrile syndrome or high fever, sever headache, pain behind the eyes, muscle and joint pains, and rash. Dengue Haemorrhagic Fever a potentially fatal complication that is characterized by high fever, haemorrhagic phenomena (often with liver enlargement) and in sever cases circulatory failure. There is no specific treatment for Dengue Fever (WHO 2002).

St. Louis Encephalitis: St. Louis encephalitis can occur year round in the southern United States where mild climates exist. St. Louis Encephalitis is the most common variety of viral encephalitis in the U.S. From the years 1964-1998 there have been 4,478 confirmed cases of St. Louis Encephalitis. The last major outbreak occurred in the Midwest from 1974-1977 when over 2,500 cases were reported. Most people who are infected with St. Louis Encephalitis never show any symptoms, while mild cases will have flu-like symptoms as slight fever and headache. Headache, high fever, disorientation, coma, tremors, convulsions, paralysis or death mark severe infections (Shrover and Day 1997, Vicioso 2003).

Western Equine Encephalitis: Western Equine Encephalitis is an arbovirus that is spread by mosquitoes. It is found in North, South, and Central America, but most cases are in the western and central regions of the United States. WEE is a disease that can be spread to horses and humans by infected mosquitoes. The disease cannot be transmitted from human to human. The virus is common around farming areas and irrigated fields. Culex tarsalis is a primary transmitter of WEE. A wide range of symptoms accompany WEE infection, ranging from headaches and fevers to more severe maladies including high fever, headache, drowsiness, irritability, nausea, and vomiting, confusion, weakness, and coma. Since 1964 only 639 cases of WEE have been confirmed in the United States. Fewer than 5 cases are reported each year. Vaccines are available for horses, but not humans (WEE 2003).

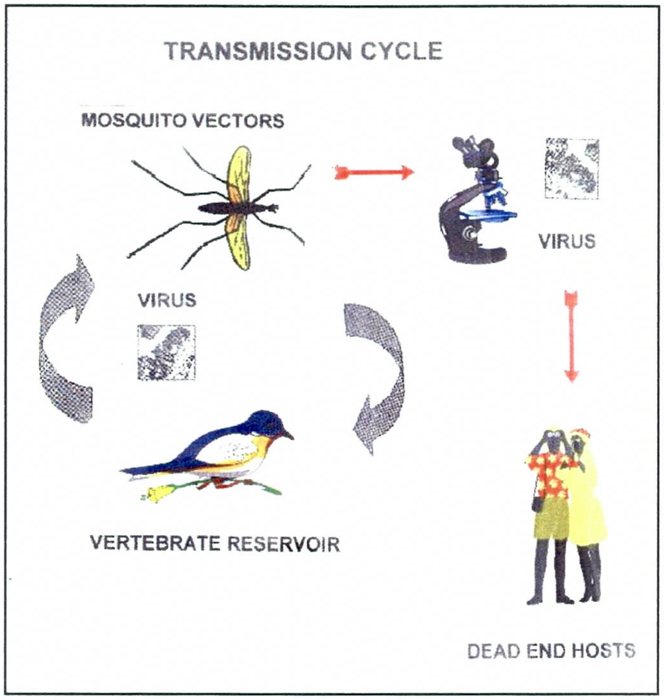
West Nile Virus: West Nile Virus is an arbovirus closely related to St. Louis encephalitis. It has been commonly found in Africa, West Asia, and the Middle East. Up until 1999 West Nile Virus had been commonly found in humans and birds of the previously mentioned regions. However, in 1999 WNV was reported in New York City. The origin of the strain found in New York is unknown, but it closely resembles the strains found in the Middle East. Since 1999 West Nile Virus has spread thought the East Coast then the Midwest and now into most western states. This continued expansion of the West Nile Virus in the U.S. indicates that it is permanently established in the Western Hemisphere (CDC 2002a). In temperate regions of the world, WNV cases generally occur in late summer and early fall but in southern climates it can be transmitted year round. In addition to humans, horses, cats, bats, chipmunks, skunks, squirrels, and rabbits are at risk to WNV infection (CDC 2002b)

There is little chance of getting infected with West Nile virus from a mosquito bite. It is estimated that less than one percent of mosquitoes transmits the virus and less than one percent of the people who are bitten become ill. Although chances of getting ill are slim, persons over the age of 50 are at higher risk of getting seriously ill. If symptoms do occur in a mild manor they may include slight fever and a headache. Severe symptoms include high fever, headache, confusion, muscle aches, and weakness.

Modes of Transmission

Mosquitoes are vectors of many arboviruses that contact humans. Not only are mosquitoes responsible for transmission of arboviruses to humans, but also other mammals and birds. Figure 3 depicts the transmission cycle. Arboviruses are transmitted through a "bite" from a mosquito that was previously infected by taking a blood meal from an infected bird. Most arboviruses cannot be transmitted from person to person or from birds to humans. Birds who live near bodies of water are susceptible to arbovirus infections. For a short time after a bird is infected with a virus, the bird will carry high levels of that virus in its blood. After the birds recover from the virus, they become immune to the organism. But if a mosquito gets its blood meal from a recently infected bird, the mosquito will then become permanently infected with the virus. The mosquito will then transmit the virus during every blood meal it takes. This pattern of mosquitoes feeding upon birds helps spread the virus throughout the bird population. Most mosquitoes feed upon birds as their primary source of a blood meal and they only feed upon humans as a second choice. Only female mosquitoes transmit the arboviruses because they need blood meals from animals to develop fertile eggs. They require a blood meal for each batch of eggs they lay (Reeves 1990, Jacob 2003).

Figure 3: Transmission Cycle



Nuisance Impacts and Allergic Reactions

Pain and itching from mosquito bites are the most prevalent nuisances to humans. Female mosquitoes require a blood meal from a vertebrate host to stimulate the development of an egg clutch. This behavior puts humans at risk of annoying to painful bites, regardless of the medical impact. Most mosquitoes exhibit hunting behavior in the evening making human nighttime recreation an at-risk activity. Some mosquitoes as *Aedes* and *Psorophora* will attack humans and large animals during the day whenever the immediate surroundings are disturbed. These two genera include aggressive and painful biters. *Aedes* and *Psorophora* also hunt mammals at dusk in open areas with low vegetation profiles. Arizona residents are simply not accustomed to mosquitoes, and just a few bites cause discomfort and loss of recreational value for outdoor activities.

Mosquito-induced allergic reactions encompass the symptoms of dermal irritation and/or respiratory allergy caused by abnormal stimulation of the immune system. An allergen, usually a protein-based macromolecule, provokes a response that is either a localized inflammation of the target organ or a systemic reaction as anaphylaxis. Reactions range from itching of the skin (pruritus) to nasal congestion and mucous flow (allergic rhinitis), to asthma or respiratory failure (Armitage *et al.* 1995).

While feeding, mosquitoes secrete saliva into the host's skin and the chemicals within create a local skin reaction in many people and animals (Snow 1990). The salivary compounds have a brief anaesthetic effect followed by a reaction that triggers itching for 15 to 30 minutes. The intensity of the reaction varies with the species of mosquito and the sensitivity of the host. Individuals receiving frequent bites can become de-sensitized whereby the bite response is minimal or absent. Conversely, individuals receiving frequent bites can become progressively sensitized with bites requiring immediate medical attention.

Mosquito Species of Importance

The following section describes floodwater mosquitoes that are common to Arizona and that may develop populations in the El Rio project area.

Psorophora - general characteristics:

- Eggs usually deposited on the ground
- Eggs can remain dormant for long periods of time
- Larvae develop rapidly after flooding
- Vector of West Nile Virus

Psorophora columbiae: A large mosquito that is an aggressive biter during the daytime or evening. The mosquito will fly from one to ten miles from their breeding site in search of a blood meal. It over-winters in the egg stage. Eggs are laid on the ground in areas subject to flooding from irrigation canals, streams or accumulated storm water. When hydrated, eggs hatch within four to five days after flooding.

Psorophora discolor: A medium-sized mosquito that breeds in pools caused by rain or in side pools along streams and irrigation channels. Larvae generally are found at the bottom of the pool. They rise to hang below the surface of the water just prior to pupation. The larval stage generally lasts from 10-14 days. They are active biters of humans during the evening.

Psorophora signipennis: A medium-sized mosquito which is widespread in Arizona. It inhabits temporary ground pools and is able to complete its life cycle in as little as five days. Larvae may be found in temporary standing water of grassy areas, roadside ditches, irrigation channels, ground pools, and partly dried up stream beds.

Aedes and *Ochlerotatus*- general characteristics:

- Pest mosquitoes and vectors of disease
- Lay eggs on the ground or above the water in tree holes or artificial containers
- Eggs hatch only after a long dry period followed by flooding
- Certain species have synchronized development with all individuals essentially at the same stage of the life cycle at the same time
- Transmit bird malaria parasite
- Transmit heartworm parasite
- Transmit Yellow and Dengue Fevers
- Transmit West Nile Virus

Aedes vexans: A medium-sized mosquito widespread in Arizona. It breeds in temporary sunlit fresh water pools including rain pools, irrigation pools, flood waters, and roadside ditches. Eggs are laid on the ground and hatch quickly after flooding. Larval forms exist for 10 to 21 days, depending upon temperature, before adults emerge. They usually rest in grass or other vegetation during the day and feed at dusk. They are known to be extremely aggressive biters.

Ochlerotatus dorsalis: A medium-sized mosquito that overwinters in the egg stage and hatches in the early spring. It can produce several broods throughout the year. Preferred habitat is open, grassy ground pools near irrigation and intermittent flooding. Breeding sites include sunlit or partially shaded temporary pools and ditch waters. Females are aggressive biters during the day or night, but especially at twilight. They may fly up to ten miles from their breeding site.

Aedes aegypti: A small-sized mosquito that is totally black except for white spots on the thorax and head and white rings on the legs. The thorax is decorated with a white lyre-looking shape with two dull yellow lines that would represent the chords. Eggs are laid separately on the damp surfaces of artificial containers such as cans, jars, or old tires. Eggs can resist desiccation for up to one year. Eggs hatch in 2 to 3 days when flooded by deoxygenated water. The female takes blood meals in early morning or late afternoon and prefers humans in preference to other animals. It usually bites body parts close to the ground such as ankles. It tends to be peridomestic; usually found in or in close proximity to human dwellings. The mosquito typically has a home range of only 40 to 100 meters. It may remain active throughout the winter in the southern U.S. It is the primary vector of Yellow and Dengue Fevers.

Stagnant Water Forms

Anopheles - general characteristics:

- Widespread throughout Arizona
- Eggs are laid on surface of water and have flotation devices
- Eggs hatch with one to three days of deposition
- Larvae are found parallel to water surface
- Nighttime feeders, but active in the morning and at twilight
- Most prefer animal rather human blood meal
- Bites have minimal discomfort effect

- Transmit bird malaria parasite
- Transmit heartworm parasite
- Transmit human malaria (species not found in Arizona)
- Probable vector of Western Equine Encephalitis

Anopheles franciscanus: A medium sized mosquito that breeds in ground pools, stock ponds, receding streams, and large artificial containers. *An. franciscanus* prefers warm breeding sites in full sunlight and with abundant algae growth. Flight range is about one mile.

Anopheles freeborni: A medium sized mosquito that breeds in waters free of wave action. Eggs are laid singly, but a female may produce up to three batches of 200 eggs during its lifetime. The aquatic stages may take up to 22 days to mature and life expectancy is about three to four weeks. Females may fly up to ten miles to find a blood meal.

Culex - general characteristics:

- Breed in any type of still, fresh water including artificial containers, ditches and ponds • Prefer highly organic water (sewage)
- Deposit eggs in rafts; eggs hatch in two to three days
- Rest in grass and vegetation in cool, dark, damp places during the day
- Overwinters as an adult in protected areas as buildings and caves
- Primary vector of St. Louis Encephalitis
- Probable vector of Western Equine Encephalitis
- Transmit bird malaria parasite
- Transmit heartworm parasite
- Vector of West Nile Virus

Culex tarsalis: A medium-sized mosquito that readily breed in ground pools, sewage waters, semi-permanent pools of irrigation ditches, and artificial containers which hold polluted water. Adult females lay at least two rafts of eggs that hatch within two days. Adults are active from sunrise to sunset. Adults rest during the day in caves, culverts, grasses, brush, and stream banks. Adults overwinter in caves and protected buildings. The mosquito is a known carrier of Western Equine and St. Louis Encephalitis.

Culex territans: A small mosquito that typically breeds in stream pools, ponds, and swamps. Eggs are laid above the water line and larvae enter the water upon hatching. Adults do not typically bite humans, preferring birds, mammals, and reptiles.

Culex quinquefasciatus: A medium-sized mosquito common to southern Arizona. Larvae are found in organic waters of pools and marshes. Typical breeding sites include catch basins, rain barrels, tanks, tin cans, storm drains, septic tanks, food processing plant wastewaters, and stagnant ditches. Breeding is continuous during warm weather. They are active only at night and are found in buildings and caves during the daytime. The mosquito is a known carrier of Western Equine and St. Louis Encephalitis.

Culex restuans: A medium sized mosquito that prefers to breed in stagnant, polluted water, with sewage or decaying organic matter. Typical breeding sites are ponds, side pools of streams, ditches, ground pools, and artificial containers. It is considered important in transmission of bird malaria.

Culex erythrothorax: A medium sized mosquito that breeds in shallow pools with dense vegetation. Adult females prefer feeding on birds. If their breeding site is disturbed, this species will bite humans during the day or night.

Culiseta - general characteristics:

- Breed in cooler marshy areas, stream side pools, and grassland flood water pools
- Some species prefer organically rich waters

- Overwinter in protected areas
- Prefer to feed on animals
- Possible vector of bird malaria parasite
- Probable vector of Western Equine Encephalitis
- Vector of West Nile Virus

Culiseta inornata: A large mosquito found in seepage pools from irrigation, floodwaters, and frequently in artificial containers. Larvae are commonly found in cool water. They over-winter as adult females that emerge at first warm weather of winter or spring. It rarely feeds on humans. *Cs. inornata* can be found naturally infected with Western Equine Encephalitis. Preferred habitat of some regional species described in Table 1.

Table 1

Preferred Habitat of Regional Mosquito Species

Habitat Type	**Mosquito Species**
Irrigation/flooded areas	*Aedes dorsalis* *Aedes vexans* *Culex tarsalis* *Psorophora confinnis* *Psorophora signipennis*
Alkaline areas	*Ochlerotatus dorsalis* *Culex tarsalis*
Permanent ponds and streams	*Culex tarsalis* *Culex territans*
Fresh water	*Anopheles p. franciscanus* *Anopheles freeborni*
Artificial containers/organic waters	*Culex tarsalis* *Culex pipiens* *Culex restuans*

HEALTH AND QUALITY OF LIFE ISSUES RELATED TO MIDGES

Health Impacts

Typically, only non-biting midges have been found in central Arizona field surveys. These midges are not known to carry any diseases (McDonald *et al.* 1973), but may be responsible for allergic reactions in humans.

The first implication of Chironomid midges in allergic disease was presented in the southern United States in 1938 and was further documented in 1984 (Weil 1940, Kagen *et al.* 1984). Chironomid hemoglobin in their body fluids, and scales on the surface of the midge body apparently contain allergens which can cause coughing, wheezing, itching, and formation of weals when scratched. In Japan, midges have been implicated in cases of bronchial asthma. Occupational exposure to midges has caused conjunctivitis, rhinitis, and dermatitis in hypersensitive individuals. Inhalation of midges and midge particles as small as 10 microns may induce these reactions. Under extreme conditions of adult emergence, inhalation of midge flies has caused asphyxiation of cattle (Kagen *et al.* 1995, Armitage *et al.* 1995).

It has been suggested that midges existing near polluted water may come in contact with bacteria and organic insecticides that could be transported to the terrestrial environment (Armitage *et al.* 1995). However, transmission to humans via this pathway has not been well documented.

An indirect health impact may occur in the attempt to manage mosquito and midge populations. Hypersensitive individuals and animals can exhibit acute or chronic side effects related to chemical pesticides used for insect abatement.

Quality of Life-Recreational and Social Impacts

Chironomid swarms often limit human activity outdoors because the adults can be inhaled or fly into the mouth, eyes, or ears. Studies in Minnesota have shown that people can tolerate one mosquito bite every 90 seconds; bites more frequent than that are considered a nuisance in that part of the United States (McComas 1993). Respondents to a recent citizen survey (AC&T 1996) identified impairment of evening recreation and relaxation as the two most important quality of life issues associated with the insects in nearby agricultural areas. Nuisances created by biting mosquitoes and swarming midge flies were the basis of the selection. Other affected activities included morning and evening yard work, afternoon outdoor relaxation, and agitation and irritation to pets.

Midges soil automobiles and cover headlights and windshields. On rare occasions swarms can create hazardous driving conditions which can lead to traffic accidents. Accumulations of dead adults and unsightly spider webs spun around resting adults require the frequent cleaning and washing of property. Dead midges have an offensive odor that persists in damp weather for several days even after the removal of the bodies.

The attraction of adult midges and mosquitoes to lights causes great human discomfort in residential areas. Adults swarm around lighted outdoor electrical fixtures and other objects which attract insects. Midges and some mosquitoes can enter homes through standard window screens. Once midges are inside they can stain laundry, deface walls, ceilings, curtains and other furnishings, contaminate food, and create distressful conditions for the residents. Mosquitoes can contaminate foods, and disrupt the sleep of pets and humans when the insects buzz in ears or bite.

In agricultural areas, midgeflies can damage seeds and seedling of some plants, thereby decreasing production and profits. Mosquitoes and midges can harass livestock by causing skin and eye irritations. These conditions can indirectly affect beef cattle, hogs, and dairy animals by decreasing weight gain and milk production (Siverly 1972). Loss of livestock can also occur. Horses may be lost via equine encephalitis. Under extreme conditions, inhalation of adult midges by cattle can cause asphyxiation (Armitage *et al.* 1995).

Midge flies occasionally clog air conditioners and car radiators, thereby decreasing their effectiveness, increasing energy costs, and possibly reducing their operational longevity. Dead fragments of some Chironomid species stick to car paint causing damage. Midges tend to collect along eaves of buildings and create an unsightly mess when they die. Under hot weather conditions, midges congregate in shady, cool locations and deposit meconium or release egg masses that stain surfaces. The odor of decaying midges resembles that of dead fish. The surfaces often require washing or repainting. Where midges are prevalent, spider webs and spiders abound. These latter conditions result in increased maintenance costs for homeowners and businesses (Armitage *et al.* 1995).

Large swarms of nuisance midges or aggressive, biting mosquitoes can have an indirect economic impact on many areas. Businesses dependent upon walk-in client traffic, including tourist and recreational sites, may observe reduced numbers of visitors as a result of the insects. Presence of adult mosquitoes and midge flies lowers the real estate value of the land that produces them and also adjacent properties within their flight range (McComas 1993).

HISTORICAL SITE-SPECIFIC FINDINGS

Limited published data exist for mosquito and midgefly population densities, distribution, and composition within the El Rio project area. However, a large body of data exists for similar habitats in proximal areas.

Historical Mosquito Data

A considerable amount of data exists as a result of monitoring efforts supported by the City of Phoenix to establish baseline and operational data for the Tres Rios Constructed Demonstration Wetland (AC&T 1999a, 1999b, 2000a, 2000b, 2000c, 2001a, 2001b, 2001c, 2002a, 2002b, 2002c, 2002d, 2003a, 2003b; Wass 1997a, 1997b, 1998). Data were collected adjacent to the wetland basins, in surrounding riverine habitats, and in the nearby agricultural community of Holly Acres. These areas contain aquatic habitats that are reasonably representative of those that are found within the El Rio project boundaries.

Species Identified

Table 2 presents a list of the mosquito species that were collected during the City of Phoenix monitoring efforts.

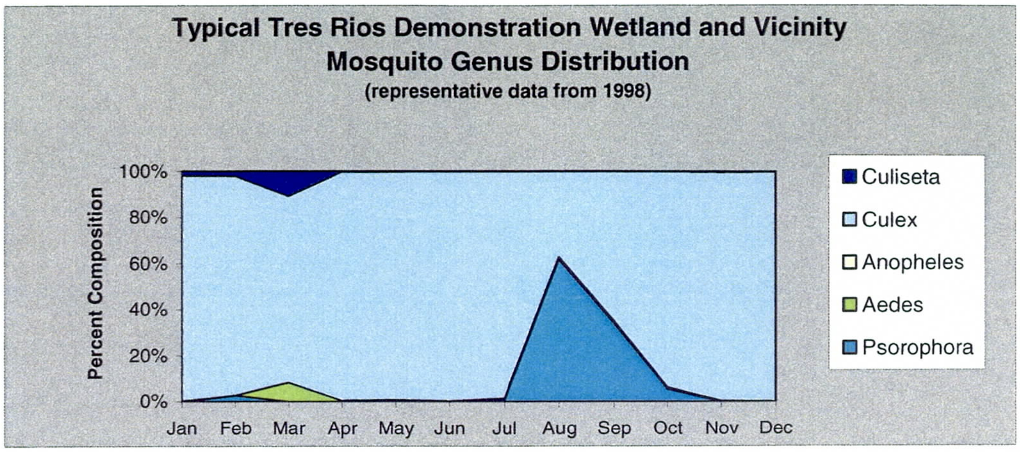
Table 2

Mosquito Species Collected During Phoenix Monitoring Events

Mosquito species	Tres Rios Wetland					Holly Acres		
	1998	1999	2000	2001	2002	2000	2001	2002
Psorophora columbiae	X	X	X	X	X	X	X	X
Ps. discolor		X						
Ps. signipennis	X		X	X		X		
Aedes vexans	X	X	X			X	X	X
Ochlerotatus dorsalis		X		X				
Anopheles franciscanus	X	X	X	X	X	X	X	
An. freeborni				X	X		X	
Culex tarsalis	X	X	X	X	X	X	X	X
Cx. territans								X
Cx. quinquefasciatus	X	X	X	X	X	X	X	X
Cx. restuans		X	X	X	X			
Cx. erythrothorax	X	X	X	X	X	X	X	
Culiseta inornata	X	X	X	X	X	X	X	X

The data show that a variety of species have been captured in the area. Dominant species include *Ps. columbiae, Ae. vexans, An. franciscanus, Cx. tarsalis, Cx. quinquefasciatus, Cx. erythrothorax,* and *Culiseta inornata*. Typical seasonal abundance of mosquito genera is provided in the figure below. *Culex* mosquitoes dominate throughout most of the year. Floodwater mosquitoes as *Psorophora* and *Aedes* appear when precipitation is abundant. Cold weather forms as *Culiseta* appear during the winter months. The species captured include vectors of West Nile Virus, bird malaria parasite, dog heartworm, Yellow and Dengue Fevers, and St. Louis and Western Equine Encephalitis. (Figure 4)

Figure 4: Mosquito Genus Distribution



Mosquito Densities

Average mosquito densities per trap per night are presented for the City of Phoenix data in the figures below. Many of the data include trap sites that are not within active mosquito management areas. Maricopa County Vector Control Department (MCVCD) and Arizona Department of Health Services consider mosquito densities greater than 20 per trap per night as indicative of potential vector-related health problems. The data collected as part of the City of Phoenix studies and habitat similarities suggest that problematic mosquito densities are likely to occur within the El Rio project area. (Figure 5 and 6)

Figure 5: Mosquito Counts Tres Rios

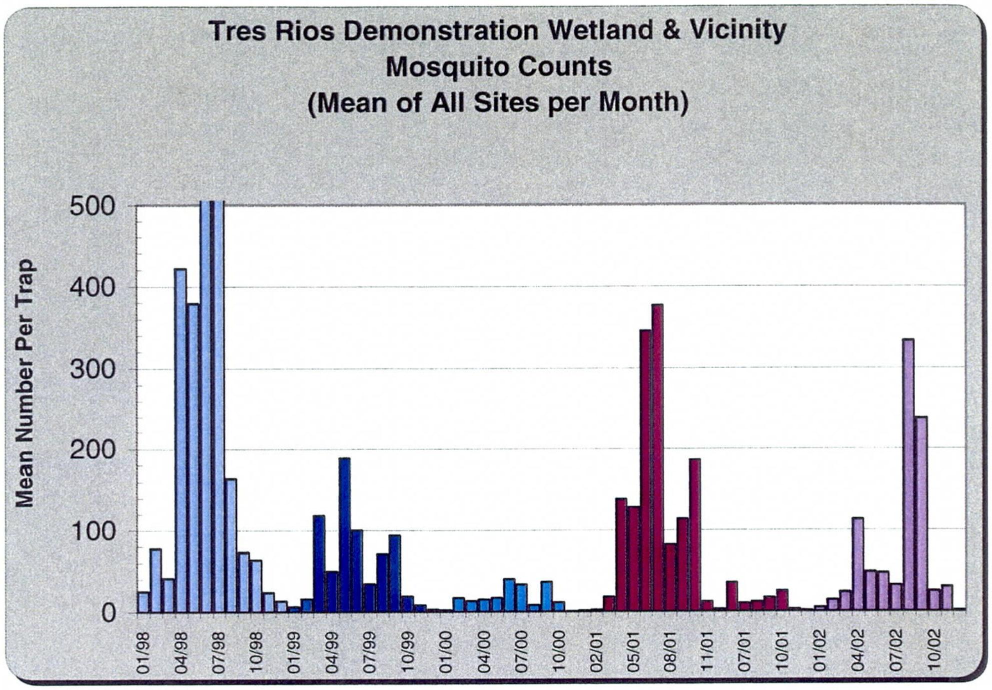
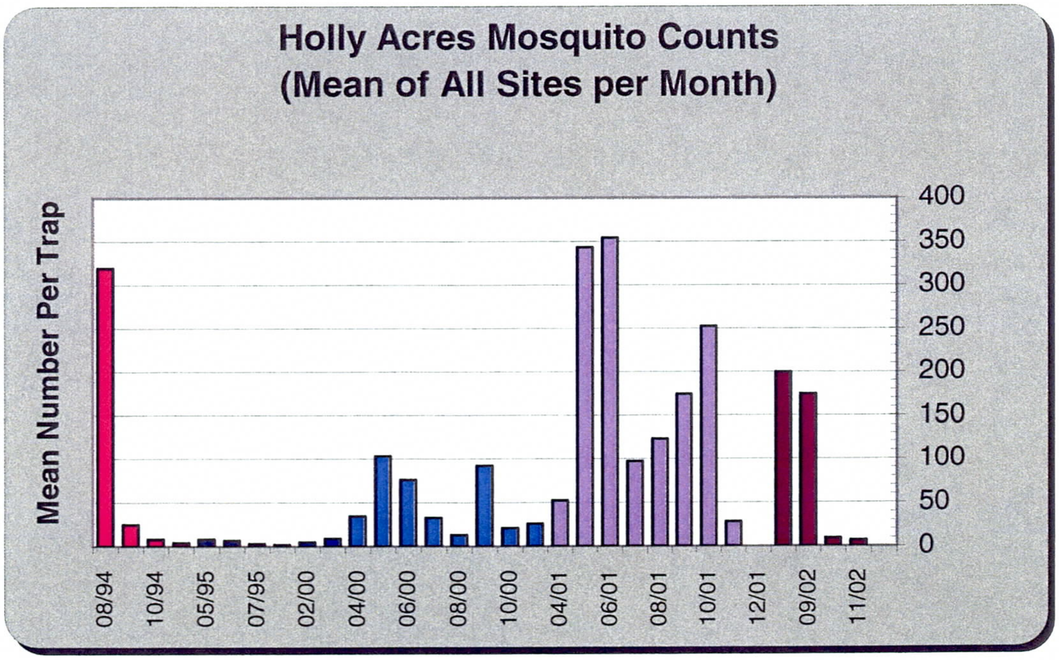


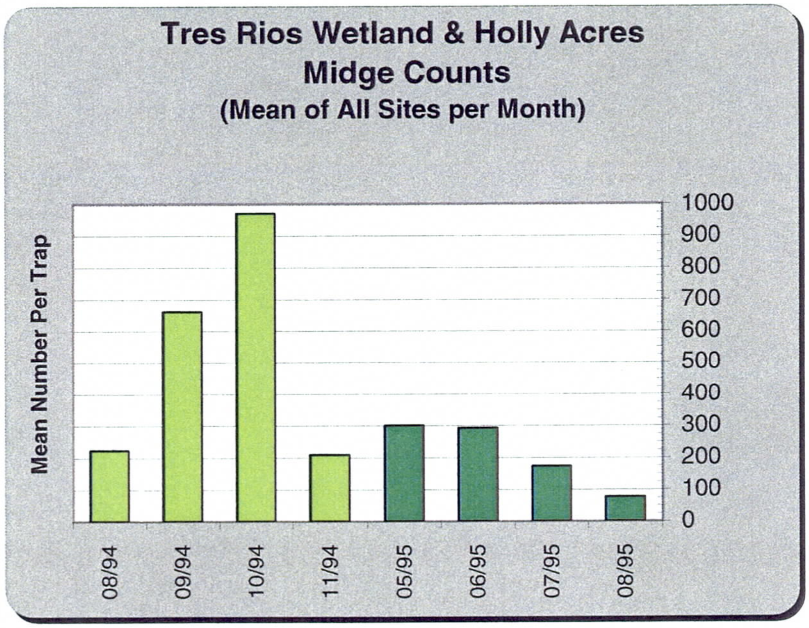
Figure 6: Mosquito Counts Holly Acres



Historical Midge Data

Midge counts presented in Figure 7 are based on samples collected near the Tres Rios Constructed Wetland, Holly Acres, and properties adjacent to the 91st Avenue Wastewater Treatment Plant.

Figure 7: Midge Counts



The data suggest that midge densities in wetland and irrigated areas may become sufficiently great to cause interference with recreational and work-related activities.

Recent Site-Specific Mosquito Data

Adult mosquito density data were collected from October 9 through November 16, 2002 in support of a baseline assessment for the project boundaries. A total of 23 different sites were monitored a single time. Standard taxonomic references were used for identifying the species of mosquito collected (Carpenter 1946, Neilsen and Reese 1961, Chapman 1966, McDonald 1973, Bohart 1978, Darsie and Ward 1981). Six mosquito species were collected during the period; their densities at each site are presented in the table below. Narrative descriptions of the site locations are in Table 3. Table 4 describe the location of each trap.

Table 3

Number of Mosquitoes and Species by Location

Site No.	Total mosquitoes	Aedes vexans	Anopheles franciscan.	Culex tarsalis	Culex quinque.	Culex restuans	Culex inornata
01	34	30	0	4	0	0	0
02	88	0	0	88	0	0	0
03	78	0	1	74	0	3	0
04	40	0	0	40	0	0	0
05	9	0	0	8	0	0	1
06	83	0	0	83	0	0	0
07	151	0	0	151	0	0	0
08	187	0	0	187	0	0	0
09	218	5	1	212	0	0	0
10	221	3	0	218	0	0	0
11	202	1	0	201	0	0	0
12	22	1	1	18	0	0	2
13	21	2	0	19	0	0	0
14	102	0	0	102	0	0	0
15	67	4	0	59	0	0	4
16	200	3	0	187	0	0	10
17	15	0	0	9	0	0	6
18	7	1	0	2	1	0	3
19	16	0	0	7	3	0	6
20	4	0	1	1	0	0	2
21	7	0	1	4	0	0	2
22	3	1	0	1	0	0	1
23	1	0	0	0	0	0	1

Despite sampling after the typical period of maximum mosquito density had passed, collections still contained as many as 221 mosquitoes per trap night. A total of 15 of the 23 samples exceeded the warning limit of 20 mosquitoes per night.

Table 4

Location of each Trap Site

Site No.	Location description	Latitude	Longitude
01	Estrella Parkway & Gila River	33.23.695	112.23.537
02	Tuthill Bridge @ Gila River south	33.21.302	112.29.226
03	Airport Road south @ Gila River	33.21.302	112.30.271
04	Waterman Wash	33.20.100	112.30.708
05	Bullard Avenue @ Gila River	33.23.642	112.30.466
06	Jackie Meck Lake 1	33.23.566	112.22.466
07	Jackie Meck Lake 2	33.23.393	112.21.999
08	Jackie Meck Lake 3	33.23.317	112.21.810
09	Jackie Meck Lake 4	33.23.242	112.21.743
10	Jackie Meck Lake 5	33.23.172	112.21.682
11	Jackie Meck Lake 6	33.23.147	112.21.536
12	Dean Road @ Gila River	33.21.593	112.31.327
13	Rainbow Road @ Gila River	33.21.560	112.32.373
14	Buckeye Wastewater Treatment Plant	33.21.566	112.34.936
Site No.	**Location description**	**Latitude**	**Longitude**
15	Miller Road @ Gila River	33.20.861	112.35.448
16	East of Miller Road in Gila River	33.20.880	112.35.049
17	Eagle Mountain Road west	33.20.478	112.32.125
18	Eagle Mountain Road east	33.20.490	112.31.941
19	Gila River 1	33.21.041	112.31.429
20	Gila River 2	33.20.922	112.32.341
21	Gila River 3	33.21.140	112.31.017
22	West of Highway 85	33.19.924	112.37.508
23	East of Highway 85	33.19.913	112.37.361

PROJECT OPPORTUNITIES AND CHALLENGES

The number of adult mosquitoes and midgeflies in the project area will have a significant impact on the recreational and aesthetic value of the project. The simple nuisance aspects of these organisms can impact quality of life for visitors and nearby residents. The mosquito species that may develop in the area have significant public health implications. Economic impacts can develop in terms of disease transmission to livestock (horses and cattle). Potential breeding sites for midgefly and mosquitoes are displayed on a GIS exhibit located in Appendix A.

Habitat Availability for Mosquitoes and Midgeflies

The river ecosystem and adjacent agricultural and residential properties provide numerous habitat opportunities for mosquitoes and midges. The potential habitats can be grouped into several major categories: open surface waters, transient pools, vegetated aquatic transition zones, flowing waters, and miscellaneous opportunistic habitats (NJMCA 2003).

Open Surface Waters

Large permanent ponds: Relatively large bodies of surface water subject to wave action, with minimal shoreline vegetation or littoral zones, relatively deep water, and resident predatory fishes are unlikely sites for mosquito breeding. However, these sites can provide adequate habitat for midge fly larvae. Open waters containing soft or sandy bottoms with even a small accumulation of organic detritus can provide suitable substrate and food for midge larvae. The numbers of planktivorous and bottom feeding fishes in the large pools strongly influence the final density of larvae and production of terrestrial adult midgeflies.

Small Isolated Temporary Pools**:** Relatively small pools of water can support both mosquito and midge larvae. Usually small, shallow pools have sufficient algae growth because of nutrient concentration, warm temperatures, and high maximum light penetration into the water. Accordingly, ample algae growth and decomposition creates organically rich water and substrate and provides habitat and food for the larvae. Pools that exist for up to one month provide sufficient time for stagnant water mosquitoes and midge larvae to complete their life cycle. Pools that that are wetted intermittently provide ideal habitat for floodwater mosquitoes that lay eggs that are resistant to desiccation and actually require wet and dry periods. If fishes are entrapped during the formation of small pools, the larvae become concentrated prey and can often be completely eliminated. Figure 8 contains a picture from a transient pool in the project area.

Figure 8: Transient Pool

***Vegetated Aquatic Transition Zones*:** Vegetated aquatic zones include marsh habitats containing cattail or bulrush as dominant plant species. Two basic categories exist:

- Cattail or other emergent aquatic plants creating a continuous dense stand covering nearly 100 percent of the water surface area
- Cattail or other emergent aquatic plants growing along the shallow periphery of open waters

Both habitats provide mosquito attraction potential to varying degrees. Dense emergent aquatic vegetation as cattail or bulrush creates quiescent water where oviposition can occur for midges or mosquitoes. The density of the vegetation impacts accessibility by aquatic predators; the denser the vegetation the more difficulty predators have reaching the larvae. Many mosquito species also prefer waters that are sheltered from direct sunlight. Overhanging trees or other vegetation provide preferred habitat. Adult midgeflies and mosquitoes require cool resting areas during their relatively inactive daytime. Cottonwood, salt cedar and other emergent aquatic vegetation close to the marsh provide needed resting areas. Finally, nearby salt cedar provide nectar for adult mosquito feeding.

***Flowing waters*:** Mosquito and midge species found in central Arizona rarely breed in flowing waters. Water movement is not conducive to oviposition or larvae survival. Figure 9 contains an example of a flowing water body in the project area.

Figure 9: Flowing Water

***Opportunistic Habitats*:** Opportunistic habitats include man-made aquatic systems inadvertently created by mismanagement or poor housekeeping. These habitats will be more closely related to residential and agricultural properties and activities than the river ecosystem.

Poor irrigation practices can provide midge and mosquito habitat. Over-irrigated fields and pastures, where water is allowed to stand for days or weeks, provide breeding sites for floodwater mosquitoes and midgeflies. Accumulation of debris in irrigation ditches creates standing water and formation of bottom deposits that become habitats for both insects. Discarded tires, abandoned watering tanks, and even discarded containers that can fill with rain or irrigation water are suitable habitats for many container-breeding mosquitoes including *Aedes* and *Culex*.

Habitat Types and Nuisance Potential

The table below summarizes the potential for nuisance conditions caused by mosquitoes and midgeflies, based on habitat type within the project area. The rankings are based on the typical ability of the insects to survive and reproduce in each aquatic habitat and associated vegetation type. Rankings for potential development of nuisance conditions are as follows: (1) very low, (2) low, (3) moderate, (4) high, and (5) very high.

Habitat/Vegetation Type	Potential for Nuisance Condition	
	Midgeflies	Mosquitoes
Open Surface Water:		
Permanent Pond or Pool	4	1
Small Temporary Pool	2	3
Vegetated Aquatic Transition Zone:		
Marsh (continuous emergent cover)	1	5
Marsh (peripheral emergent cover)	3	2
Flowing water	1	1
Opportunistic Habitat (potholes, containers, potholes, etc.)	3	3

Although certain habitat types such as marshes provide desirable habitat for terrestrial and avian species, they are not preferred habitat as far as protecting against vector insects. Aquatic vegetation species, with high numbers of stems per surface area, attract and shelter mosquito larvae from predators. Similar aquatic plant species filling the same ecological niche, but having a very different growth pattern could be introduced to reduce vector attraction. Open surface waters provide fishery potential and passage for natural predators to mosquito breeding sites, but also provide habitat for midges. Managing open surface waters to provide an appropriate aquatic predator-prey base can lead to biological regulation of midge larvae density. Thus, fishery enhancement and management may become an essential component of the restoration plan.

Enhancing the number and flow duration of intermittent and ephemeral streams can physically prevent insect oviposition in these areas and reduce larval habitat for nuisance species, while stimulating development of natural mosquito predators.

Therefore, a planning challenge exists; to provide expanded habitat for desired wildlife, while minimizing attraction of nuisance and vector insects. Creating a balanced blend of habitat types can engage the challenge. (See also Natural Biological Control Potential and Integrated Pest Management Plan sections below.)

Breeding Potential Assessment

Figure 1 provides a visual representation of potential mosquito breeding areas within the project boundaries. Sites are ranked as "low", "moderate", or "high" breeding potential based on recent adult trapping surveys. Mosquito densities less than 20 per trap night received a "low" rating; 21 to 75 adults per trap per night received a "moderate" rating, and greater than 75 adults per trap per night indicated a "high" breeding potential. The aerial extent of each zone is based on estimates of available habitat near the sampling point.

Figure 2 presents a visual representation of potential midge breeding habitats. Breeding areas are characterized as either "low" or "moderate to high" potential based on habitat type and aerial cover.

Vector Transmission Potential

Birds are the primary source of arboviruses that mosquitoes transmit to humans. The Gila River system provides ample habitat for a large number and wide variety of birds. Of the 165 bird species found to be infected with WNV by CDC surveillance through December 2002 (USGS 2002), 58 have been identified in the Gila River region of Arizona (Audubon Society 2002). Table 6 lists birds that have been reported within the Gila River area and that also have been shown to carry the West Nile Virus. When the West Nile Virus arrives in Arizona, this list will most probably grow as new species of birds are infected (USGS 2002).

Table 6

Potential Bird Species to Carry West Nile in the Gila River Area

Bird species (common name)	Scientific name
Eurasian Wigeon	*Anas penelope*
Mallard	*Anas platyrhynchos*
Ruby-throated Hummingbird	*Archilochus colubris*

Table 6 Continued

Bird species (common name)	Scientific name
Killdeer	*Charadrius vociferus*
Ring-billed Gull	*Larus delawarensis*
Great Blue Heron	*Ardea herodias*
Green Heron	*Butorides virescens*
Least Bittern	*Ixobrychus exilis*
Turkey Vulture	*Cathartes aura*
Black Vulture	*Coragyps atratus*
Mourning Dove	*Zenaida macroura*
Belted Kingfisher	*Ceryle alcyon*
Cooper's Hawk	*Accipiter cooperii*
Sharp-shinned Hawk	*Accipiter striatus*
Red-tailed Hawk	*Buteo jamaicensis*
Rough-legged Hawk	*Buteo lagopus*
Bald Eagle	*Haliaeetus leucocephalus*
Osprey	*Pandion haliaetus*
Merlin	*Falco columbarius*
Domestic Chicken (Red Junglefowl)	*Gallus gallus*
Turkey (domestic and wild)	*Meleagris gallopavo*
Virginia Rail	*Rallus limicola*
Cedar Waxwing	*Bombycilla cedrorum*
Northern Cardinal	*Cardinalis cardinalis*
Common Raven	*Corvus corax*
Song Sparrow	*Melospiza melodia*
Savannah Sparrow	*Passerculus sandwichensis*
Fox Sparrow	*Passerella iliaca*
House Finch	*Carpodacus mexicanus*

Table 6 Continued

Bird species (common name)	Scientific name
Barn Swallow	*Hirundo rustica*
Red-Winged Blackbird	*Agelaius phoeniceus*
Brown-headed Cowbird	*Molothrus ater*
Great-tailed Grackle	*Quiscalus mexicanus*
Loggerhead Shrike	*Lanius ludovicianus*
Northern Mockingbird	*Mimus polyglottos*
Thrasher	*Toxostoma*
Yellow-rumped Warbler	*Dendroica coronata*
Yellow Warbler	*Dendroica petechia*
Common Yellowthroat	*Geothlypis trichas*
Nuthatch	*Sitta*
Wren	*Thryothaurus*
Wren	*Troglodytes*
Bluebird	*Sialia*
Brown Pelican	*Pelicanus occidentalis*
Cormorant	*Phalacrocorax*
Sapsucker	*Sphyrapicus*
Pied-billed Grebe	*Podilymbus podiceps*
Great Horned Owl	*Bubo virginianus*
Barn Owl	*Tyto alba*
Ostrich	*Struthio camelis*

Other Vertebrates

Table 7 contains a list of animals that have been shown to carry the West Nile Virus and include many animals that may be present within the El Rio project area (CDC 2002b).

Table 7

Carriers of West Nile Virus

Animal (common name)	Scientific name
Domestic Cattle	*Bos taurus*
Domestic (Suffolk) Sheep	*Ovis aries*
Domestic Dog	*Canis familiaris*
Domestic Cat (feral)	*Felis catus*
Domestic Rabbit	*Oryctolagus cuniculus*
Domestic Horse	*Equus equus przewalski caballus?*
Donkey	*Equus asinus*
Squirrel	*Sciurus*
Chipmunk	*Tamias*

The table shows that not only are organisms associated with riverine habitats susceptible to mosquito-vectored infection, but so too are domesticated animals that can be found on local agricultural properties. Therefore, a reasonable potential for mosquito-transmitted disease exists within the project area.

Natural Biological Control Potential

A balanced aquatic ecosystem provides a number of biological predators to both mosquitoes and midgeflies. Waters that are more permanent and that have a diverse biota have the greatest potential for biological regulation of nuisance and vector species.

A number of important invertebrate predators such as waterbugs, water boatman, and backswimmers are likely to be found in the project area. They are more apt to inhabit permanent waters. Some predators such as dragonfly and damselfly larvae will prefer, but not be entirely limited to, flowing systems.

Based on species lists for the project area, terrestrial vertebrate predators are not likely to have much impact on either midgeflies or mosquitoes. Although swallows are present, they will more likely feed on larger and more numerous flying insects than mosquitoes or midgeflies. Bats are not desirable because of negative public perception arising from rabies concerns.

Fish could be a major biological control mechanism for nuisance and vector insects. However, the river has been typically depauperate of fishes since the 1970s. Recent collections of fishes from the lower (King *et al.* 1997) and middle Gila River (King and Baker 1995) indicate that channel catfish (*Ictalurus punctatus*), common carp (*Cyprinus carpio*), largemouth bass (*Micropterus salmoides*), and desert sucker periodically inhabit the waters. Data collected through 2001 by Arizona Game and Fish Department (personal communication Dave Weedman, AZG&F) for the Gila River near the Tres Rios Wetland indicate that *Tilapia zilli* and *T. aurea*, largemouth bass, common carp, catfish, black crappie (*Pomoxis nigromaculatus*), black bass (*Morone mississippiensis*), yellow sunfish *(Lepomis cyanellus*), threadfin shad (*Dorosoma petenense*), yellow bullhead (Ameiurus natalis), red shiner (*Cyprinella lutrensis*), sailfin molly (*Poecilia latipinna*), and mosquitofish (*Gambusia affinis*) have more recently intermittently occupied the waters. Frequent lack of fish is attributed to poor fish habitat resulting from scouring, high sediment loads, and poorly developed macroinvertebrate food supply. Conditions improving the longevity and habitats of insect larvae-consuming carp, sunfish, shiners, crappie, and mosquitofish are desirable in terms of insect management.

INTEGRATED PEST MANAGEMENT PLANS

Fortunately, because mosquitoes and midge flies are insects that share similar terrestrial and aquatic habitats, management methods for one are often effective against the other. Accordingly, a number of common mosquito and midge fly management options for freshwater impoundments are presented below. Together they form the basis of an integrated pest management (IPM) program. Please note that design, operation, and water quality characteristics of the project components will impact the appropriateness and effectiveness of various management options at any given time (FMCA 1997, Lembi 1997).

IPM combines five aspects of mosquito and midge control to provide the best possible situation for managing insect populations. The five basic components of the IPM are:

1. Surveillance
2. Larviciding
3. Biological management
4. Source reduction (habitat management)
5. Adulticiding

Habitat Management

Source reduction is usually more effective and economical in comparison to biological and chemical management techniques. In particular, management strategies that reduce or eliminate the need for chemical insecticides are more desirable for water recharge and habitat development.

Emergent Vegetation Management

Aquatic vegetation provides benefits of enhancing settling rates of suspended particulates, absorption of nutrients and certain pollutants in plant tissues, and providing physical attachment structures for microbes involved in additional water purification. However, mosquito production is strongly associated with vegetation density and coverage. Thick vegetation, as well as design features and operational procedures that hinder access to mosquito and midge breeding and development sites exacerbate insect abatement. (O'Meara *et al.* 1988; O'Meara and Purcell 1990a, 1990b).

Negative impacts of vegetation can sometimes outweigh the benefits of enhanced water quality improvement. Vegetation in and around reservoirs provides adult mosquito and midgefly refuge from predators and physical disturbance, and increases food resources. Decaying vegetation provides food for mosquitoes and organically rich sediment for midge fly larvae habitation (Karpisac *et al.* 2002). Wave action created when aquatic plants are limited decrease the likelihood of oviposition by midges and especially, mosquitoes. Ponds should be kept clear of dense stands of marginal, emergent, and submerged vegetation. Management activities to reduce aquatic vegetation may include planting of low density species, increasing water depths, isolating plants with deep zones, harvesting (physical removal), applying herbicides (Gangstad 1986), dry-ups, and controlled burning.

Water Level Management

Water depth of greater than four feet is desirable in most aquatic systems for limiting mosquito production. Water depth has limited impact on midge fly larvae development, although very shallow pools usually do not support large numbers. Shallow areas in impoundments can be filled or deepened to reduce mosquito habitat. Because small pools and basins in the project area could periodically be drawn down, they will be prone to mosquitoes that seek areas of fluctuating water levels. Floodwater mosquitoes, such as *Aedes* and *Psorophora* may develop. The ability to quickly manipulate water levels can be essential in minimizing these mosquitoes. Draw down can be an effective mosquito control method, but can be counter-productive if aquatic vegetation is present. Complete drying of some areas may be a means of desiccating mosquito larvae and most eggs. Midgefly larvae are able to survive in damp mud at extremely low oxygen concentrations. Tilling, although probably not feasible, would provide additional benefit of exposing partially buried midge fly larvae to desiccation and damaging floodwater mosquito eggs. Both midge flies and mosquitoes seldom lay eggs on moving waters. Therefore, assuring that adequate stream flows are maintained and providing large open water areas subject to wind-generated wave action are methods of reducing vector and nuisance insect problems (CH2Mhill 1999).

Wear compatible with project goals, design features should include banks that provide access by predators. Management practices that produce depressions (e.g., tire tracks) and pools of standing water should be avoided. Shoreline configuration should not isolate sections from the main basin. If compatible with basin recharge goals, permanent deep zones can be designed for predacious fish refuge while the remainder of the basins draws down. A maximum water depth should be maintained as long as practical during peak mosquito breeding season, otherwise complete basin dry up could become necessary. Basins should be graded flat to prevent minor depressions that would contain shallow water during dry down periods. Should it become necessary to treat for larvae, smaller basins provide ease of larvicide application and improved distribution of chemicals from the shoreline. Relatively small basins permit easy access for any mechanical harvesting measures (O'Meara and Purcell 1990b, USEPA 1990, Cooke 1993, USEPA 2000).

Any conveyance channels should be maintained to prevent seepage or flooding of low-lying areas that could promote mosquito production when wetted. Earthen berms or levees should be able to structurally support management activities including vehicle traffic that might be necessary for insect management activities.

Algae Management

Water quality entering the ponds and streams should be of highest quality possible. Nitrogen and phosphorus will promote development of algae and aquatic macrophytes. Unmanaged algae growth eventually settles to the lake bottom to form organic deposits that become food and habitat for midge larvae. Mats of algae or floating macrophytes can reduce mosquito oviposition, but wave action generally disrupts the floating vegetative coverage and provides adequate space for oviposition.

Biological Predator Enhancement

Natural predators help manage mosquito numbers. Providing suitable lentic and lotic habitats and refuge for natural insect predators can minimize need for pesticide applications. Invertebrate mosquito predators include: water scorpions, juvenile waterbugs, water boatman, backswimmers, giant water bugs, tadpoles, water striders, dragonfly and damselfly larvae, hellgrammites (dobsonfly larvae), whirligig beetles, predacious diving beetles and their larvae (tiggers), and water scavenger beetles (Hiltner 2002, Indiana Department of Natural Resources 2003, Somerlot 2003).

Purple martins, other swallows, and bats have been recognized as natural controls for mosoquitoes and other flying insect pests (Hernando County 2003). These organisms tend to inhabit tree cavities and rocky cliffs. Although these organisms consume mosquitoes and midgeflies as part of their diets, they may preferentially consume larger and more abundant insects and often have limited impact on mosquito or midge control. The implication of bats as potential transmitters of rabies has created a negative public opinion regarding introduction or intentional attraction of the organisms into recreational areas.

Larvae-eating fish are beneficial particularly in standing waters with limited food resources, vegetation, and predatory fishes. It is advantageous to introduce both surface feeders and bottom feeders. Typical surface feeders include the mosquito fish (*Gambusia affinis*) and the fathead minnow, *Pimephales promelas*. These fish will prey on mosquito larvae as the insects swim and hang at the water surface and midge pupae as they move through the water column prior to emergence. Bottom-feeding fish used for larvae control include gold fish (*Crassius auratus*), common or Israeli carp (*Cyprinus carpio*) and koi. These fish frequently scour the bottom, disrupting the midge tubes, and consuming the dislodged larvae. Other larvae-eating fish include stickleback, guppies, sunfish, and carp (Rauch 2003).

Surveillance and Education

Monitoring prior to and following watercourse rehabilitation is recommended. Ascertaining baseline conditions is important in establishing adult mosquito and midgefly densities contributed by outlying areas and not directly associated with the watercourse. This knowledge can be a critical factor in determining responsibility and selection of mitigation measures should mosquitoes or midge fly complaints arise from nearby residents, site visitors, or facility workers. Monitoring following implementation is essential for identifying problems at the earliest signs and immediately responding to conditions before complaints or more expensive mitigation measures are required.

Monitoring for Mosquitoes

The purpose of monitoring mosquito abundance is to (a) measure the size and spatial distribution of the population determine potential health risk, (b) evaluate the success of management measures, and (C) identify breeding areas.

Adult Mosquito Monitoring

Adult mosquitoes are most commonly collected using EVS (Encephalitis Vector Survey) carbon dioxide traps. The traps are set out in the late afternoon at a height of approximately six feet. Steel cages are sometimes used to protect the traps against vandalism. The traps use carbon dioxide as the primary mosquito attractant. The upper trap consists of a one-gallon, insulated, dry ice container. The container is perforated to allow sublimated carbon dioxide gas to escape and attract mosquitoes. Mosquitoes drawn to the carbon dioxide enter the trap through an opening of the middle, mechanical section. Mosquitoes are drawn in and down by the airflow created by a small, battery-powered fan. A small lamp, visible from the top of the mechanical section acts as a secondary attractant. The bottom section consists of a catch bag made of netting. The mosquitoes are held in the bag until the trap is collected the next morning. The bags containing captured mosquitoes are transported to the laboratory where they are placed in a freezer to humanely kill the insects.

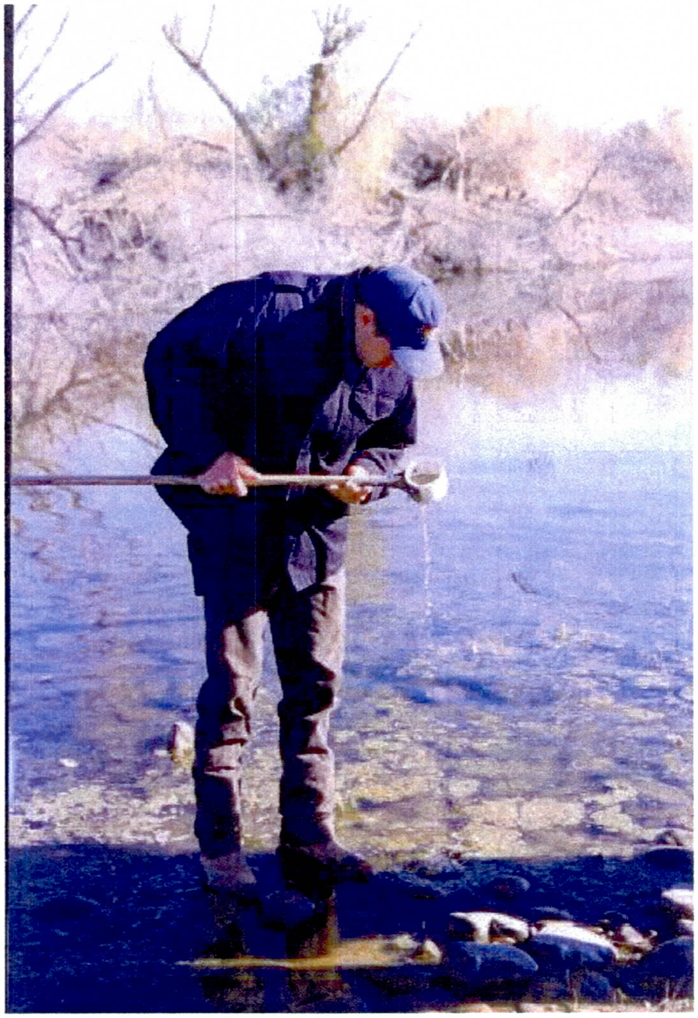
Arbovirus monitoring

Encephalitis-related viruses exist primarily in birds infected by mosquitoes. If the infection level in the bird population is high enough, the disease could possibly enter the human population by the bite of a mosquito that has acquired the infection by feeding on a viremic bird. Surveillance can be accomplished by netting and trapping birds and conducting blood analyses. Alternatively, adult *Culex* mosquitoes, the generally accepted primary vector of many diseases associated with man, can be collected and analyzed for the virus. MCVC in conjunction with Arizona Department of Health Services conduct these analyses as part of their routine monitoring program.

Mosquito Larvae Monitoring

Mosquito larvae are typically sampled manually with a standard dipper in standing water locations. One or more dips are made in areas of suspected breeding (i.e. in shaded, vegetated, stagnant water zones). Records are maintained to track the changes in density of various species and evaluate need for remedial treatment. In deeper water, vertical plankton nets may be deployed from a boat to collect larvae from the water column. Figure 10 contains a picture of a person monitoring larvae.

Figure 10: Monitoring Larvae



Mosquito Identification

The genus and species of collected mosquitoes is important in helping to identify breeding grounds (floodwater versus stagnant water; container breeder versus pond breeder) and success of any mitigation measures. It is also crucial for assessing possible human health impacts based on the presence or absence of possible vectors. Accurately identifying mosquitoes to the species level usually requires specially trained personnel.

Monitoring for Midgeflies

The purpose of monitoring midgefly abundance is to (a) measure the size and spatial distribution of the population determine potential nuisance conditions, (b) evaluate the success of management measures, and (c) identify breeding areas.

Adult Midge Monitoring

Adult midges are collected using New Jersey Light Traps. Traps are set out in the late afternoon and are hung at a height of approximately six feet. The traps use an incandescent, 40-watt light bulb as the primary attractant. The upper trap consists of aluminum housing containing the light source. Midges are drawn to the light and enter the trap through an opening of the middle, mechanical section. Mosquitoes are drawn in and down by the airflow created by a small fan. The bottom section consists of a catch jar equipped with a small section of pesticide strip to immobilize the insects. The trap jar is collected the next morning. The jars containing captured insects are transported to the laboratory where they are placed in a freezer to preserve the insects until they are identified and counted.

Midge Larvae Monitoring

Midgefly larvae are usually collected from the bottom sediment of ponds and lakes. An Ekman or Ponar dredge is generally used and deployed from a boat. The dredges are basically spring loaded jaws which are either activated automatically by the sampler striking the hard bottom of the lake (Ponar) or manually by a weighted messenger deployed by the on board technician (Ekman). The collected sediment may be screened and washed in the field using a US60 or finer sieve, and the larvae counted directly. Samples may also be transported back to the laboratory where midges are separated by density gradient flotation or manual sorting. Total number of larvae is generally recorded on an aerial (square meter) basis.

Midge pupae may also be measured using a vertical towing (Wisconsin or Birge-type) plankton net. The net is dropped to the bottom of the water column and manually lifted to the surface. The organisms concentrated in the collection bucket are transferred to a sample bottle and preserved with alcohol. The number of larvae per cubic meter of water is usually computed and recorded.

Educating Neighbors

Management of surrounding properties can have a significant influence on mosquito and midge populations with the project area. Off-site properties that breed mosquitoes or midgeflies can result in transferring the organisms into the project habitats. Mosquitoes have flight patterns that can range from a few hundred yards to miles. Midgeflies do not fly far from breeding areas but because of their weak flight are subject to winds that can carry them for miles.

Because of the possibility of translocation of nuisance and vector insects, nearby property owners need to be aware of conditions that are conducive to aquatic insect breeding. Some of the steps neighbors can follow to help prevent infestations of undesirable aquatic insects are:

- Remove old tires and containers from the property that can fill with water and serve as breeding sites for mosquitoes.
- Keep irrigation ditches free of floating and settleable organic matter accumulations that serve as breeding sites for mosquitoes and midges, respectively.
- Control irrigation to limit the time standing water remains on the property to no more than 48 hours.
- Manage algae growth in pools and ponds to prevent sediment build up that can become midge larvae habitat
- Minimize aquatic macrophyte (aquatic emergent weeds) surrounding ponds and reservoirs that can become sheltered breeding sites for mosquitoes.
- Grade ruts and depressions to eliminate pooled water.

Chemical Management Techniques

Organophosphorus pesticides, insect growth regulators (IGRs), and pyrethroids are now routinely used for larvae and adult fly management. In the case of midgefly larvae, susceptibility of species varies considerably, and species occupying the same habitat may respond differently to a particular chemical. The use of chlorinated hydrocarbons has been eliminated because of problems of biomagnification in the food chain, occasional fish mortality, and development of resistance in midge and mosquito populations.

Non-pesticide based mosquito larvicides are also available. Surface films, usually reserved for use in small ponds and pools, cause suffocation of larvae. Bacteria-based larvicides produce toxins in the digestive tract of some midge and almost all mosquito larvae.

Organophosphorus Pesticides

The most effective organophosphorus pesticides are Temephos and Chloropyrifos. Other compounds include Fenthion, Malathion, Phenthoate, and Methyl and Ethyl Parathion, Bromophos, Fenitrothion, Dichlorvos, and Diazinon. The primary drawback of using these pesticides is that they may interfere with the nervous system of non-target insects.

Temephos (Abate®): Temephos is an organophosphorus pesticide that is applied by either ground equipment or air equipment as a mosquito larvicide. Application rates vary with type of breeding site and amount of organic matter in the water. Commercial formulations should not harm vegetation in breeding areas. As with other organophosphorus pesticides, non-selectivity and development of resistant populations must be considered before use. The larvicide can be applied to flood irrigated lands, pools, and ditches and in containers infested with *Aedes* mosquitoes. It is effective against larvae of both midges and mosquitoes and also blackflies. It should not be used in ditches used for irrigation of food, forage, or pasture crops. The 4% pellets are required for midge larvae control. The product can be effective for up to 30 days when prepared as a gypsum-based, slow-release pellet, but length of control is highly influenced by water chemistry, organic content, and dilution factor. Temephos may be toxic to birds and fish and should not be used near sensitive aquatic resources without approval of Arizona Game and Fish Department.

Chloropyrifos: Chloropyrifos (Dursban®) is an organophosphorus adulticide commonly used for ground and aerial thermal or ultra-low volume (ULV) applications. It is registered for adult mosquito control, but is toxic to over 100 insects. Although, it is typically non-toxic to non-target organisms at ULV dosages, the spray may be toxic to fish, birds, and other wildlife. Although Dursban is considered one of the least toxic organophosphorus products, it more persistent in the environment than many other insecticides and its production is likely to be discontinued. Dursban may be found in combination with Permethrin to provide a less toxic, low odor, rapid knockdown product. It is more effective at cooler temperatures and offers an alternative when insect populations become resistant to other chemical treatments

Malathion: Products containing Malathion, such as Cythion®, are sprayed for control of adult midges and mosquitoes. Malathion is an organophosphorus pesticide that has stomach and contact toxicity to a number of insects and spiders. It should be used with caution when desirable insects are present. It is commonly used in livestock and agricultural areas, and in home gardens on both food and ornamental plants. Unfortunately, there is a time restriction between contact with certain crops and consumption. Thus, use of the product would require coordination between farmers and gardeners in the area. This pesticide may be found in combination with an IGR (pyrethroid) for quicker knockdown and lower dosage application.

Pyrethroids

Most pyrethroids are superior in activity against midge flies in comparison to organophosphorus compounds, but have a low index of safety to some non-target invertebrates and fish. Specially formulated synthetic pyrethrins can be applied as ULV fogs for adult midge and mosquito management. Mortality occurs within 30 minutes of treatment, but as with other fogs, there is little longevity to the insecticide. Synthetic pyrethroids are advantageous because they are rapidly degraded in the environment (80% reduction within 24 hours), are some of the least toxic chemicals used for adult midge and mosquito control, are ineffective against non-target organisms, and are effective against organophosphorus-resistant populations. Natural pyrethrin-based insecticides are labeled for use in sensitive locations where chemical buildup and production of resistant populations are of concern.

Permethrin: Permethrin is a synthetic IGR formulated for ultra-low volume (ULV) cold mist spraying. It is commonly used for control of adult mosquitoes and midges in residential areas and parks. The product is available in "no odor" formulations. It is rapidly biodegradable and has low toxicity to most non-target organisms. However, the product can be toxic to fish and other aquatic invertebrates and cannot be used where drift could reach sensitive aquatic sites.

Growth Regulators

Insect growth regulators (IGRs) include juvenile hormone analogues such as Methoprene and chitin synthesis inhibitors as Diflubenzuron. IGRs interfere with organism development and prevent emergence from the infested water body. Laboratory and field studies have shown that these chemicals are highly effective against a variety of midge species at very low (part per billion range) concentrations in lakes, flood channels, and water spreading basins. They provide an alternate means to control midge species resistant to organophosphorus pesticides. However, their use has been shown to have temporary or chronic effects on some non-target species. Use of IGRs such as the commercially available Altosid® would be practical in small pools, and semi-permanent pools and channels where non-target species interactions are unimportant. IGRs used in appropriate amounts are biodegradable, do not accumulate in the food chain, and are not toxic to most waterfowl, amphibians, crustaceans, and beneficial insects and invertebrates when used at label application rates. The chemical is usually supplied as pellets or briquets for time released application. Solid briquets can be reactivated each time they are wetted providing long-term management in intermittent channels and pools. A capsulated product is also available for total dispersal within a few seconds.

Surface Films

Mosquitoes respire through a siphon that is periodically positioned against the water-air interface. Surface films are sprayed on the water to prevent the exchange of gases and cause suffocation of the insects.

Bonide® or Golden Bear®: The oils are can be applied to water in wetlands, pools, and residential yards to suffocate mosquito larvae. For agricultural and residential areas, application should be made approximately 3 to 4 days following flood irrigation to kill pupae.

Larvicide Oil GO® The product is an oil-based larvicide sprayed on the surface of the water to suffocate the immature form via elimination of its oxygen supply. It is used for control of mosquitoes breeding in swamps, flood waters, and wetlands. The product has recently been replaced by GB1111® (personal communication, Larry Erickson, Clarke Mosquito Control, Roselle, IL).

Monomolecular films: Agnique® is a synthetic, monomolecular film sprayed on the water surface to suffocate the immature forms via elimination of their oxygen supply.

Bacterial Agents

Two bacterial agents are currently registered for use in managing mosquito and midge larvae: *Bacillus thuringiensis israelensis* (*Bti*) and *Bacillus sphaericus (Bs)*. These agents are packaged in liquid suspensions or are incorporated into dispersible granules. Control is achieved when these products can rapidly disperse in the water; thus, aquatic vegetation that limits coverage will reduce their effectiveness. *Bs* is a more effective control agent for mosquitoes in wastewaters with high organic content and/or suspended solids. However, *Bs* has a narrower host range than *Bti*; most *Aedes* species are not susceptible to *Bs*. Similarly, some midge species are more or less sensitive to the bacterial agents.

Both bacterial agents provide host-specific toxins that produce larvicidal proteins in the digestive tract. The agents are effective against larvae of mosquitoes, black flies, and midge flies; they are relatively benign to all other aquatic organisms. The products are safe to humans at label application rates and rapidly degrade by UV degradation in aquatic systems. Development of *Bs*-resistant strains of mosquitoes is possible because of the single-toxin produced by the bacteria. This does not appear to be the case for Bti because it has two toxin precursors.

Bti. *Bacillus thuringiensis*, the naturally occurring spore- and crystal-forming bacterium producing a larvicidal endotoxin is available in a variety of commercial products (e.g., VectoBac®, Acrobe®). Double the normal application rate is often recommended for highly polluted waters containing large amounts of suspended solids or organic matter. Treatments are sometimes required as often as every 4 to 10 days. For mosquito control only, floating briquets can be used in small ponds and ditches to provide sustained release of Bti for up to 30 days. The product becomes ineffective when desiccated.

Bs: In highly polluted waters or waters containing significant amounts of organic matter where *Culex* mosquitoes are likely to breed, *Bacillus sphaericus* (Vectolex®) granules can be applied for larvae control. The bacteria also contain an endotoxin that is larvicidal for approximately 1 to 4 weeks.

RECOMMENDATIONS

The following recommendations are provided to minimize and manage nuisance and vector insects within the El Rio project area:

- Regulate the amount of marshy areas, particularly those that create complete cover of permanent ponds
- Create a blend and balance of habitat types
- Manage open surface waters to sustain an aquatic predator-prey base that can provide biological control of midgefly larvae
- Enhance and manage the fishery
- Increase the number and flow duration of intermittent and ephemeral streams to reduce oviposition and larval habitat for nuisance species
- Manage emergent vegetation density
- Optimize beneficial aquatic emergent plant species that reduce mosquito breeding and provide habitat for terrestrial and avian wildlife
- Provide habitat for natural predators of mosquito and midge larvae
- Use an Integrated Pest Management approach for developing nuisance and vector insect control strategies and practices

REFERENCES

Aquatic Consulting & Testing, Inc. 1996. City of Phoenix vector and midge control program. Final Report. City of Phoenix Water Services Department, Index S-933861.

Aquatic Consulting & Testing, Inc. 1999a. Tres Rios Demonstration Wetland mosquito data, Sep 1998-Apr 1999. Project WS90140001. City of Phoenix Water Services Department.

Aquatic Consulting & Testing, Inc. 1999b. Tres Rios Demonstration Wetland mosquito data, May -July 1999. Project WS90140001. City of Phoenix Water Services Department.

Aquatic Consulting & Testing, Inc. 2000a. Tres Rios Demonstration Wetland mosquito monitoring summary report Jan-Mar 2000. Project WS90140001. City of Phoenix Water Services Department.

Aquatic Consulting & Testing, Inc. 2000b. Tres Rios Demonstration Wetland mosquito monitoring summary report April-July 2000. Project WS90140001. City of Phoenix Water Services Department

Aquatic Consulting & Testing, Inc. 2000c. Holly Acres mosquito monitoring report February-July 2000. . Project WS90140001. City of Phoenix Water Services Department.

Aquatic Consulting & Testing, Inc. 2001a. Tres Rios Demonstration Wetland mosquito monitoring summary report August-December 2000. Project WS90140001. City of Phoenix Water Services Department

Aquatic Consulting & Testing, Inc. 2001b. Tres Rios Demonstration Wetland mosquito monitoring summary report January-August 2001. Project WS90140001. City of Phoenix Water Services Department.

Aquatic Consulting & Testing, Inc. 2001c. Initial vector surveillance Cave Buttes Recreational Area. Wilson & Company, Phoenix, Arizona.

Aquatic Consulting & Testing, Inc. 2002a. Tres Rios Demonstration Wetland mosquito monitoring summary report August-December 2001. Project WS90140001. City of Phoenix Water Services Department.

Aquatic Consulting & Testing, Inc. 2002b. Holly Acres mosquito monitoring report Jan-Aug 2001. Project WS90140001. City of Phoenix Water Services Department.

Aquatic Consulting & Testing, Inc. 2002c. Holly Acres mosquito monitoring annual summary 2001. Project WS90140001. City of Phoenix Water Services Department.

Aquatic Consulting & Testing, Inc. 2002d. Mosquito monitoring summary Tres Rios Demonstration Constructed Wetland January-June 2002. Project WS90140001. City of Phoenix Water Services Department.

Aquatic Consulting & Testing, Inc. 2003a. Tres Rios Demonstration Constructed Wetland mosquito monitoring Jul-Dec 2002. Project WS90140001. City of Phoenix Water Services Department.

Aquatic Consulting & Testing, Inc. 2003b. Holly Acres mosquito monitoring summary: 2002. Project WS90140001. City of Phoenix Water Services Department.

Armitage, Cranston, and Pinder. 1995. The Chironomidae. Biology and ecology of non-biting midges. Chapman and Hall Publishers.

Audubon Society. 2002. Christmas bird count. December 27, 2002.

Bohart, R.M. and R.K. Washino. 1978. Mosquitoes of California. Third Edition. University of California Division of Agricultural Sciences. Publication 4084. Berkely, CA. 152 pp.

Carpenter, S.J., W.W. Middlekauf, and R.W. Chamberlain. 1946. The mosquitoes of the southern United States. The American Midland Naturalist, Monograph No. 3. The University Press, Notre Dame, Indiana. pp 4-7.

Chapman, R. 1966. The mosquitoes of Nevada. Entomology Research Division, USDA and College of Agriculture, University of Nevada. 38 pp.

Centers for Disease Control. 2002a West Nile Virus questions and answers. http://www.cdc.gov/ncidod/dvbid/westnile/qa/overview.html

Centers for Disease Control. 2002b. West Nile Virus transmission. http://.cdc.gov/ncidod/dvbid/westnile/qa/transmission.html

Centers for Disease Control. 2003. Dengue Fever. http://cdc.gov/ncidod/dvbid/dengue/index.html

CH2Mhill. 1999. A mosquito control strategy for the Tres Rios Demonstration Constructed Treatment Wetlands. Draft Report, July 1999. City of Phoenix Water Services Department, 140 pp.

Colusa Mosquito Abatement District. 1997. Wetland development and management guidelines for the control of mosquitoes. Colusa, CA.

Cooke, G.D., E.B. Welch, S.A. Patterson, and P.R. Newroth. 1993. Restoration and management of lakes and reservoirs. Second Edition. Lewis Publishers, Ann Arbor, MI.

Darsie, R.F. and R.A. Ward. 1981. Identification and geographical distribution of the mosquitoes of North America, north of Mexico. American Mosquito Control Association, Fresno, CA.

Day, E. 1996. Midges. Virginia Cooperative Extension.

Florida Mosquito Control Association. 1997. Florida mosquito control handbook. University of Florida. (Evans)

Gangstad, E.OP. 1986. Freshwater vegetation management. Thomas Publications. Fresno, CA. 360 pp.

Green, D.R. 2003. Arboviruses. http://drgreen.org/blank.cfm?print=yes&id=21&action=detail&ref=1028

Hammer, D.A. (ed.). 1990. Constructed wetlands for wastewater treatment. Lewis Publishers. Chelsea, MI. 831 pp.

Hernando County Board of Commissioners. 2003. Survey of mosquito control practices. Nature Bulletin N0. 223-A (19). http://skipper.physics.sunysb.edu/mosquito/mosquito.html

Hiltner, S. 2002. Controlling mosquitoes in wetland plantings. Ellerbe Creek Watershed Association. www.ellerbecreek.org/controllingmosquitoes.htm

Indiana Department of Natural Resources. 2003. Indiana water conservation plan. Division of Fish and Wildlife, Indianapolis, IN.

Jacob, J. 2003. Encephalitis: The role of birds. 2003. University of Florida. http://edis.ifas.ufl.edu/BODY_PS045

Kagen, S.L., J.W. Tunginger, and R. Johnson. 1984. Lake fly allergy: incidence of chironomid sensitivity in an atopic population. Journal of Allergy and Immunology 73:187.

Karpisak, M.K., R.D. Wass, R.J. Freitas, and S.B. Hopf. 2002. Constructed wetland technology and mosquito populations in Arizona. University of Arizona, Tucson.

King, K.A. and D.L. Baker. 1995. Contaminants in fish and wildlife of the middle Gila River, Arizona. U.S. Fish and Wildlife Service, Phoenix, Arizona. 64 pp.

King, K.A., B.J. Andrews, C.T. Martinez, and W.G. Kepner. 1997. Environmental contaminants in fish and wildlife of the lower Gila River, Arizona. U.S. Fish and Wildlife Service, Phoenix, Arizona. 64 pp.

Koehler, P.G. 1999. Blind mosquitoes (aquatic midges). University of Florida Cooperative Extension Service (UF/IFAS).

Los Angeles County West Vector Control. 2000. Midge biology: chironomid midges.

Lembi, R. 1997. Indiana commercial pesticide applicator training manual. Purdue University.

McComas, S. 1993. Lake smarts: the first lake maintenance handbook. USEPA Office of Water, Washington, D.C.

McDonald, J.L., T.P. Sluss, J.D. Lang, and C.C. Ross. 1973. Mosquitoes of Arizona. Agricultural Experiment Station, University of Arizona, Tucson. Technical Bulletin 205.

MSN with Encarta. 2003. Malaria. http://encarta.msn.com/encnet/refpages/refarticle.aspx?refid=761566151

Nayar 1991. Human Malaria. University of Florida. Technical Bulletin . *In* Florida Mosquito Control Handbook, Florida Mosquito Control Association.

Nayar, J.K. 1998. Mosquito-borne dog heartworm disease. University of Florida.

Neilsen, L.T. and D.M.Reese. 1961. An identification guide to the mosquitoes of Utah. University of Utah, Biological Series Vol. XII No.3. Salt Lake City, UT.

New Jersey Mosquito Control Association. 2003. Larval habitats of mosquitoes. http://www-rci.rutgers.edu

Ogg, B. 1995. Midges:non-biting gnats. University of Nebraska Cooperative Extension. Lincoln, NE.

O'Meara, G.W., D.H. Mook, and V.L. Larson. 1988. Habitat management for the control of wastewater Culex mosquitoes. Florida Medical Entomology Laboratory, IFAS University of Florida, Vero Beach.

O'Meara, G.W. and A.D. Gettman. 1997. The Asian tiger mosquito in Florida. University of Florida, Technical Bulletin. *In* Florida Mosquito Control Handbook, Florida Mosquito Control Association.

O'Meara, G.W. and R.E. Purcell. 1990. Guidelines for controlling mosquitoes in water retention/detention area. Florida Department of Health and Rehabilitation Services.

O'Meara, G.F. and R.E. Purcell. 1990. Mosquitoes associated with wastewater. Florida Mosquito Control, Technical Bulletin No. 1.

Rauch, M. 2003. Debuzzing mosquitoes the natural way. Gaiam.com. http://www.gaiam.com

Reeves. 1990. Epidemiology and control of mosquito-borne arboviruses in California, 1943-1987. California Vector and Mosquito Control Association, Sacramento, CA. 508 pp.

Shroyer, D.A. and J.F. Day. 1997. Saint Louis Encephalitis: sometimes a Florida problem. University of Florida, Technical Bulletin. *In* Florida Mosquito Control Handbook, Florida Mosquito Control Association.

Siverly, R.E. 1972. Mosquitoes of Indiana. Indiana State Board of Health. Indianapolis, IN. 126 pp.

Snow, K.R. Mosquitoes. Richmond Publishing Company, Ltd. Slough, England. 66 pp. 1990)

Somerlot, B. 2003. Health wetlands devour mosquitoes. Indiana Department of Natural resources. 2003. http://www.new-albany.k12.oh.us/district/news/mosquito.html

Townsend, L. 1997. Midges and gnats. University of Kentucky, College of Agriculture, Department of Entomology, Cooperative Extension Service.

United States Geological Survey. 1992. Species found positive for WNV in surveillance efforts. http://www.nwhc.usgs.gov/research/westnile/wnvaffected.html

United States Environmental Protection Agency. 1990. The lake and reservoir restoration guidance manual. EPA-440/4-90-006. USEPA Office of Water, Washington, DC.

United States Environmental Protection Agency. 2000. Constructed wetlands treatment of municipal wastewaters. EPA/625/R-99/010. Office of Research and Development, Cincinnati, OH.

Vicioso. 2003. St. Louis Encephalitis (SLE).
http://vicioso.com/health/disease/encephalitis/SLE.html

Wass, R. 1997a. Tres Rios Demonstration Constructed Wetland project: 1996/1997 operation and water quality report City of Phoenix, Water Services Department.

Wass, R. 1997b. Tres Rios mosquito monitoring summary 1997. City of Phoenix, Water Services Department.

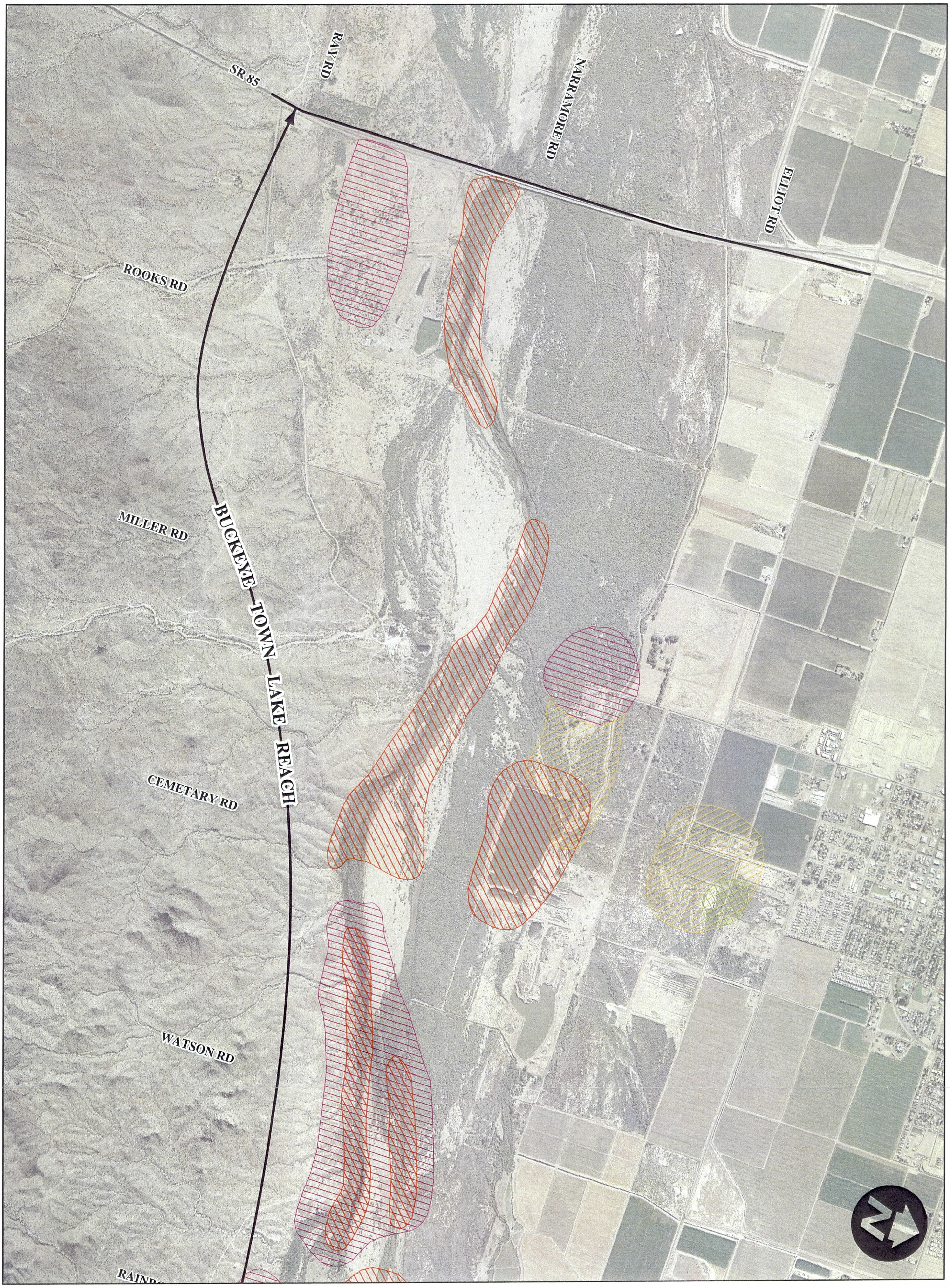
Wass, R. 1998. Tres Rios mosquito monitoring summary 1998. City of Phoenix, Water Services Department.

Western Equine Encephalitis. 2003. http://astdhpphe.org/infect/wee.html

Weil, C.K. 1940. Summer hay fever of unknown origin in the southwest. Journal of Allergy 11:361-375.

World Health Organization. 2001. Yellow Fever. http://www.who.int/inf-fs/en/fact100.html

World Health Organization. 2002. Dengue and Dengue Haemorrhagic Fever.
http://who.int/inf-fs/en/fact117.html

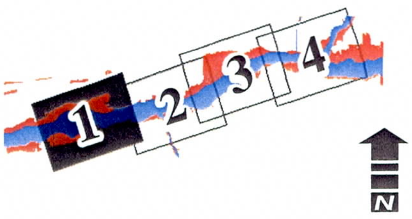


Flood Control District
of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Stantec Consulting Inc.
8211 S. 48th St.
Phoenix, AZ 85044

Potential Breeding Sites

- Midgefly High
- Midgefly Low
- Mosquito High (>75 adults/trap/night)
- Mosquito Moderate (20-75 adults/trap/night)
- Mosquito Low (<20 adults/trap/night)



EL RIO WATERCOURSE MASTER PLAN

MOSQUITO & MIDGEFLY VECTORS

SHEET 1 OF 4 (BUCKEYE TOWN LAKE REACH)

11 NOV 2005

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1 Inch = 2000 Feet

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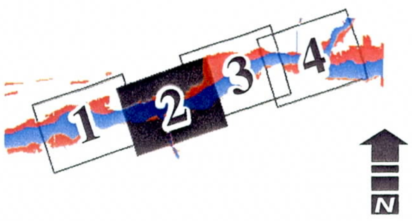

EL RIO

EL RIO WATERCOURSE MASTER PLAN

MOSQUITO & MIDGEFLY VECTORS
SHEET 2 OF 4 (TUTHILL REACH)
11 NOV 2005

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1 Inch = 2000 Feet

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Flood Control District
of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Stantec Consulting Inc.
8211 S. 48th St.
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Potential Breeding Sites

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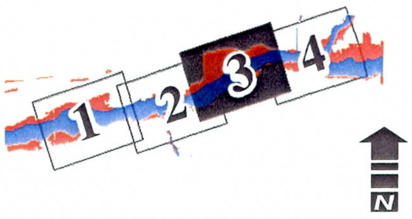
- Mosquito Moderate (20-75 adults/trap/night)
- Mosquito Low (<20 adults/trap/night)



EL RIO WATERCOURSE MASTER PLAN

MOSQUITO & MIDGEFLY VECTORS

SHEET 3 OF 4 (PERRYVILLE REACH)

11 NOV 2005

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1 Inch = 2000 Feet

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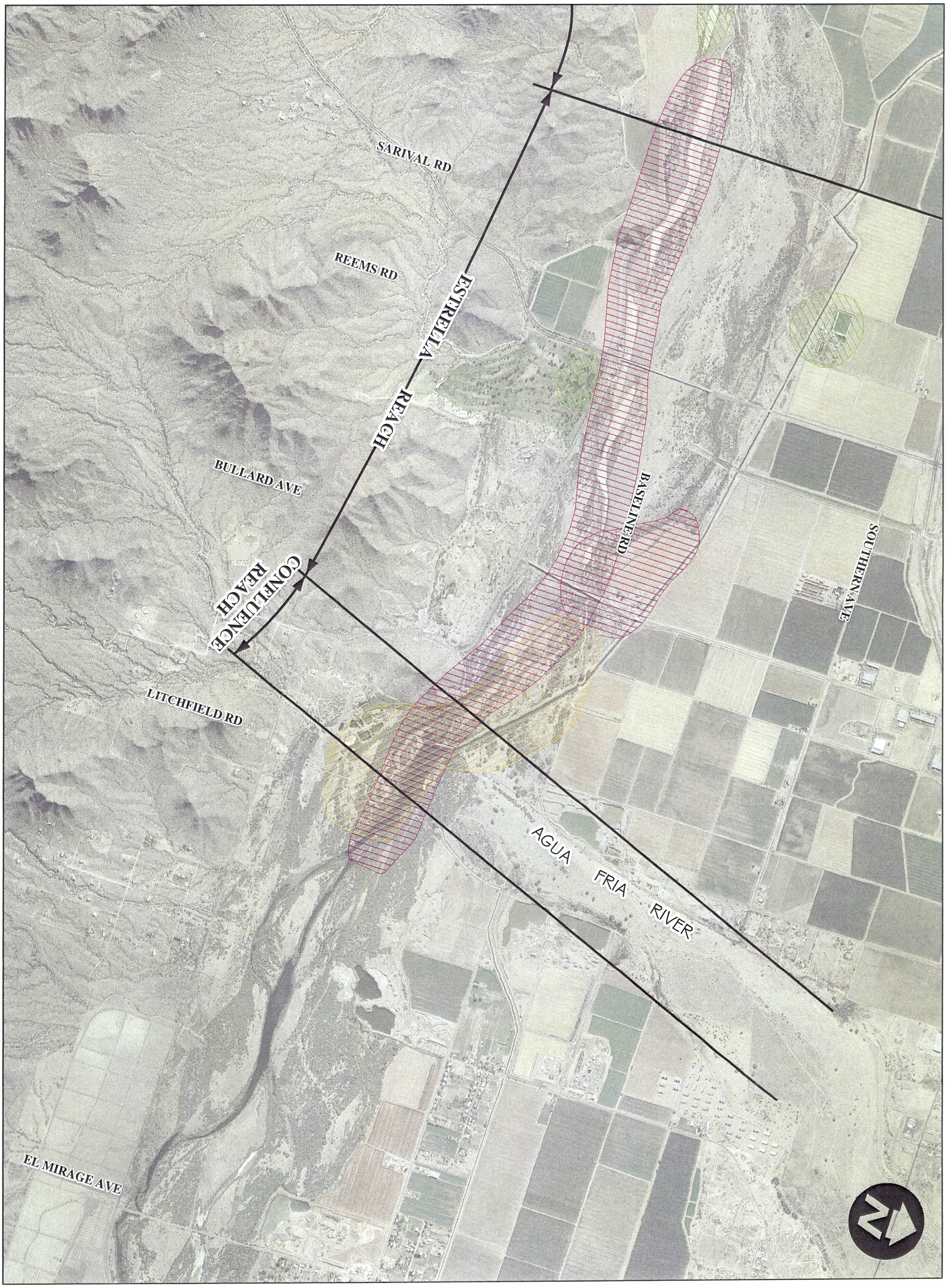

Flood Control District
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Phoenix, AZ 85009

Potential Breeding Sites

- Midgefly High
- Midgefly Low
- Mosquito High (>75 adults/trap/night)
- Mosquito Moderate (20-75 adults/trap/night)
- Mosquito Low (<20 adults/trap/night)

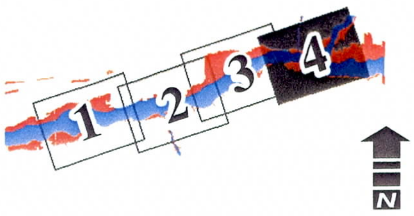
EL RIO

EL RIO WATERCOURSE MASTER PLAN

MOSQUITO & MIDGEFLY VECTORS

SHEET 4 OF 4 (ESTRELLA REACH)

11 NOV 2005



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1 Inch = 2000 Feet

Stantec Consulting Inc.
8211 S. 48th St.
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Stantec

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El Rio Watercourse Master Plan

EL RIO ENVIRONMENTAL RESOURCES

SECTION 2
BIOLOGICAL RESOURCES

PREPARED FOR:

FLOOD CONTROL DISTRICT
of
Maricopa County

PREPARED BY:

EcoPlan Associates, Inc.
Environmental Science & Resource Economics
701 W. Southern Avenue, Suite 203, Mesa, AZ 85210

July 2003

STANTEC CONSULTING Inc.
Project No. 8200240

Contract FCD 2001C024

Contents

EXECUTIVE SUMMARY

The El Rio Watercourse Master Plan (WCMP) and Area Drainage Master Plan (ADMP) will develop and identify possible alternatives or solutions for providing flood control along the Gila River from the confluence of the Agua Fria River to the State Route (SR) 85 bridge (Figures 1 and 2). This stretch of the Gila River is approximately 17.5 miles long and is referred to as El Rio. The width of this report's study area coincides with the existing floodplain. This report contributes to the environmental portion of the WCMP. Specifically, it will report the findings of a field reconnaissance delineating the plant communities within the corridor; identify and evaluate endangered species habitat; suggest areas that might be suitable for possible restoration or enhancement; and identify areas that might contain important or unique wildlife habitat. Each of these components of the field reconnaissance is presented as a sub-section within this report. Also, each sub-section contains a narrative portion with references to the appendices which contain a Geographic Information Systems (GIS) overlay map and representative photographs.

Twelve distinct plant communities were identified by ground-truthing both aerial and infrared photographs of vegetation communities within the El Rio study area. Based on a review of aerial photos, combined with known vegetation structural characterizations, and photos taken in the field (see Appendix A and E), it was possible to map the vegetative communities and structural types present in the study area.

Two endangered species and one candidate species have potential to occupy the El Rio study area. They are: the Yuma clapper rail *(Rallus longirostris yumanensis)* (YCR), one of seven North American bird subspecies of clapper rail, the southwestern willow flycatcher *(Empidonax trailli extimus)* (WIFL), a riparian obligate bird species restricted to dense stands of vegetation along perennial waters and the yellow-billed cuckoo *(Coccyzus americanus)* (YBC), a relatively rare bird species that occur in mature native riparian stands of cottonwood and willow and large mesquite bosques (Corman and Magill 2000).

Marsh habitat in the study area should be preserved and if possible enhanced to benefit the Yuma clapper rail. The plant communities of salt cedar/cottonwood, arrow-weed/willow/salt cedar, arrow-weed/willow, salt cedar/cottonwood/willow, cottonwood/willow and willow/salt cedar should be considered potential occupied habitat for the southwestern willow flycatcher when they occur adjacent to perennial water, and given the appropriate level of protection. Finally, YBCs have been documented both directly adjacent to and within the study area, the larger deciduous and native/non-native mixed stands in close proximity to perennial water should be preserved, and overspray from insecticide spraying in the agricultural areas should be kept away from the riparian areas of the river corridor. Surveys for the YCR, WIFL, and YBC species should be conducted if areas of suitable habitat are to be impacted by any project activity.

During field reconnaissance several areas were identified as "Opportunity Areas." Opportunities for enhancement were recommended based on density of native riparian vegetation, the occurrence of unique wildlife features within a particular stretch of river, and proximity to high quality habitat and perennial water. Areas that are currently owned by private parties and contain large amounts of native riparian vegetation were also identified.

Primary conclusions and recommendations include the following:

- Twelve distinct plant communities were identified within the El Rio study area.
- Two endangered species and one candidate species have potential to occupy the El Rio study area: YCR, WIFL, and YBC respectively.
- Marsh habitat in the study area should be preserved and enhanced, if possible to benefit the YCR.
- The plant communities of salt cedar/cottonwood, arrow-weed/willow/salt cedar, arrow-weed/willow, salt cedar/cottonwood/willow, cottonwood/willow and willow/salt cedar should be considered potential occupied habitat for the southwestern willow flycatcher when they occur adjacent to perennial water, and given the appropriate level of protection.
- The larger deciduous stands should be preserved as potential suitable breeding or nesting habitat and/or travel corridors for YBC.

INTRODUCTION

The El Rio Watercourse Master Plan (WCMP) and Area Drainage Master Plan (ADMP) will develop and identify possible alternatives or solutions for providing flood control along the Gila River from the confluence of the Agua Fria River to the State Route (SR) 85 bridge (Figures 1 and 2). This stretch of the Gila River is approximately 17.5 miles long and is referred to as El Rio. The width of the study area varies but coincides with the existing floodplain.

The developed alternatives will include a combination of both structural and non-structural flood control solutions. These solutions will be based upon environmental considerations, system hydrology, hydraulics, lateral migration potentials and sediment trends of the Gila River. It is the objective of the Flood Control District of Maricopa County (District) to develop flood control alternatives that provide opportunities for multiple uses within the El Rio corridor. These uses include but not limited to both passive and active recreation, education, wildlife habitat and riparian preservation, enhancement or development, and other related uses.

This report contributes to the environmental portion of the WCMP. Specifically, it will report the findings of a field reconnaissance delineating the plant communities within the corridor; identify and evaluate endangered species habitat; suggest areas that might be suitable for possible restoration or enhancement; and identify areas that contain important or unique wildlife habitat. Each of these components of the field reconnaissance is presented as a sub-section within this report. Each sub-section contains a narrative portion with references to the appendices which contain a Geographic Information Systems (GIS) overlay map and representative photographs.

DESCRIPTION OF THE STUDY AREA

The study area lies within the floodplain of the Gila River, beginning at the confluence of the Agua Fria and extending to the SR 85 Bridge over the Gila River. The study area is bounded on the south by the Estrella Mountains and the Buckeye Hills, and on the north by primarily agricultural land. (Figure 1 – Study Area Location, Figure 2 - Study Area Vicinity).

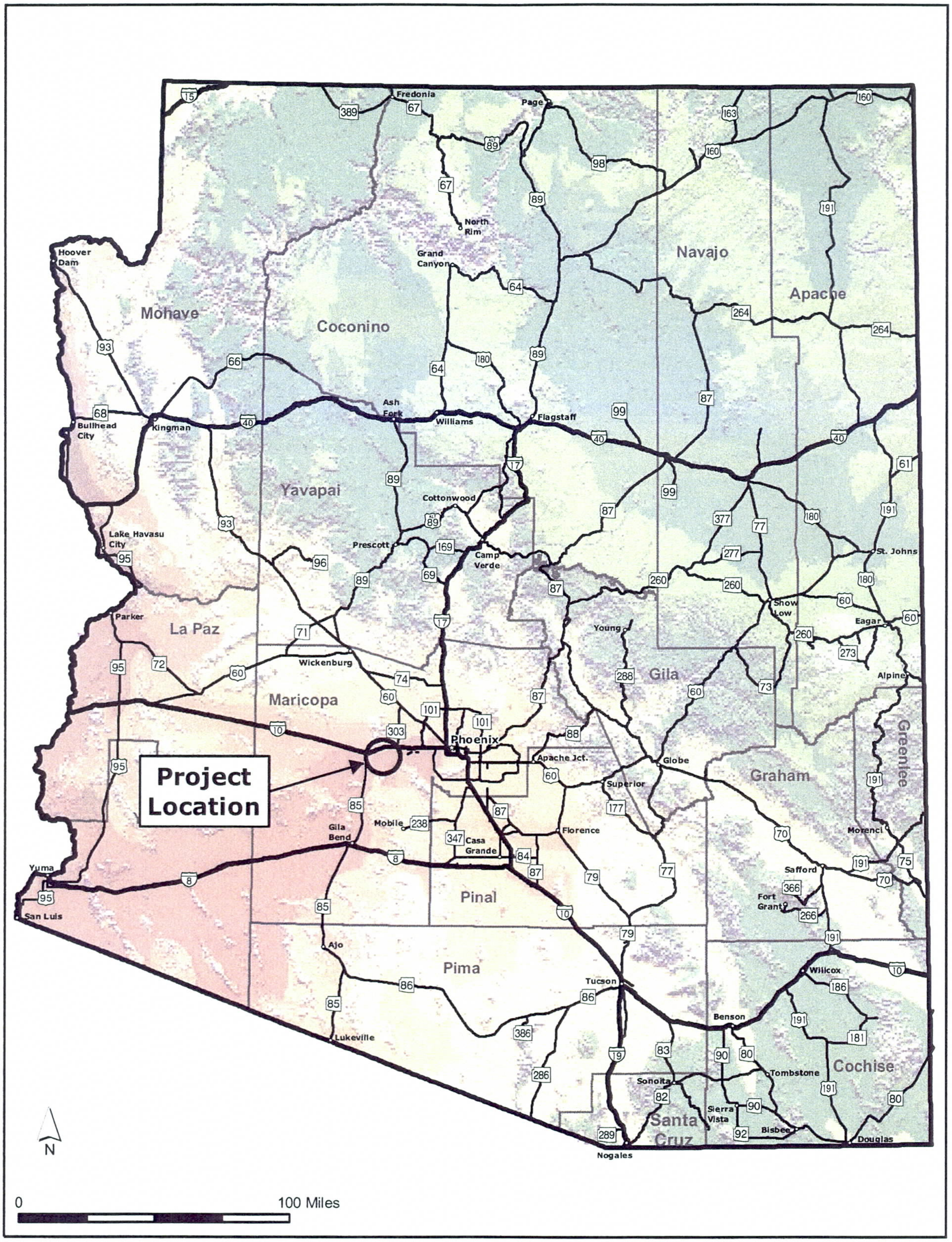


Figure 1. Project Location. El Rio Study Corridor, Confluence of the Agua Fria River and Gila River to SR 85, Maricopa County, Arizona.

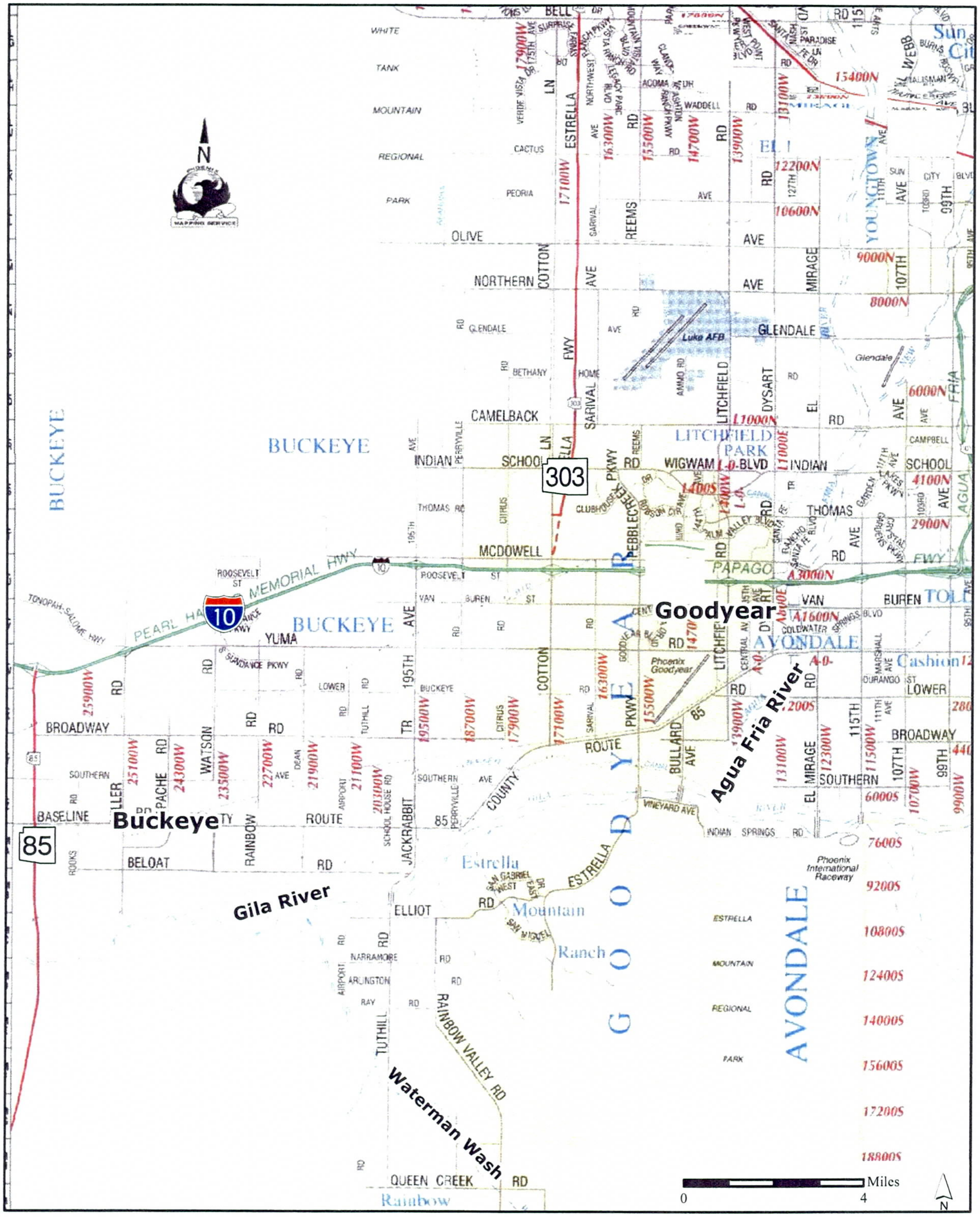


Figure 2. Project Vicinity, El Rio Study Corridor, Confluence of the Agua Fria River and Gila River to SR 85, Maricopa County, Arizona.

Much of the study area is densely vegetated and dominated on the eastern end by the salt cedar *(Tamarix ramosissima)* plant community, which is often nearly impenetrable. West of Jackrabbit Road, the monotypic salt cedar stands are replaced by a mix of salt cedar and native riparian species where Goodding willow *(Salix gooddingii)* is co-dominant with salt cedar. In addition, larger bodies of water are more prevalent west of Jackrabbit Road and almost continuous to the end of the study area at the SR 85 Bridge. However, due to dense cattail marshes and beaver dams, the river is not traversable for the entire distance.

The study area has numerous access points, but most require the use of a 4-wheel drive vehicle. East of the Estrella Mountain Regional Park entrance, one large and several small water bodies occur and can be accessed from Estrella Parkway. Other access points are possible from the Estrella Parkway Bridge, Jackrabbit Road Bridge, and Waterman Wash, which cross Eagle Mountain Road.

Historically in Arizona, floodplains consisted of primarily the Sonoran Riparian Deciduous Forest vegetative community, which was dominated by Fremont cottonwood *(Populus fremontii),* Goodding willow, and velvet mesquite *(Prosopis velutina)*. Various contributing factors have caused a change over the past century in the natural flow and hydrologic regime of the river systems in Arizona. These factors include, but are not limited to, the building of dams, which interrupt the annual flood cycles and reduce the recruitment of native riparian species, the diversion of water for irrigation, and the increased pumping of groundwater. In addition, the harvesting of the native riparian woodland species and the introduction of exotic species, most notably salt cedar, have resulted in the conversion of former native riparian deciduous forest habitat to a community dominated or co-dominated by salt cedar.

PLANT COMMUNITIES WITHIN EL RIO STUDY AREA

SURVEY METHODOLOGY

The corridor was divided into three sections (Upper, Middle, and Lower) for ease of identification and survey. EcoPlan Associates, Inc. evaluated and characterized vegetation at points approximately every 0.5 miles for the length of the study area. At each sample point, an upstream (east facing photo) and downstream (west facing photo) were taken (Appendix A), dominant and co-dominant plant species and other plant species present were identified (Table 1), and unique wildlife features such as beaver lodges or great blue heron rookeries were identified (Appendix B). In areas where plant communities could not be properly identified due to the density of the vegetation, higher elevation observation points were located in order to classify the vegetation. Also, due to the high density of the vegetation surrounding the open water areas, a canoe was launched from lake access points and used to locate and properly identify marsh and edge vegetation.

Plant communities were delineated by ground-truthing both aerial and infrared photographs of vegetation communities within the El Rio study area. Vegetative communities classified in the study area have been adapted from Anderson and Ohmart (1984), with changes and additions based on local conditions. Based on a review of aerial photos, combined with field observations and photos taken in the field (see Appendix A and E), vegetative communities and structural types present in the study area were mapped (Table 2). No minimum area thresholds were used in the assignment of the various plant communities. Plant associations were defined as plant communities based upon the frequency of their occurrence in the study area, uniqueness and consistency in their plant associations, and percentage of their coverage as related to other unique communities in the study area.

RESULTS

The Upper reach extends from Meck Lake (at the eastern end)to just west of Cotton Lane. This reach contains a moderate amount of surface water contributed by the City of Phoenix 91st Avenue wastewater treatment plant. Meck Lake is a storage lake that provides water for the Buckeye Irrigation District. The plant community in the Upper reach consists primarily of monotypic stands of salt cedar, except for the Opportunity Area (see Appendix H) immediately west of Meck Lake. The Middle reach extends from just west of Cotton Lane to just east of Waterman Wash. The eastern half of the Middle reach is characterized by primarily dry lakebeds (marked with saline deposits) and mostly monotypic stands of salt cedar. The western half of the Middle reach, beginning near

Table 1. Plants Observed in the El Rio Study Area * Indicates exotic species		
Scientific Name	**Occurrence**	**Common Name**
Allenrolfea occidentalis	common	pickle-weed
Ambrosia deltoidea	uncommon	triangle-leaf bursage
Amsinkia intermedia	uncommon	fiddleneck
Atriplex canescens	common	four-wing saltbush
Atriplex elegans	common	wheelscale saltbush
Atriplex lentiformis	common	quail brush
Baccharis salicifolia	uncommon	seepwillow
Baccharis sarothroides	uncommon	desert broom
Bowlesia incana	common	hairy bowlesia
Brassica turnfortii	uncommon	mustard
**Bromus rubens*	uncommon	red brome
Calicoseris wrightii	uncommon	white tack stem
Cercidium floridum	uncommon	blue paloverde
Cercidium microphyllum	uncommon	foothill paloverde
Chorizanthe brevicornu	uncommon	brittle chorizanth
Conyza coulteri	common	conyza
Cryptantha angustifolia	common	narrow-leaved cryptantha
**Echinochloa crusgalli*	common	barnyard grass
Encelia farinosa	common	brittle bush
Eriogonum deflexum	common	skeleton weed
Eriophyllum lanosum	uncommon	woolly daisy
Eschscholtzia mexican	uncommon	Mexican poppy
**Gutierrezia sarothrae*	common	snakeweed
Heliotropium curassaviicum	uncommon	alkalai heliotrope
**Hordeum jubatum*	common	fox-tail barley
Hordeum murinum	uncommon	mouse barley
Hymenoclea salsola	common	Burro brush
Hymenoclea monogyra	common	Burro brush
Isocoma acradenius	common	Jimmy weed
**Lactuca serriola*	common	prickly lettuce
Larrea tridentata	uncommon	creosotebush
Monolepis nuttalliana	uncommon	Patata
Nama hispidum	common	bristly nama
Nicotiana attenuata	uncommon	coyote tobacco
Oenothera deltoides	common	dune primrose
Oligomeris linifolia	uncommon	desert cambess
Olneya tesota	uncommon	ironwood
Pectocarya recurvata	uncommon	pectocarya
**Phalaris minor*	abundant	littleseed canary grass
Pluchia purpurascens	abundant	marsh fleabane
Polygonum pensylvanicum	uncommon	pinkweed
**Polypogon monspeliensis*	uncommon	rabbitfoot grass
Populus fremontii	common	Fremont cottonwood
Prosopis pubescens	uncommon	screw-bean mesquite
Prosopis velutina	uncommon	velvet mesquite

Table 1. (continued) Plants Observed in the El Rio Study Area * Indicates exotic species		
Scientific Name	**Occurrence**	**Common Name**
Rumex hymenosepalus	uncommon	canigre
Salix gooddingii	abundant	Goodding willow
Salix exigua	uncommon	coyote willow
**Salsola iberica*	common	Russian thistle
**Schismus arabicus*	abundant	Arabian grass
Scirpus americanus	common	bulrush
**Sisymbrium irio*	abundant	London rocket
Solanum elaeagnifolium	common	silver-leaf nightshade
**Sonchus asper*	common	spiny sow thistle
Spergularia marina	abundant	sand-spurry
Stephanomeria pauciflora	common	desert straw
Suaeda torreyana	common	desert seepweed
**Tamarix aphylla*	uncommon	athel
**Tamarix ramosissima*	abundant	Salt cedar
Tessaria sericea	common	arrow-weed
Tiquellia plicata	uncommon	plicate coldenia
Typha latifolia	common	cattail
Ziziphus obtusifolia	common	gray thorn

Table 2: El Rio Study Area Vegetative Cover Types and Pre-Project Acreages

Cover Type	Symbol	Acreage	% of Total
Agriculture	Ag	4,875	5.4 %
Arrow-weed/Willow/Salt Cedar	AWS	526	0.6 %
Arrow-weed/Willow	AW	340	0.4 %
Saltbush/Quail brush	ATX	1,923	2.1 %
Cobble Strand	CS	32,816	36.2 %
Cottonwood/Willow	CW	1,079	1.2 %
Marsh	M	181	0.2 %
Salt Cedar	SC	46,817	51.6 %
Salt Cedar/Cottonwood/Willow	SCW	360	0.4 %
Willow/Salt Cedar	WS	1,805	2.0 %
	Total	**90,722**	**100.0 %**

Jackrabbit Road, transitions into diversified vegetation. Cottonwood/willow galleries become more dominant as the number and size of the water bodies increase. The Lower Reach extends from just east of Waterman Wash to the State Route 85 Bridge. Within the Lower reach, numerous large bodies of water emerge with depths of several feet. The area from Jackrabbit Road west to SR 85 contains the highest diversity of habitat and the healthiest community of native vegetation found in the study area.

PLANT COMMUNITY DESCRIPTIONS

Sonoran Desert Scrub (SDS): Foothill paloverde *(Cercidiun microphylum)*, saguaro *(Carnegiea gigantean),* and triangle-leaf bursage *(Ambrosia deltoidea)* dominate the Arizona Upland Subdivision of Sonoran Desert Scrub (SDS) habitat in the foothills and bajadas of the Estrella Mountains and hills abutting the southern boundary of the study area (Turner and Brown 1994). SDS habitat abruptly ends at the Gila River floodplain. Vegetation along the desert arroyos in SDS commonly includes ironwood *(Olneya tesota),* blue paloverde *(Cercidum floridum)* and velvet mesquite *(Prosopis velutina).*

Very little of this plant community occurs in the study area with the exception of the south bank up-slope from the floodplain.

Cobble/Strand (CS): The majority of land surrounding the low-flow channel of the river corridor consists of cobble or sand substrate with sparse vegetation intermingled. Isolated velvet mesquite, Freemont cottonwood *(Populus fremontii),* Goodding willow *(Salix gooddingii),* and brittlebush *(Encelia farinosa)* are dispersed throughout this cover type.

Although sparsely vegetated, this community provides foraging areas for raptors, travel corridors for migrating and dispersing fauna, and denning areas for various species of reptiles, badgers *(Taxidea taxus),* and kit fox *(Vulpes velox).* Active restoration or enhancement is not likely to be considered in these areas since they are valuable for water conveyance during flood events.

Arrow-weed/Salt Cedar/Willow (AWS): In this community type, arrow-weed *(Tessaria sericea)* is co-dominant with salt cedar *(Tamarix ramosissima)* in the understory which accounts for 50 percent of the vegetation, with the remaining 50 percent consisting of an overstory of Goodding willow. Arrow-weed sometimes forms dense stands near the waters edge but is also found in saline soils in more xeric habitats.

This plant community would provide an opportunity for selective removal of salt cedar to allow the native species to flourish, thereby creating native galleries of willow with an edge of arrow-weed.

Arrow-weed/Willow (AW): Arrow-weed constitutes from 50 percent to 75 percent of the species, with the remaining percentage primarily Goodding willow. Arrow-weed often forms dense stands near the water's edge, but is also found in saline soils in more xeric habitats.

The native vegetation in this community appears to be healthy with all age classes represented and therefore, could be left in their natural state. At a minimum, these areas of native vegetation should be preserved and expanded if possible through the use of supplemental plantings.

Salt Cedar (SC): Continuous, dense stands of salt cedar dominate this plant community. Due to the dense overstory and understory of salt cedar and the likely presence of saline soils there is no co-dominant plant species in this community.

Various techniques could be implemented in select areas to attempt to return them to a native species regime. Factors such as soil salinity, and the present and future surface and groundwater levels will need to be examined before any restoration is planned and implemented.

If salt cedar galleries are removed there might be an opportunity to replace them with various xeric species, such as screwbean mesquite, whose salinity tolerance is higher than deciduous native species and other mesquite species.

Salt Cedar/Cottonwood/Willow (SCW): At least 65 percent of the total trees in this community are salt cedar, with at least 20 percent of the remainder being Freemont cottonwood and Goodding willow.

This community provides the best opportunity for enhancement. Selective removal of salt cedar and augmentation with native species could allow the community to flourish as it has in other portions of the state.

Saltbush/Quail Brush (ATX): Four-wing saltbush *(Atriplex canescens)* and quail brush *(Atriplex lentiformis)* constitute 90 percent or more of total vegetation in this community. Quail brush is frequently found in salt cedar woodlands and in saltbush-dominated areas. Relatively little of this community occurs in the study area, however, where it does occur, it is in areas of prior disturbance and in some of the steep overbank areas adjacent to open water.

There might be an opportunity to augment this community with various xeric species, such as screwbean mesquite, whose salinity tolerance is higher than other native tree species and other mesquite species.

Cottonwood/Willow (CW): Fremont cottonwood and/or Goodding willow constitute at least 75 percent of total trees present in the overstory. Often there is an understory of salt cedar present. These areas should be preserved and protected from degradation and, if possible enhanced.

Willow/Salt Cedar (WS): Goodding willow and salt cedar are co-dominant plants in this community. Goodding willow is typically found adjacent to open water, whereas salt cedar is usually located farther from the water.

Selective salt cedar removal in these areas might allow the willow to flourish and increase in number and density.

Agriculture (AG): Although some agriculture occurs on the southern boundary of the floodplain, most of the agricultural land is located along the northern boundary. Some of these agricultural lands are located within the floodplain of the Gila River. Irrigation run-off from these regions contributes a large portion of the water in the Gila River corridor.

The agricultural lands north of the corridor are a valuable buffer for the habitat along the river. At a minimum, the areas within the floodplain should be preserved to maintain that buffer and provide for water conveyance during large storm events.

Marsh (M_): Cattail *(Typha latifolia)* is the dominant plant species. Two marsh-type habitats are described based upon the density and relative dominance of the species.

> **Marsh Type 1 (M1):** Small linear patches or clumps along the bank or in shallows bordered with cottonwood, willow, tamarisk, and/or arrow-weed.
>
> **Marsh Type 2 (M2):** 100 percent coverage growing in large patches in calm waters or backwaters. These areas are also bordered with cottonwood, willow, tamarisk, and/or arrow-weed.

Not only are these areas valuable for the endangered Yuma Clapper Rail as foraging and nesting areas, but also for other species such as the little green heron and least bittern, both of which are fairly common in the corridor. Marsh Type 2 has a higher habitat value to the YCR than Type 1, but both marsh types can serve as foraging areas.

Table 3. Endangered Species in the El Rio Study Area

Species Name	Status *	Plant Community	Occurrence within El Rio
Arizona agave *Agave arizonica*	E	Not Applicable	No suitable habitat.
Arizona cliffrose *Purchia subintegra*	E	Not Applicable	No suitable habitat.
Bald Eagle *Haliaeetus leucocephalus*	T	Waterbody	Yes, transient. Not observed during field reconnaissance.
Cactus Ferruginous Pygmy-owl *Glaucidium brasilianum*	E	SDS, CW	No. Although the project occurs in the historical distribution for the species, pygmy-owls have not been documented in Maricopa County since

Table 3. Endangered Species in the El Rio Study Area			
Species Name	**Status ***	**Plant Community**	**Occurrence within El Rio**
cactorum			1972.
California Brown Pelican *Pelecanus occidentalis californicus*	E	Waterbody	Yes, transient. Not observed during field reconnaissance.
Desert pupfish *Cyprinodon macularius*	E	Waterbody	No. Currently restricted to the Salton Sea (California) and Quitobaquito Spring in southeastern Arizona.
Gila chub *Gila intermedia*	PE	Waterbody	No. Gila chub have been documented to occur in tributaries upstream of the project area. However, confirmation of their presence in the project area would require formal surveys.
Gila topminnow *Poeciliopsis occidentalis occidentalis*	E	Waterbody	No. Gila topminnows have been documented to occur in tributaries upstream of the project area. However, confirmation of their presence in the project area would require formal surveys.
Lesser long-nosed bat *Leptonycteris curasoae yerbabuenae*	E	SDS	No. Marginal distribution records occur from the Phoenix area but none were observed during field reconnaissance.
Mexican Spotted Owl *Strix occidentalis lucida*	T	Not Applicable	No suitable habitat.
Razorback sucker *Xyrauchen texanus*	E	Waterbody	No. Current hydrologic regime would not support the razorback.
Sonoran pronghorn *Antilocapra Americana sonoriensis*	E	Not Applicable	No suitable habitat.
Southwestern Willow Flycatcher *Empidonax trailii extimus*	E	CW, WS, SC	Yes. Not observed but suitable habitat occurs between SR 85 and Jackrabbit Road, and at the confluence of the Gila and Agua Fria.
Yellow-billed Cuckoo *Coccyzus americanus*	C	CW, WS, SC	Yes. Not observed but survey data indicates historical presence.
Yuma Clapper Rail *Rallus longirostris yumanensis*	E	Marsh, Waterbody	Yes. Not observed but survey data indicates populations of Yuma Clapper Rails are increasing within the project area.

Source: USFWS 2003.

SUMMARY

Twelve unique plant communities were identified within the study area, (Appendix G, Sheet 1) recognizing that the "communities" of cobble/strand and agriculture are cover types rather than true plant communities. Within those communities numerous plant species were observed (Table 1). No minimum area thresholds were used in the assignment of these various communities. Plant associations were considered plant communities based upon the frequency of their occurrence in the study area, uniqueness and consistency in their plant associations, and percentage of their coverage as related to the other unique communities in the study area.

With the exception of the SDS and M1 communities, each will be a separate GIS layer and can be viewed separately or in conjunction with other communities. The majority of the SDS community is located outside of the floodplain. M1 is difficult (nearly impossible) to depict due to its small clumps and/or narrow, linear configuration. This community will be included in the "open water" areas based upon field investigations since each of the lakes contains some coverage M1 habitat.

Since plant communities are of varying value to the species occupying the corridor, they are difficult to rank for overall habitat value. For example, the AG and CS communities also have value as foraging areas and movement corridors. Further, although the monotypic salt cedar is of low value to Great Blue Herons, it is of relatively high value to white-winged doves as nesting habitat. Generally however, native plant communities are of higher value to wildlife and contain the greatest density and diversity of animal species. Within the El Rio corridor, plant communities that are associated or within one hundred meters of perennial water are the highest quality habitats and should be preserved. These habitats are also potential suitable habitat for the two endangered and one candidate species discussed earlier in this report.

ENDANGERED SPECIES WITHIN THE EL RIO STUDY AREA

Two endangered species and one candidate species have potential to occupy the El Rio study area. Various criteria, which are described below, were used to identify areas that have potential suitable habitat (Appendix G, sheet 3).

YUMA CLAPPER RAIL *(Rallus longirostris yumanensis)*

Endangered

The Yuma Clapper Rail (YCR) is one of seven North American subspecies of clapper rail. They feed on crayfish, small fish, clams, isopods, and a variety of insects and invertebrates. They breed from mid-April to mid-September after which most individuals migrate to Mexico for the winter. Although this migration behavior was believed to be normal, recent data suggests that a number of birds in Arizona reside year-round. Nesting sites and foraging areas are located in stands of tall cattails. The requirements of site availability, prey diversity and abundance, and protection from avian predators can be satisfied in a relatively small area of marsh, often no larger than 0.29 acres (Dickey, 1923. AUK. 40(1): 90).

Until 2001, the YCR population along the Gila River area, in and adjacent to El Rio, appeared to be declining from a high of 52 birds in 1991 to a low of 16 in 2000. However, in 2001 AND 2002 the number of birds detected through surveys increased to 44 and 57 respectively.

To ensure that these population numbers remain stable or increase in the future, both M1 and M2 areas need to be preserved and possibly enhanced through creation of backwaters and additional lake edge areas, and managing water levels. Surveys should be conducted if either M1 or M2 areas are proposed to be impacted.

Habitat Evaluation Criteria

- Presence of cattail
- Marshes
- Sandy river bottom
- Corridor for transiting birds

Survey Protocol

- Surveys conducted between March 15 and May 15.
- Minimum of 2 surveys at each location each year.

- Start survey 30 minutes prior to sunrise.
- Continue survey for no longer than 3 hours.
- Calling stops between 150 – 200 meters.
- Surveys cannot be conducted if wind speed over 10 mph.
- One-minute listening period prior to calling.
- Two minute calling period followed by a two minute listening period and another two minute calling period and a final one minute listening period.
- Surveys need not be conducted for more than one year but should be conducted in the year of construction.

SOUTHWESTERN WILLOW FLYCATCHER *(Empidonax traillii extimus)*
Endangered

The Southwestern Willow Flycatcher (WIFL) is a riparian obligate species restricted to dense stands of vegetation along perennial waters. Nests and territorial birds are found in native riparian galleries and dense non-native monotypic stands of salt cedar. They are a neo-tropical migrant that appears in Arizona during the month of April and migrates south to Mexico and Central and South America in late August.

Although there have been no confirmed records of territories for this bird within the El Rio study area, a nesting pair was documented at the Tres Rio site just east of El Rio. This bird was found in habitat similar to what is present in the El Rio study area. Areas that should be considered potential occupied habitat include the plant communities of SC, AWS, AW, SCW, CW, and WS when they occur adjacent to perennial water. Surveys should be conducted in these areas if suitable habitat is going to be impacted by any project activities.

Habitat Evaluation Criteria

- Willow and/or salt cedar (between 3-15 meters high) adjacent to, within 100 meters, or hanging over perennial water
- Presence of sub-canopy with dense interior
- Distinct overstory (canopy) of willow and/or salt cedar
- Presence of nests that resemble WIFL nests in overhanging vegetation

- Undocumented occurrence of species inhabiting similar habitat nearby
- Corridor for transiting birds

Survey Protocol

- Minimum of three surveys at each site, one during each period outlined below.
- Survey 1: May 15 - 31.
- Survey 2: June 1 - 22.
- Survey 3: June 22 - 10.
- Successive surveys at least 5 days apart.
- Initial approach stand quietly for 1 - 2 minutes or longer, listening for spontaneously singing WIFL.
- Broadcast tape for 15 - 30 seconds, then listen for approximately 1 - 2 minutes.
- Repeat procedure (including a 10 - 20 second quiet pre-broadcast listening period) every 20 - 30 meters throughout each survey site, more often if background noise is loud.
- Surveys need not be conducted for more than one year but should be conducted during the year of construction.

YELLOW-BILLED CUCKOO *(Coccyzus americanus)*
Candidate

Yellow-billed Cuckoos (YBC) are a relatively rare species that occur in mature native riparian stands of cottonwood and willow and large mesquite bosques. However, surveys during the 1998 and 1999 breeding years indicate that mixed native and non-native stands are also being utilized (Corman and Magill 2000). During the 1998 YBC surveys, 7 YBCs were located along the Gila River from 83rd Avenue to 115th Avenue. This location is just east of the El Rio study area. During the 1999 survey year, 3 YBCs were located at the far western end of the El Rio study area at the SR 85 Bridge over the Gila River, and one was located at the 107th Avenue alignment over the Gila River just east of the study area.

In recent years the YBC population has declined mostly due to a combination of habitat loss, modification, and fragmentation (Franzreb 1987, Laymon and Halterman 1989, Hughes 1999); decreased water tables (Phillips et al. 1964); and possibly the use of pesticides (Gaines and Laymon 1984, Laymon and Halterman 1986, Rosenberg et al. 1991, Hughes 1999). To assist in reducing this trend, the larger native deciduous galleries and mixed native/non-native stands adjacent to perennial water should be preserved. In addition, since YBCs feed primarily on insects, overspray from insecticide spraying in the agricultural areas should be kept away from the riparian areas of the river corridor. Surveys should be conducted if suitable YBC nesting habitat is proposed to be impacted.

Habitat Evaluation Criteria

- Willow and/or cottonwood or willow and/or cottonwood and salt cedar (greater than 5 meters high) adjacent to or within 100 meters of perennial water
- Presence of sub-canopy with dense interior
- Distinct overstory (canopy) of willow and/or salt cedar

Survey Protocol

- Conduct surveys between June 15 - August 10.
- Conduct surveys between 6:30 am and noon.
- Surveys should be 10 to 14 days apart.
- Avoid surveys if wind speed is greater than 7 mph or it is raining.
- Avoid surveys when temperatures exceed 100 degrees F.
- Survey stops should be approximately every 200 meters at the edge of the habitat.
- If habitat is greater than 100 meters in width, multiple transects needed.
- Call ten times at each stop with a 30-60 second listening period between calls.
- Alternative method is five calls at each stop if stops are 100 meters apart.
- Surveys need not be conducted for more than one year but should be conducted in the year of construction.

SUMMARY

Although the El Rio study area contains suitable habitat for all three bird species, only the YCR and YBC have been documented as occupying the area. The past two years of surveys have shown a substantial increase in the local YCR population and it is important to continue this trend. All of the M2 habitat for this species should be preserved and if possible the M1 habitat should be enhanced.

Although the YBC populations have declined in this area of the Gila River, their continued presence on the eastern and western ends adjacent to the study area indicates the species' willingness to occupy similar habitats as are found in the El Rio study area. All the larger native deciduous galleries and mixed native/non-native stands adjacent to perennial water should be preserved. In addition, since the study area includes dense stands of exotic and native plant communities and perennial water, the entire study area could be considered a travel corridor for this species.

The nearest documented sighting of a WIFL was at the Tres Rio constructed wetlands just east of the study area where a single nesting pair was located. However, the study area does contain plant communities that are considered suitable habitat. Over 45% of the currently occupied sites within the WIFL's range in the United States have plant communities similar to those found in the El Rio study corridor. The GIS overlay illustrates the areas that are suitable for breeding sites based upon their vegetative composition and density and other habitat requirements such as proximity to permanent water.

Any project activities that could negatively impact areas that have been determined to be potential suitable habitat for any of the species mentioned above should be preceded by formal surveys.

UNIQUE WILDLIFE AREAS

Numerous species of wildlife inhabit the El Rio study area. However, certain areas have been identified as being essential to a particular species' survival. Those areas include nesting or roosting areas, lodges and dams, and burrows or dens, which were located during field reconnaissance and on the aerial photos. Unique Wildlife Areas are in addition to the suitable habitat identified for the two endangered and one candidate species previously discussed. The GIS overlay (Appendix G, sheet 2) identifies the locations of the unique wildlife areas and the suitable and optimal endangered/candidate species habitats.

Evaluation Criteria for Unique Wildlife Areas

- Distinct natural feature indicating the presence of a specific species of wildlife
- Feature exhibits indicators of consistent and long-term use by wildlife
- Other signs such as droppings, tracks, nests or dens, or actual observations indicating the presence of the species
- Perennial water present or nearby

Eighteen unique wildlife areas were identified, including two Great Blue Heron rookeries. One rookery is on the eastern border of the study area and one is at the approximate mid-point. Both are active with recent signs of occupation. The other unique areas identified include four beaver lodges, two of which exhibit signs of recent occupation and one that is a bank beaver lodge, which also appears to be currently occupied. Lodge #1 is located on Lower Tuthill Lake; Lodge #2 is located in backwater west of Lighthouse Marsh; and Lodge #3 is on Lower Miller Lake. The bank beaver lodge is located on Headstone Marsh. At the downstream end of the lakes, maintained beaver dams were identified. Other unique areas include an egret roost and numerous beaver dams. Due to the amount of beaver sign and activity in the corridor, there may be additional lodges or bank dens but they were not located.

In order to maintain the long-term health of the unique areas associated with beaver and the surrounding vegetation, it might be necessary to install flow control devices in the larger beaver dams. These devices will assist in regulating the maximum height of the water behind the dam. As more water is retained, water levels increase and cause what could be long-term inundation of the CW, SCW and WS communities. Long-term inundation of the native species could result in their demise, potentially resulting in an increased acreage of monotypic stands of salt cedar.

The entire study area is invaluable as nesting, foraging and loafing areas and movement corridors for other species of wildlife. Mule deer, fox, raccoon, and bobcat tracks were seen throughout the study area, and there were several sightings of javelina and coyote. In addition, past studies (EcoPlan Associates, Inc., 2002) have documented the presence of 129 species of birds. The larger contiguous areas of native and native/non-native mixed habitat should not be fragmented by any project activities in order to maintain this area's valuable wildlife habitat. This protection is especially important for areas adjacent to perennial water.

OPPORTUNITY AREAS

During field reconnaissance several areas were identified as "Opportunity Areas." Opportunities for enhancement were recommended based on density of native riparian vegetation, the occurrence of unique wildlife features within a particular stretch of river, and proximity to high quality habitat and perennial water. Areas that are currently owned by private parties and contain large amounts of native riparian vegetation were also identified.

Evaluation Criteria for Opportunity Areas

- Opportunities for enhancement were suggested based on density of native riparian vegetation, the occurrence of unique wildlife features within a particular stretch of river, and proximity to continuous habitat.
- Segments adjacent to continuous habitat that contain large amounts of native riparian vegetation, but the land is owned by private parties
- Contain areas that could be enhanced because exotic species are low in numbers
- Current mining operations that could be utilized for planting native riparian vegetation without removal of exotics (these areas are devoid of vegetation)
- Perennial water

Within El Rio, a variety of specific areas have potential for habitat restoration and/or enhancement, land exchange, or use as wildlife viewing and/or interpretation areas. On the GIS overlay, (Appendix G, sheet 4) there are seven areas, which have the greatest potential for success identified. However, many areas west of Jackrabbit Road might present opportunities for some habitat manipulation in order to enhance their value to wildlife.

One area within the boundaries of Estrella Mountain Regional Park has potential for native riparian gallery restoration and wildlife viewing and interpretation. Currently, a fairly large stand of cottonwoods and willows is present, adjacent to an occupied beaver flowage. This area serves as a prime example of the constituent elements that were considered when identifying "opportunity" areas. Other areas west of Jackrabbit Road were chosen as opportunity areas because native riparian species seem to be out-competing the invasive non-native salt cedar. These areas could be enhanced through the elimination of salt cedar, thus allowing the native cottonwood and willow to propagate and flourish.

Two other opportunity areas were identified as land-exchange opportunity areas. The land is currently privately owned. One area is located south of Meck Lake and is currently utilized for a materials source pit. This area is adjacent to Estrella Mountain Regional Park and could provide an opportunity for a large restoration site for education, wildlife viewing, and passive outdoor recreation. The second area is located west of Waterman Wash and contains some of the largest galleries of mature cottonwood in El Rio.

NATURAL RESOURCE AGENCY ISSUES AND CONCERNS

ARIZONA GAME AND FISH DEPARTMENT (AGFD), PHOENIX HEADQUARTERS

Interviewer: Tim Wade, Senior Biologist, EcoPlan Associates, Inc.

AGFD Representative: Bill Werner, Aquatics Program Manager, Habitat Branch

- Although salt cedar is a non-native and not the desired tree for riparian zones, it can provide extensive blocks of wildlife habitat. Removal of stands of salt cedar that have no or little habitat value does not create a net loss of habitat and is acceptable. Note also that WIFL have been documented nesting in salt cedar under specific conditions, a factor which must be considered in planning and implementing any revegetation project involving removal of salt cedar.

- Removal of salt cedar and enhancement of a cottonwood/willow stands, which appear to be sustaining themselves but are starting to be crowded out by salt cedar, is a viable strategy. There needs to be sufficient site-specific soil testing and analysis of present and future water regimes to be successful.

- It is unrealistic and not a natural condition to expect to have habitat from bank to bank on a river corridor. All rivers have a portion between the banks that is devoid of vegetation. In perennial rivers this portion is open water. In desert rivers this may be sand or cobble or other normally dry substrate.

- The reach just east of the 115th Avenue Bridge can be used as a reference reach for the Gila River in the project area. It was used by the Tres Rio Project due to its longevity and typical conditions.

- Activities such as bird watching, hiking, equestrian use, and other passive activities are possible future uses of the corridor. Hunting opportunities will be reduced as the cities along the corridor annex county land. Fishing is a viable activity also, however water quality must be improved before fishing in the corridor can be encouraged by public entities. Fishing opportunities, which are supported by water other than from the river itself, may allow for fish consumption by avoiding contaminant issues.

- Acquisition or exchange of lands within the corridor to consolidate habitat and maintain a river corridor is encouraged to allow the river to support habitat and still provide for flood control and prevent encroachment. Encroachment into the floodplain reduces options for planners. Maintenance of "green infrastructure" should be promoted, i.e. taking care of the river as infrastructure so that it functions for flood conveyance, habitat, recreation, etc. The river corridor should be as wide as can be accomplished. Uses within that corridor which can withstand flooding would not necessarily be inconsistent.

- Removal of salt cedar from areas of existing cotton/willow stands has shown to be a viable method to increase vitality of the cottonwood/willow stand.

- In areas where beaver are present population control methods or protection of trees will be necessary to protect native riparian vegetation. Preferred foods will be the first to be eaten by beaver.

- A holistic approach to management of the river corridor is necessary to reduce operation and maintenance costs and provide for multi-use recreation.

- Restoration projects need to be self-sustaining.

- There should be a thorough analysis of how the system is functioning now and why it is functioning as such. This information will provide guidance for any enhancement or restoration activities. Enhancement or restoration needs to be realistic given the current setting and conditions.

- Look for opportunities for the establishment of mesquite bosques on the bench areas. These can be self-sustaining once established.

- Ensure that restoration occurs in areas that will not be negatively impacted by fairly frequent flooding, such as a five-year event.

- Try to include Waterman Wash in the project. Changes in the wash's flow regime may negatively affect sediment transport and sediment characteristics of main channel.

- Drainage wells may provide additional water for restoration/enhancement opportunities.

- Understanding the future water regime of the river is vital to this project. Water conditions in the future may change drastically as surrounding land is transitioned from agriculture to residential use or wastewater is diverted to other uses.

- Explore opportunities for land exchanges within the project area.

- Gravel operations could be useful in removing material to accomplish certain tasks such as reestablishment of a low-flow channel or open water areas.

- Pothole areas should be linked to provide a linear contiguous habitat within the corridor.

ARIZONA GAME AND FISH DEPARTMENT, REGION VI

Interviewer: Tim Wade, Senior Biologist, EcoPlan Associates, Inc.

AGFD Representatives: Russell Haughey, Habitat Program Manager
Tom Hildebrandt, Wildlife Program Manager

- Riparian restoration projects are often unsuccessful due to lack of proper site analysis, planning, and unrealistic expectations (see article titled "Trial and Error, Assessing the Effectiveness of Riparian Revegetation in Arizona).

- The AGFD has concerns regarding the lack of success of previous riparian restoration projects in this vicinity. Habitat mitigation for the 1,000' clearance and the New River channelization projects, as well as for other types of projects, have been largely unsuccessful for a wide variety of reasons. Considering the important wildlife and habitat resources at stake, this history does not foster confidence that a project on a larger scale will be any more successful.

- Rather than focusing on in-stream and flood channel alterations to meet flood protection objectives, AGFD would like the Maricopa County Flood Control District (MCFCD) to pursue acquisition of properties likely to become damaged by flooding and preservation of open space as the primary strategy to reduce property damage from flooding. This is a more efficient use of funds rather than dedicating them to restoration, which may not be successful.

- What happens if the restoration aspects of the plan fail? In particular, AGFD is concerned that if attempts to replace salt cedar with native riparian plants fail, habitat values of the site will then be degraded from their previous condition. The

Department would like to see contingency plans detailed to ensure no-net loss of habitat values.

- Due to the significant uncertainty regarding the probable success of replacing salt cedar with native riparian vegetation, AGFD would like the MCFCD to test the methodology on small plots. Then, if these sites are successful, we would be more comfortable with expanding the scope of the native riparian restoration effort.

- Although salt cedar is a non-native and not the desired tree for riparian zones, it does provide extensive blocks of wildlife habitat. Salt cedar provides extensive nesting habitat for white-winged and mourning doves, as well as many other species of birds. Removal will create a net loss of currently utilized habitat.

- Replacement of salt cedar with native species such as willow and cottonwood, as well as velvet and screwbean mesquite, is probably an unrealistic expectation for most sites. Current flow regimes and soil conditions in many places (salinity especially) do not support the ability of natives to out-compete salt cedar and grow to maturity. Analysis of current vegetation in the study area supports this opinion. Where cottonwoods have germinated, especially since the floods of 1993, they are stunted and not thriving. Willows similarly seem to establish well, but experience high mortality (> 50%) and ultimately fail except directly adjacent to flowing channels.

- Any attempt to plant native riparian species should be preceded by a complete analysis of the soil and subsurface moisture at the proposed site, followed by a critical analysis of the suitability of the site for the intended species.

- AGFD will only support projects that can be implemented with a no net loss of wildlife habitat, diversity, and density.

- Any projects implemented on AGFD-deeded or managed lands must increase habitat values and be consistent with the purposes for which the property was acquired or is managed.

- Any areas within the corridor that contain cattail stands are potential YCR habitat.

- The entire corridor is potential habitat for YBC and WIFL.

- Fish production in the watered areas of the corridor is among the highest in the state. As a result, fish-eating birds thrive throughout the corridor. It is vital that any aspect of the project not negatively impact their nesting and foraging areas.

- Areas on and around the John Beaver property are important white-winged dove nesting habitat and must be preserved.

- Wildlife-related recreation opportunities such as bird watching and hunting (where legal) need to be preserved.

- If there is an increase in public access to the corridor, it should be limited to walk-in or equestrian access only. Any increase in vehicular access will result in more dumping and increase the potential for fire.

- Access points should be dispersed to avoid concentrating activity.

- AGFD would like to see wildlife migration corridors maintained.

U.S. FISH AND WILDLIFE SERVICE (USFWS)

Interviewer: Tim Wade Senior Biologist, EcoPlan Associates Inc.

USFWS Representative: Michael A. Martinez, Fish & Wildlife Biologist

- USFWS' primary concern is the endangered species in the corridor and their associated suitable habitat, specifically the WIFL and the YCR.

- A nesting pair of WIFL was discovered at the Tres Rio area just upstream from the El Rio project area this year. It is quite possible that there are also nesting pairs in the project area.

- The YBC needs to be considered also, even though it is only at this point a candidate species. It status as "warranted but precluded" could change depending upon future actions.

- The entire corridor is potential habitat for YBC and WIFL.

- Although salt cedar is a non-native and not the desired tree for riparian zones, it does provide extensive blocks of wildlife habitat. Removal will create a net loss of currently utilized habitat.

- Restoration related projects should not only result in no net loss of wildlife habitat, diversity, and densities, but an improvement of existing habitats.

- It is vital that any aspect of the project not negatively impact fish-eating birds and/or their nesting and foraging areas.

- Money should be spent on acquiring lands within the corridor to allow the river to remain as it is and still provide for flood control. This is a more efficient use of funds rather than expending them on restoration, which may or may not be successful.

- Upstream activities, both current and in the future, need to be factored into any proposed mitigation or restoration project to assist in ensuring long-term success.

- Opportunities for endangered fish recovery actions need to be explored. An example would be the creation of backwaters to be used for endangered fish refugia.

MARICOPA COUNTY PARKS AND RECREATION DEPARTMENT (MCPR)

Interviewer: Tim Wade, Senior Biologist, EcoPlan Associates, Inc.

MCP&R Representatives: Bill VanAusdale, Deputy Director

Molly Garrett, Estrella Mountain Park Supervisor

John Gunn, Spur Cross Ranch Park Supervisor

- Opportunity area exists near Bullard Avenue within Estrella Mountain Park boundaries. There is standing water present, stands of willow on islands and sandbars, and an abundance of wildlife. If enhanced, the area could provide opportunities for wildlife viewing and an interpretive center.

- MCPR sees the El Rio project as an opportunity to enhance passive outdoor recreation in and adjacent to Estrella Mountain Park. They also feel that as opportunities for conservation and wildlife-oriented recreation increase, so will visitation from conservation-minded individuals. These types of visitors will assist in preserving the area and keeping it free of trash and vandalism.

- MCPR is opposed to establishing and maintaining a 1,000-foot clear zone if it means a loss of habitat and negatively impacting the natural beauty which exists now within and adjacent to Estrella Mountain Park.

- There should be minimal structural flood control methods used. Instead, the river should be allowed to meander within the floodplain.

- Intensity of development, whether it be residential, commercial, or recreation-oriented, needs to be carefully evaluated to ensure minimal negative impacts to the corridor.

- If a trail system is developed, it should be as natural as possible and not allow motorized vehicular access. Trails accessible to handicapped persons should not be paved but surfaced with decomposed granite.

- If lake recreation is developed, no motorized vessels should be allowed. Electric motors could possibly be allowed, but the use of those should be fully analyzed first.

- Wildcat landfills should be removed, especially upstream. MCPR could assist in any clean-up efforts which are proposed, especially if they occurred upstream of Estrella Mountain Park.

- If possible, equestrian users should be kept out of the river bottom, up on the bench, and separated from hikers and bikers due to past conflicts between these user groups. Access to water could be accomplished through limited access trails to open water and/or watering troughs.

- Various open-water reaches and potholes should be connected to create a continuous band of open water and associated edge, understory, and overstory habitat.

- MCPR would like to receive a copy of any reports produced as the project progresses. Also, Molly Garrett would like to be added to the list of agency representatives and be invited to attend any stakeholder meetings held.

BUREAU OF LAND MANAGEMENT (BLM)

Interviewer: Tim Wade, Senior Biologist, EcoPlan Associates, Inc.

BLM-Phoenix Field Office Representatives: Don Charpio, Assistant Field Manager, Gene Dahlam, Manager, Sonoran National Monument

- The El Rio project needs to result in a proper functioning riparian system, which meets the needs of the wildlife on the public land in the project area.

- Although salt cedar is a non-native and may not be the desired tree for riparian zones, it does have some wildlife habitat value. Given the current conditions along this reach of the Gila River, salt cedar may be the only available vegetation for this area.

- BLM is open to discussion on restoration efforts on public land but will not be able to take the lead either financially or manpower wise. They will however assist in the analysis and NEPA process.

- BLM does not want any increase in motorized vehicular access.

- BLM would not support efforts to construct any type of visitor center or informational kiosk on public land.

- Any projects implemented on public lands must not result in a reduced benefit to wildlife.

- BLM would like to see any developed recreational trail system double as a fire suppression trail system. There is a need for increased access in some portions of the reach to support fire suppression efforts.

- If there is an increase in public access to the corridor, it should be limited to non-motorized (e.g., walk-in or equestrian access) only. Any increase in vehicular access will result in more dumping and increase the potential for fire.

- BLM would like to ensure that the El Rio Project Managers and any other appropriate individuals on the team comment on the ongoing BLM Phoenix South Resource Management Plan. This plan will include in the El Rio Study Area. Scoping for the plan will occur in February 2003.

CONCLUSIONS AND RECOMMENDATIONS

- Twelve distinct plant communities were identified within the El Rio study area.
- Marsh habitat in the study area should be preserved and, if possible enhanced.
- The plant communities of salt cedar/cottonwood, arrow-weed/willow/salt cedar, arrow-weed/willow, salt cedar/cottonwood/willow, cottonwood/willow, and willow/salt cedar, when they occur adjacent to perennial water, and marsh habitat, are of high value for the WIFL and the YBC.

- The plant communities of salt cedar/cottonwood, arrow-weed/willow/salt cedar, arrow-weed/willow, salt cedar/cottonwood/willow, and cottonwood/willow should be preserved and, if possible, enhanced or expanded.
- Overspray from insecticide spraying in the agricultural areas should be kept away from the riparian areas of the river corridor.
- Surveys for YCR, WIFL, and YBC species should be conducted if areas of suitable habitat are to be impacted by any project activity.
- The salt cedar/cottonwood/willow community provides the best opportunity for enhancement. Selective removal of salt cedar and augmentation with native species could allow the community to flourish as it has in other portions of the state.
- Temporal losses need to be considered when removing large expanses of any plant community.
- Soil testing should be conducted in areas being considered for enhancement or restoration.
- Restoration and enhancement projects must be self-sustaining.
- The possibility of replacing selected mono-typical stands of salt cedar with native mesquite bosques should be investigated.
- Public access needs to be controlled and limited to non-motorized travel in sensitive areas.
- The establishment of wildcat dumps and other indiscriminant dumping needs to be eliminated.
- An increased law enforcement presence will be needed if public access is increased due to the marketing of passive recreation in the area.
- Project activities should result in a net increase in either habitat values or total acreage. Those activities not meeting this criterion must be mitigated.
- Structural controls should be kept to a minimum and used only if non-structural controls are not an option.
- The floodplain should be protected from encroachment from non-compatible uses.

LITERATURE CITED AND REVIEWED

Anderson, Bertin W. 1995. Salt Cedar, Revegetation and Riparian Ecosystems in the Southwest. Revegetation and Wildlife Management Center, Blythe, CA.

Arizona Game and Fish Department 2000. Yuma Clapper Rail Surveys in AGFD Region VI, Phoenix, AZ.

Arizona Game and Fish Department 2001. Yuma Clapper Rail Surveys in AGFD Region VI, Phoenix, AZ.

Arizona Game and Fish Department 2002. Yuma Clapper Rail Surveys in AGFD Region VI, Phoenix, AZ.

Dickey, D. R. 1923. Rallus longirostris yumanensis. Arizona Game and Fish Department Heritage Data Management System.

EcoPlan Associates, Inc. 2002. Bird Survey Results for the Ecological Characterization of the Gila River Wetlands. Report prepared for the Gila River Indian Community, Sacaton, AZ.

EcoPlan Associates, Inc. 2002. Bird Vegetation Communities of the Gila River Wetlands, Within the Gila River Indian Community. Report prepared for the Gila River Indian Community, Sacaton, AZ.

Franzreb, K. 1987. Perspectives on managing riparian ecosystems for endangered bird species. Western Birds 18:10-13.

Franzreb, K. and S.A. Laymon. 1993. A reassessment of the taxonomic status of the yellow-billed cuckoo. Western Birds 24:17-28.

Gaines, D.A. and S.A. Laymon. 1984. Decline status and preservation of the yellow-billed cuckoo in California. Western Birds 15:49-80.

Graf, William L. 1982. Tamarisk and River Channel Management. Environmental Management, Vol.6, No. 4, pp. 283-296.

Hughes, J.M. 1999. Yellow-billed Cuckoo in: Poole and F. Gill (eds.), Birds of North America, No. 418. The Birds of North America, Inc., Philadelphia, PA.

Kerpez, Theodore A. 1987. Salt cedar control for wildlife habitat improvement in the southwestern United States. Resource publication / U. S. Department of the Interior, Fish and Wildlife Service: no. 169. Washington, D.C.

Laymon S.A. and M.D. Halterman. 1986. Part II. Nesting ecology of the yellow-billed cuckoo on the Kern River: 1986.

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

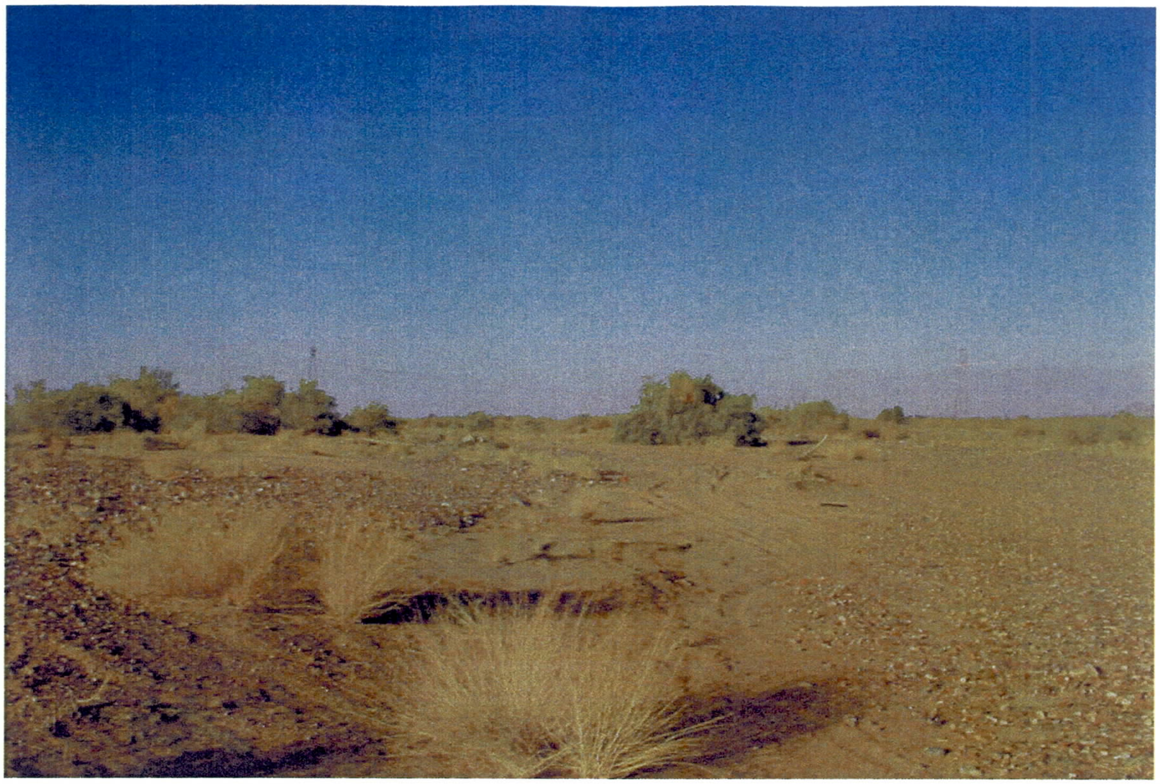
Rosenberg, K.V., R.D. Ohmart, W.C. Hunter, and B.W. Anderson. 1991 Birds of the lower Colorado Valley. University of Arizona Press, Tucson. 416 pp.

Sogge, Mark K. et al. 2001. Southwestern Willow Flycatcher Breeding Site and Territory Summary – 2000. U.S. Geological Survey report prepared for the Southwestern Willow Flycatcher Recovery Team, U.S. Fish and Wildlife Service, Region 2, Albuquerque, NM.

SAMPLE POINT PHOTOS

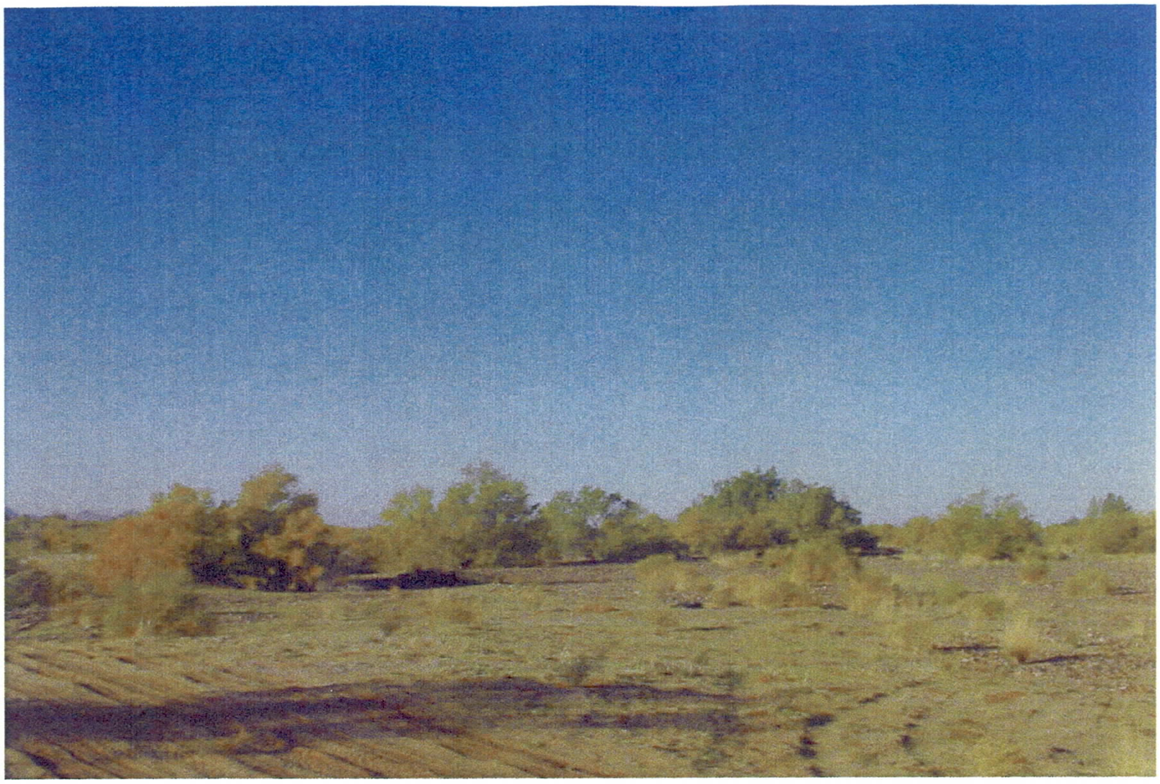
Upper Reach Sample Point #1 Towards West

Upper Reach Sample Point #1 Towards South East



Upper Reach Sample Point #2 Towards West

Upper Reach Sample Point #2 Towards East



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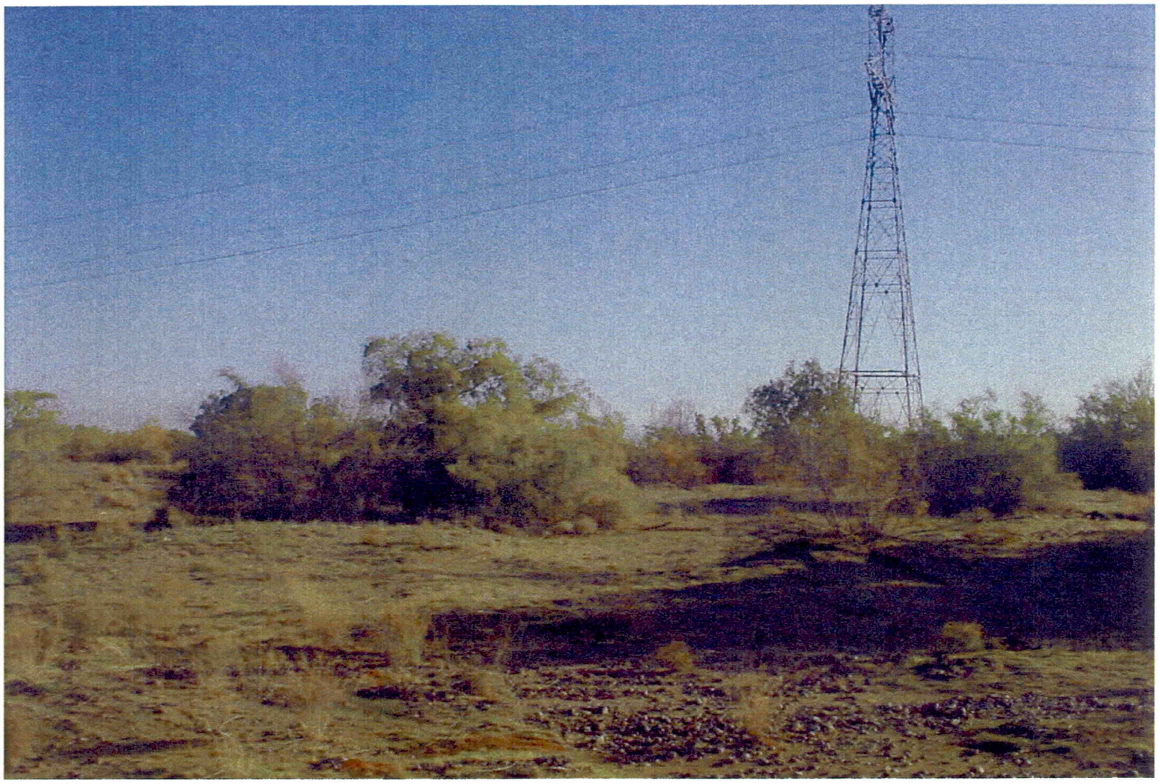


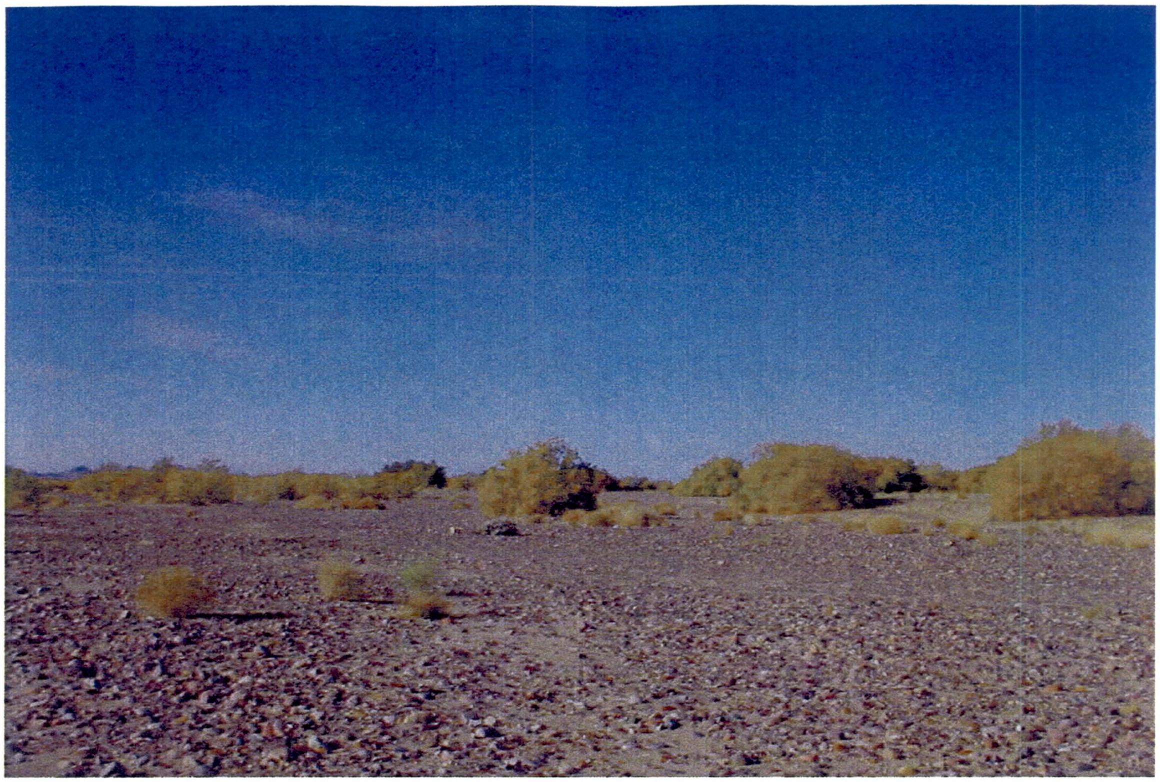
Upper Reach Sample Point #3 Towards East

Upper Reach Sample Point #4 Towards West

Upper Reach Sample Point #4 Towards East

Upper Reach Sample Point #5 Towards West

Upper Reach Sample Point #5 Towards East



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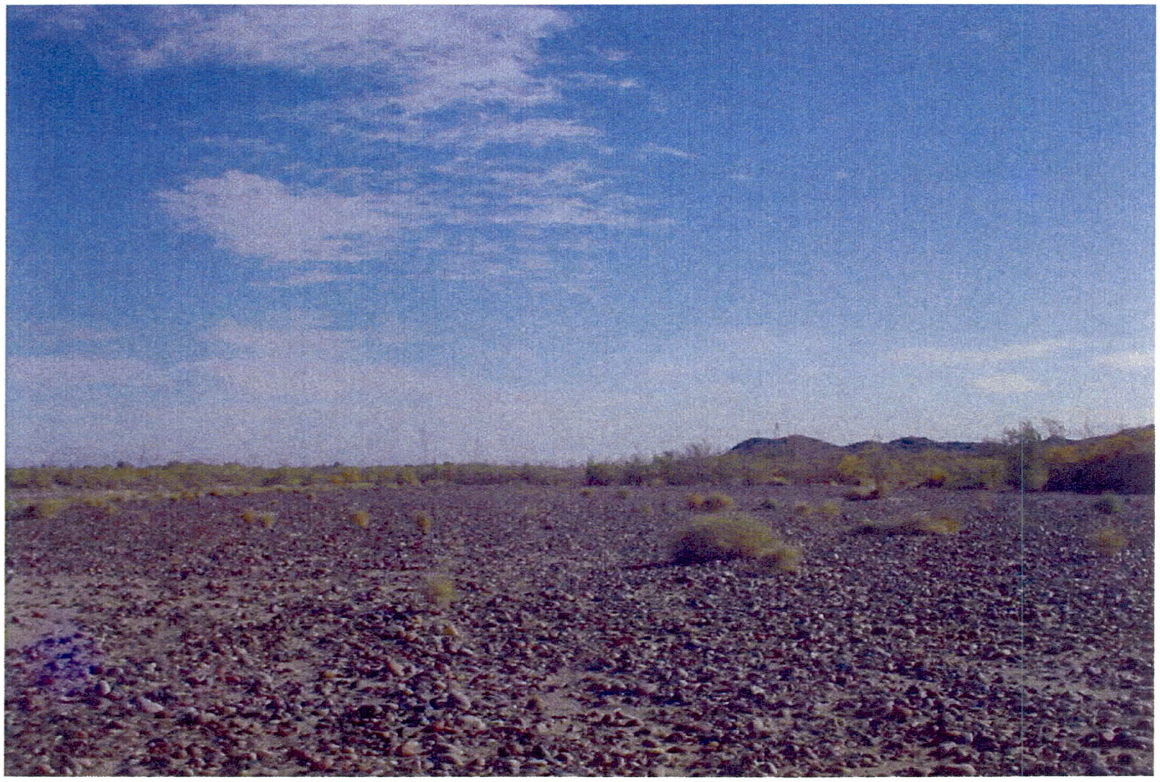


Upper Reach Sample Point #6 Towards East

Upper Reach Sample Point #7 Towards West

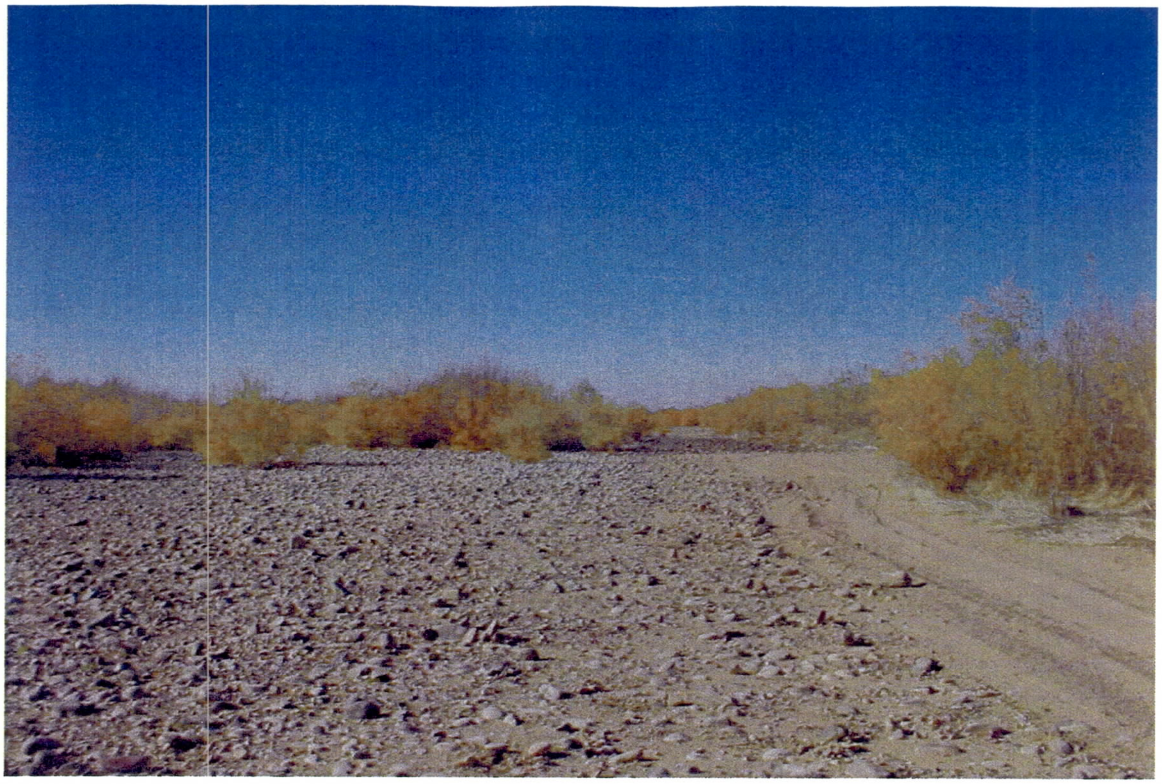
Upper Reach Sample Point #7 Towards East

Upper Reach Sample Point #8 Towards West

Upper Reach Sample Point #8 Towards East

Middle Reach Sample Point #1 Towards West

Middle Reach Sample Point #1 Towards East



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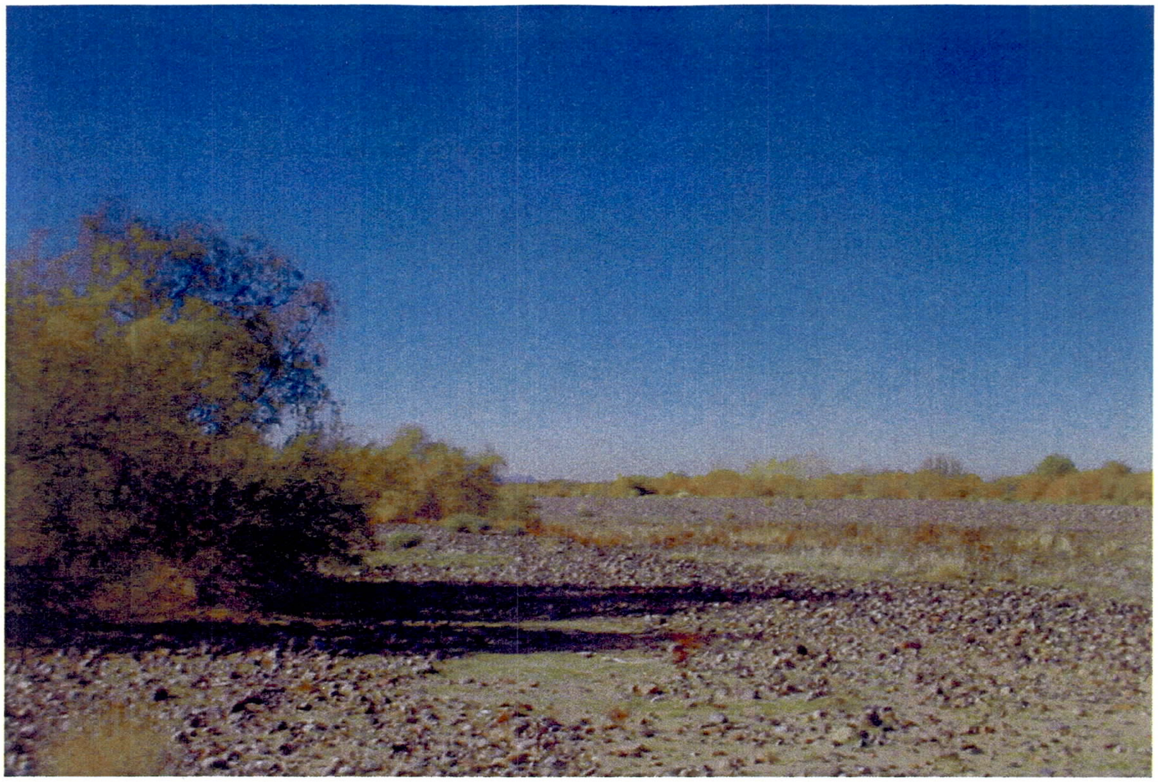
Middle Reach Sample Point #2 Towards East



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Middle Reach Sample Point #3 Towards East

Middle Reach Sample Point #4 Towards West

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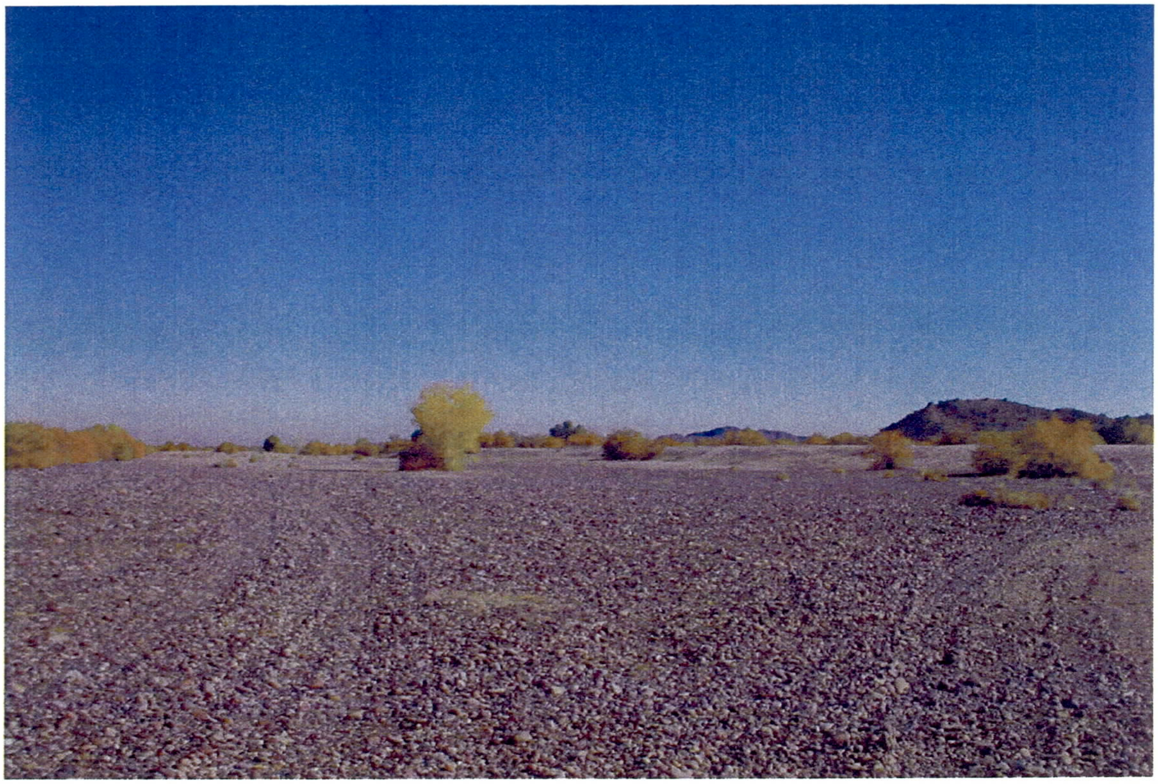
Middle Reach Sample Point #5 Towards West



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Middle Reach Sample Point #6 Towards West

Middle Reach Sample Point #6 Towards East

Middle Reach Sample Point #7 Towards West

Middle Reach Sample Point #7 Towards East

Middle Reach Sample Point #8 Towards West

Middle Reach Sample Point #8 Towards East

Middle Reach Sample point #9 Towards West

Middle Reach Sample Point #9 Towards East

Lower Reach Sample Point #1 Towards West

Lower Reach Sample Point #1 Towards East

Lower Reach Sample Point #2 Towards West

Lower Reach Sample Point #2 Towards East

Lower Reach Sample Point #3 Towards West

Lower Reach Sample Point #3 Towards East

Lower Reach Sample Point #4 Towards West

Lower Reach Sample Point #4 Towards East

Lower Reach Sample Point #5 Towards West

Lower Reach Sample Point #5 Towards East

Lower Reach Sample Point #6 Towards West

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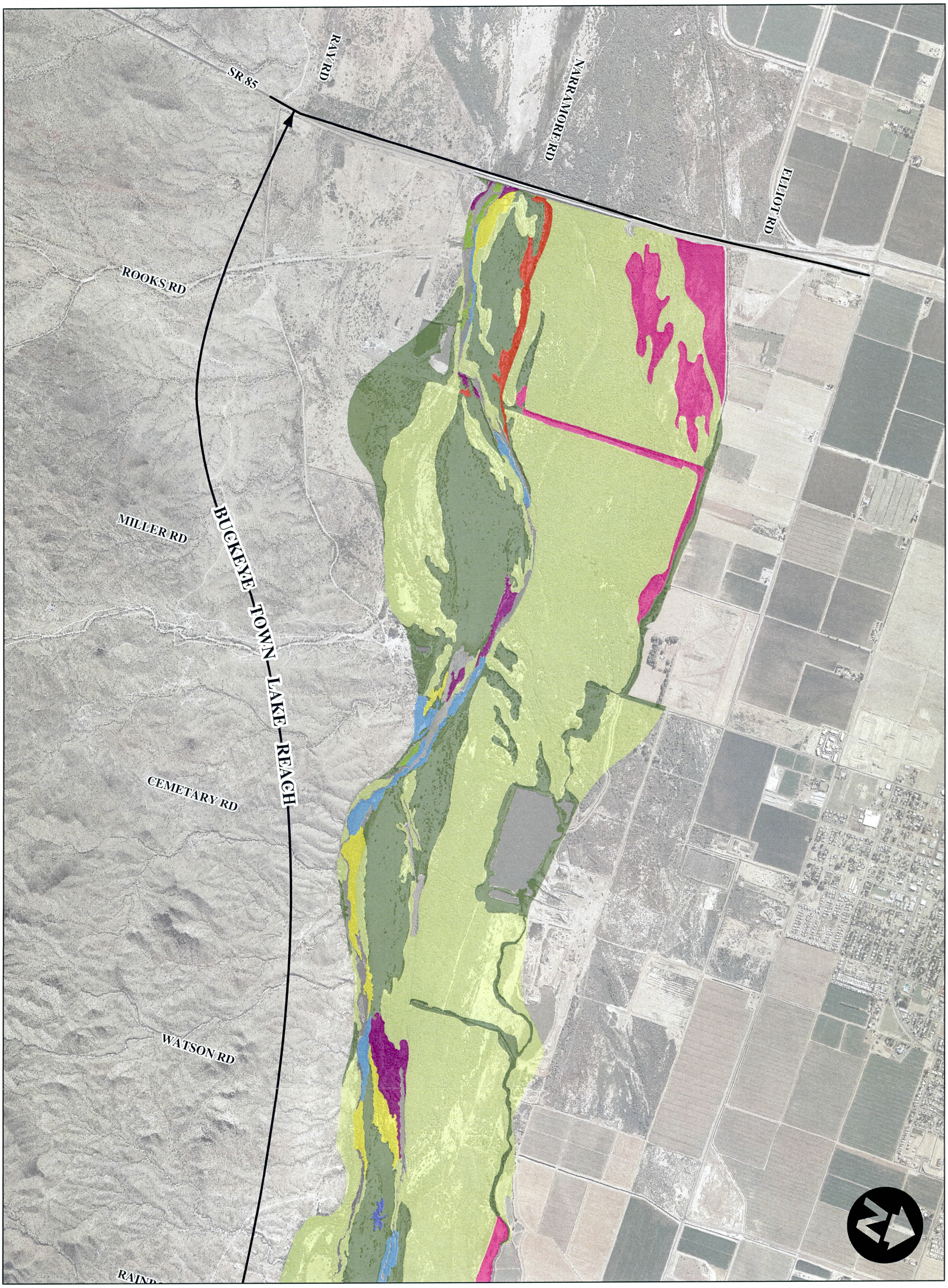
Lower Reach Sample Point #11 Towards East



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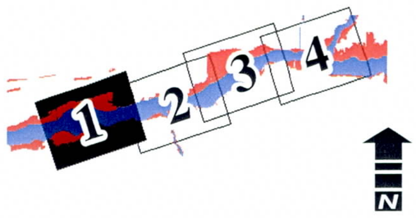
Stantec

Vegetative Communities

- Arrowweed Willow
- Arrowweed Willow Salt Cedar
- Atriplex
- Cottonwood Willow
- Cobble Strand
- Marsh 1&2
- Salt Cedar
- Salt Cedar Cottonwood Willow
- Willow Salt Cedar



EL RIO

EL RIO WATERCOURSE MASTER PLAN

VEGETATIVE COMMUNITIES
SHEET 1 OF 4 (BUCKEYE TOWN LAKE REACH)
11 NOV 2005

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1 Inch = 2000 Feet

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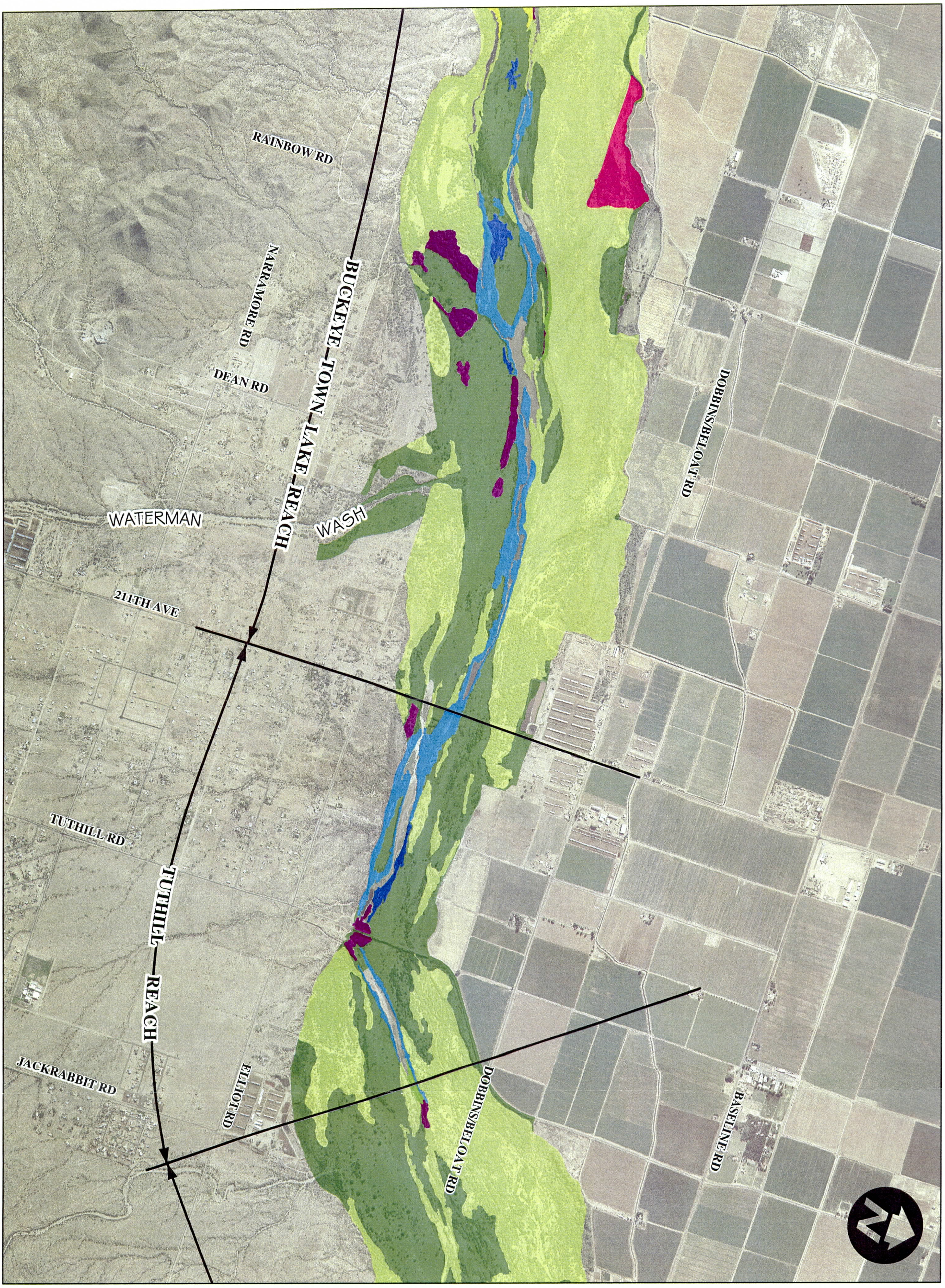

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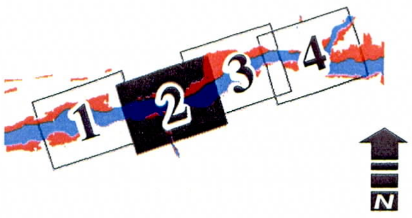

EL RIO WATERCOURSE MASTER PLAN

VEGETATIVE COMMUNITIES
SHEET 2 OF 4 (TUTHILL REACH)
11 NOV 2005

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1 Inch = 2000 Feet

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Vegetative Communities

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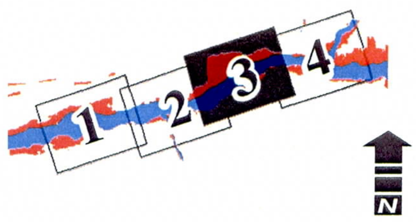
- Salt Cedar Cottonwood Willow
- Willow Salt Cedar



EL RIO WATERCOURSE MASTER PLAN

VEGETATIVE COMMUNITIES

SHEET 3 OF 4 (PERRYVILLE REACH)

11 NOV 2005

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1 Inch = 2000 Feet

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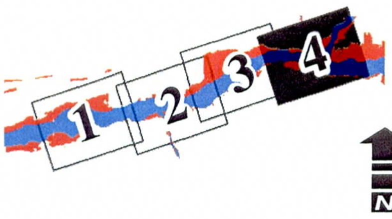
- Salt Cedar Cottonwood Willow
- Willow Salt Cedar



EL RIO WATERCOURSE MASTER PLAN

VEGETATIVE COMMUNITIES
SHEET 4 OF 4 (ESTRELLA REACH)
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1 Inch = 2000 Feet

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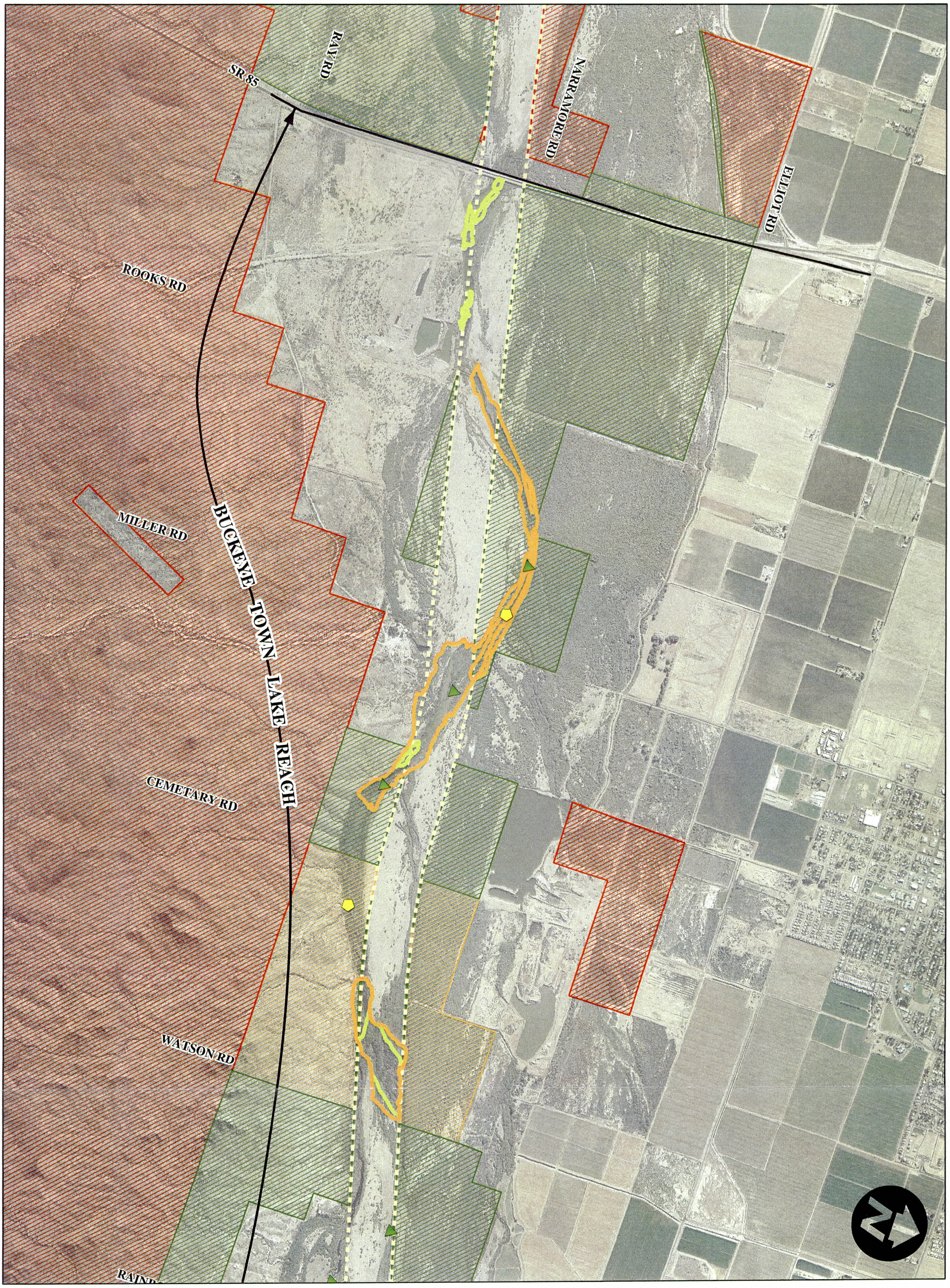

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Unique Wildlife Features
- Beaver Dam
- Egret Roost
- Beaver Lodge
- Great Blue Heron Rookery

Government Property
- Bureau of Land Management
- Game & Fish
- Parks & Recreation
- State Trust

Protected Species Potential Habitat Areas
- Yuma Clapper Rail
- Southwestern Willow Fly Catcher
- FCD 1000 Ft. Corridor

EL RIO WATERCOURSE MASTER PLAN

ENVIRONMENTAL CONSTRAINTS & OPPORTUNITIES
SHEET 1 OF 4 (BUCKEYE TOWN LAKE REACH)
11 NOV 2005

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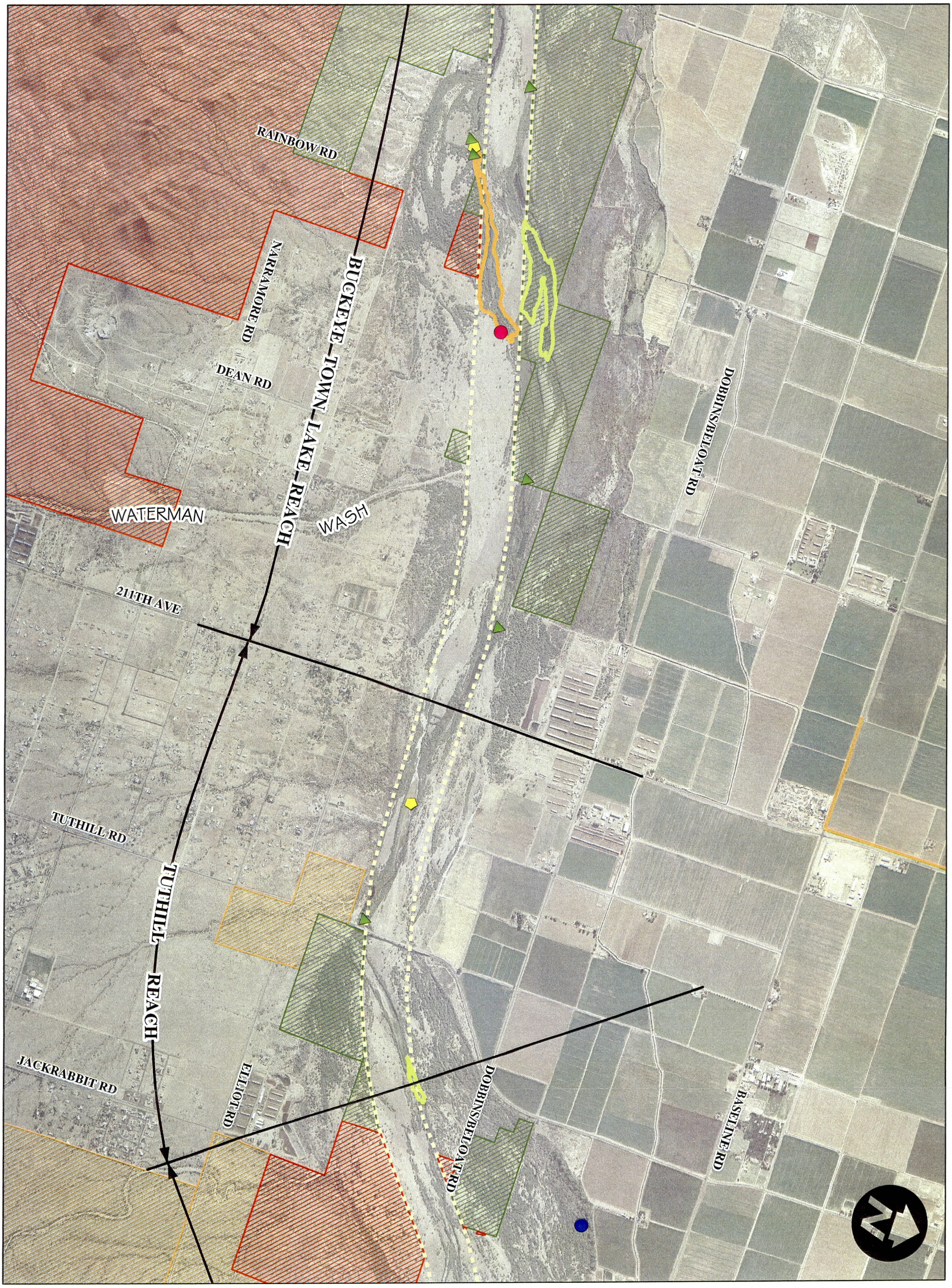

Flood Control District
of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Stantec Consulting Inc.
8211 S. 48th St.
Phoenix, AZ 85044

Unique Wildlife Features
- Beaver Dam
- Egret Roost
- Beaver Lodge
- Great Blue Heron Rookery

Protected Species Potential Habitat Areas
- Yuma Clapper Rail
- Southwestern Willow Fly Catcher
- FCD 1000 Ft. Corridor

Government Property
- Bureau of Land Management
- Game & Fish
- Parks & Recreation
- State Trust

EL RIO

EL RIO WATERCOURSE MASTER PLAN

ENVIRONMENTAL CONSTRAINTS & OPPORTUNITIES
SHEET 2 OF 4 (TUTHILL REACH)
11 NOV 2005

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1 Inch = 2000 Feet

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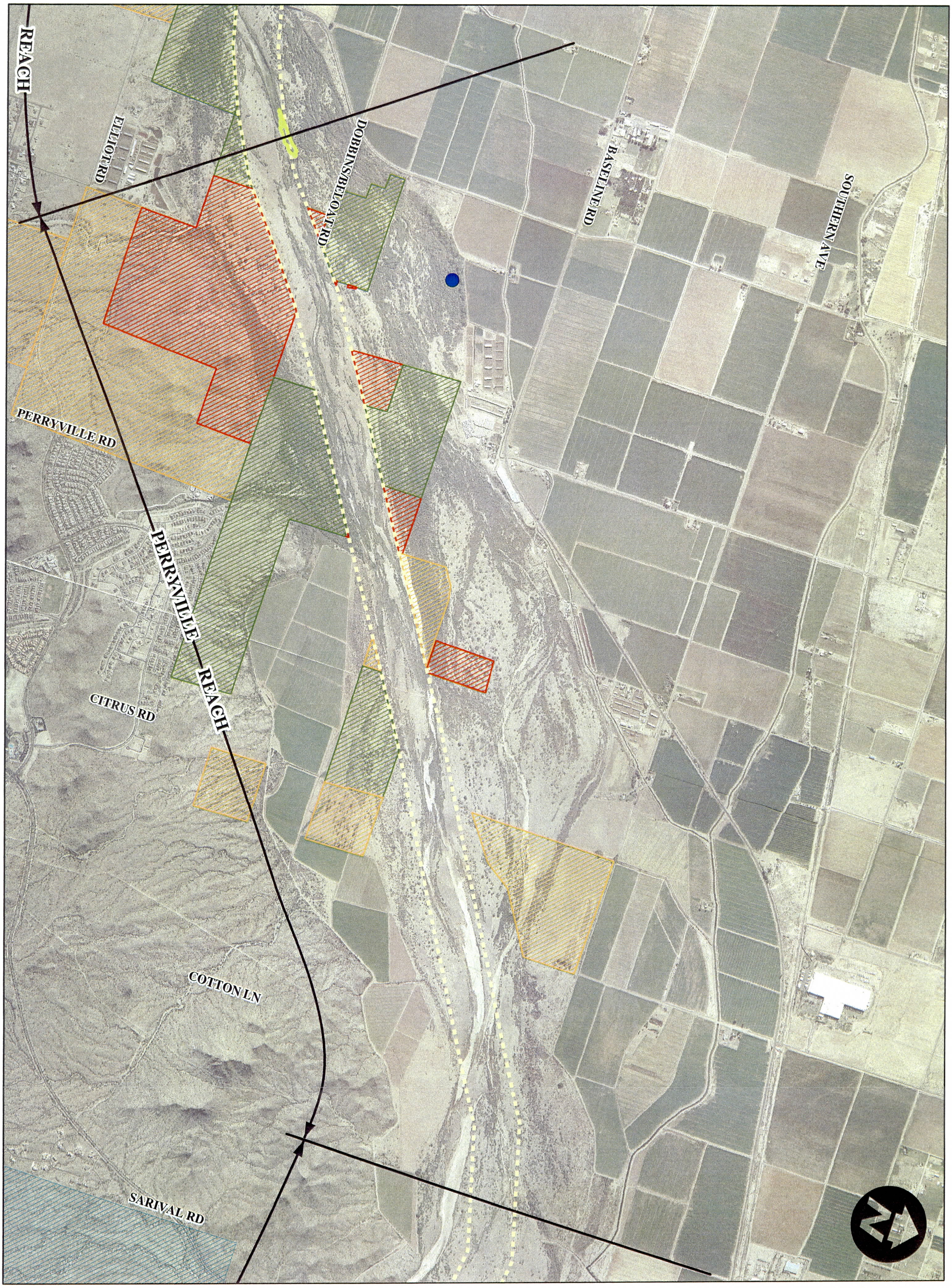

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EL RIO WATERCOURSE MASTER PLAN

ENVIRONMENTAL CONSTRAINTS & OPPORTUNITIES
SHEET 3 OF 4 (PERRYVILLE REACH)
11 NOV 2005

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1 Inch = 2000 Feet

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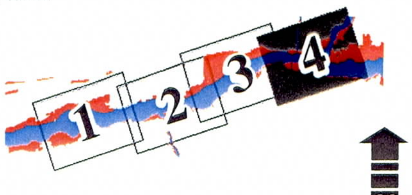

EL RIO WATERCOURSE MASTER PLAN

ENVIRONMENTAL CONSTRAINTS & OPPORTUNITIES
SHEET 4 OF 4 (ESTRELLA REACH)
11 NOV 2005

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1 Inch = 2000 Feet

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El Rio Watercourse Master Plan

EL RIO ENVIRONMENTAL RESOURCES

SECTION 3
ANTHROPOGENIC RESOURCES

PREPARED FOR:

FLOOD CONTROL DISTRICT
of
Maricopa County

PREPARED BY:
STANTEC CONSULTING INC.
8211 South 48th Street
Phoenix, Arizona 85044
(602) 438-2200

July 2003

STANTEC CONSULTING Inc.
Project No. 8200240

Contract FCD 2001C024

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EXECUTIVE SUMMARY

This portion of the environmental resources report characterizes the manmade or man-influenced features on the El Rio landscape. In many cases these features can represent both opportunities and constraints for flood control project planners and designers. These features include sources of surface water, cultural resource sites from historic and prehistoric civilizations, hazardous waste sites, solid waste sites, and current land ownership as it relates to rules and regulations governing potential flood control projects. Each of these issues becomes important in the analysis of what can be done and where it can be done in the portion of the Gila River floodway and floodplain known as the El Rio.

The anthropogenic features of the El Rio Project area are described in five sections of Volume III of the Environmental Resources Report. Each topical area was reviewed or researched to allow the preparation of a GIS layer overlay so that project planning and design, as well as interested groups and stakeholders, could consider these important resource opportunities and constraints as they relate to the flood control project goals.

OPEN WATER

Historical aerial photos and field survey techniques were used to identify the extent of open water during the winter period for the El Rio project area. The analysis determined that over 200 acres of open water are present in the 17-mile reach of the project area. This permanent open water results from discharges from municipal waste water treatment, agricultural return waters, and irrigation tailwater, as well as natural groundwater expression at the downstream end of the project area.

These discharges of surface water form habitat for aquatic species of plants and animals that either depend entirely, or seasonally, on these open water sources. The quality of the open water is defined by the discharge water sources.

The analysis of aerial photographs determined that more recent open water areas are actually more extensive than in the past. There is roughly twice the open water habitat in the last few years, including the 2002-2003 drought year, as compared to data from the 1940-1960 period.

HAZARDOUS MATERIALS

Various environmental records from federal, state, county, and local agencies were reviewed by the District to identify whether hazardous material sites or potential hazardous material sites are located within the El Rio WCMP project area or at offsite locations within the specified minimum search distances. The sites that are located in or near the project area are listed below.

- A hazardous waste generator site was located at the Gila River and the Tuthill Road Bridge. The type of hazardous material was not listed.
- The Arizona Superfund Program List (ASPL) listed one potential Water Quality Assurance Revolving Fund (WQARF) site, known as the Middle Gila site, which may be located in or within 1-mile of the project area. The location description for the Middle Gila site was not listed; however, more research is currently being done to determine where this site is. The status of the site was listed as "pending preliminary investigation" in April 1997.
- A leaking, aboveground storage tank (AST), was identified in the Gila River Floodway between Sarival Road and Cotton Lane alignments. The tank owner and leaking substance are unknown; however, the substance appears to be oil or diesel fuel. Depending on the extent of the soil contamination, the groundwater could be impacted as well.
- One closed solid waste landfill was listed as being located at Miller Road and the Gila River. The operator was listed as the town of Buckeye.
- Eleven Hazardous Material Incident sites were listed in the HAZMAT logbook and potentially occur in the project area. One site, located at the Tuthill Bridge and the Gila River, is definitely in the project area; however, the other sites did not have clear location information. Regardless, when the hazardous material incidents are reported, the ADEQ or the identified responsible party removes the hazardous materials immediately or shortly after.

If any of the El Rio WCMP alternatives include land near the sites listed above in the summary, then more research will be conducted to find out information such as the type and extent of contamination or environmental hazards associated with these sites. Likewise, if the District determines that the potential WQARF site, known as the Middle Gila River site, is within the project area and project alternatives are in the vicinity of this site, then more research will be conducted. Otherwise, based on a search of the environmental regulatory records, the planning team should not be concerned with other hazardous material sites within or near the project area for planning purposes at this time.

As a final point, this report discusses sites that the local, state, and federal environmental agencies are aware of, however, unknown hazardous sites potentially exist any where in the project area. Thus, a Phase I Environmental Site Assessment, which includes site inspections, will be done for the final selected project alternatives and alignments prior to any property acquisition and project implementation.

Unauthorized **SOLID WASTE SITES**

Planning for the El Rio WCMP includes consideration of unauthorized present and past solid waste disposal activity. The effort included compilation of a solid waste inventory of dumpsites in the El Rio project area identified during field reconnaissance. In conjunction with the compilation of the inventory of unauthorized dumpsites, a GIS-compatible map showing areas of low, medium, and high solid waste densities was prepared and a copy of the map is contained in the Appendix to this report.

Solid waste appears to be ubiquitous in the El Rio project area. However, significant concentrations are limited to areas of easy and frequent public access. The areas of significant solid waste accumulation are west of the north end of the Estrella Parkway bridge crossing of the Gila River; within an abandoned sand and gravel mine located at Miller Road and the Gila River south of the Town of Buckeye; and along a dirt road on the north bank of the Gila River between Miller Road and SR 85. An abandoned municipal solid waste landfill formerly utilized by the Town of Buckeye and located at the intersection of Miller Road and the Gila River is also considered to be significant because the waste was buried inplace when the facility was closed in the 1970s and the facility could be susceptible to exhumation by flooding.

CULTURAL RESOURCES

The El Rio project area contains numerous known significant cultural resources, as well as an unknown number of significant cultural resources. If a flood control project is potentially going to impact any cultural resources, then measures would be taken to record and mitigate any potential adverse effects to the cultural resources in the area. While well over 100 cultural resource sites are known to exist, only 10% of the project area has been surveyed. In a multidisciplinary study of the El Rio project, the subject of cultural resources offers a major value, one that should be protected, but also one that offers numerous options for education, visitation and recreation.

OPPORTUNITIES AND CONSTRAINTS

Use and development of land within the project area for the purposes of the El Rio Project will require coordination with public agencies and private owners. Certain types of development and use may be constrained by the management goals of public agencies. It may be difficult to prevent certain uses and development on private land without the cooperation of the landowners and the assistance of county and municipal planning and zoning authorities.

Opportunities to implement components of the El Rio Project may exist where the development goals of the project can be matched with those of the landowners. To the extent that the plans and development of the El Rio Project can be successfully matched with existing conditions or plans of owners of public and private land in the project area, opportunities for environmental development or enhancement will be realized.

INTRODUCTION

This portion of the environmental resources report characterizes the anthropogenic features on the El Rio Landscape. In many cases these features can represent both opportunities and constraints for flood control project planners and designers. These features include bodies of water, cultural resource sites from historical and prehistoric civilizations, hazardous waste sites, solid waste sites, and current land ownership as it relates to rules and regulations governing potential flood control projects. Each of these issues becomes important in the analysis of what can be done and where it can be done, in the portion of the Gila River floodway and floodplain known as the El Rio.

The anthropogenic features of the El Rio Project area are described in the following five sections of this Volume of the Environmental Resources Report. Each topical area was reviewed or researched to allow the preparation of a Geographic Information System (GIS) layer overlay so that project planning and design, as well as interested groups and stakeholders, could consider these important resource opportunities and constraints as they relate to the flood control project goals.

PROJECT AREA

The El Rio project area is shown on Figure 1. It extends westward and downstream from the confluence of the Agua Fria and Gila Rivers to the State Route 85 Bridge.

ORGANIZATION OF THIS REPORT

Section 3 of the Environmental Resources Report compiles information on the EL Rio project area related to human occupation and development and activity within the Gila River floodplain.

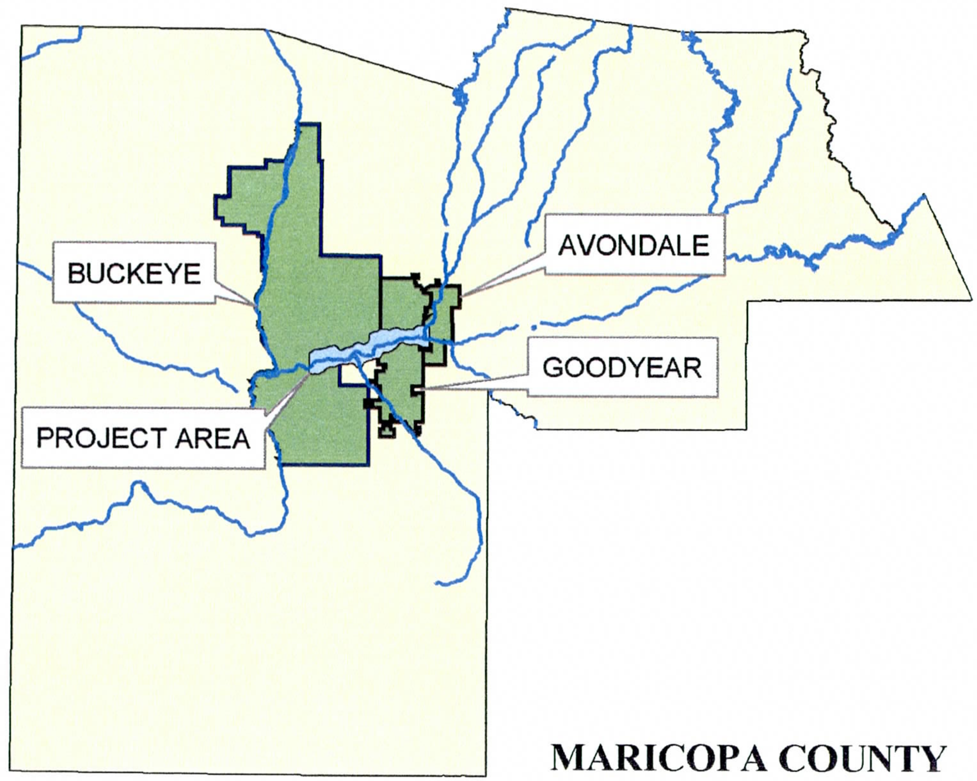


Figure 1

El Rio
Project Location Map

Flood Control District
Of
Maricopa County

Not to Scale

OPEN WATER AREAS

METHODOLOGY

Within the project area, portions of the Gila River are perennial and portions are ephemeral, dependent on storm water runoff. The perennial flow sections are dependent on surface water discharged from agricultural, industrial, and municipal water users. The analysis of open water surface areas utilized historical photography, field survey, and GIS mapping technology to determine past and present open water areas.

In order to identify the location and extent of perennial surface water, the study team reviewed the collection of aerial photographs collected in Phase I of the El Rio study. Four aerial photographs were taken during the low flow season of the year and had sufficient resolution to permit the delineation of open water extant at the time of the photograph. These four aerial photos from the Phase I inventory, as well as the most recent inventory collected by ECOPLAN field survey (during Dec 2002-Feb 2003), were used to complete the comparison of El Rio open waters.

Table 1: Project Photography Used for Identification of Historic Open Water

Flight Date	Source	Use	Locatio	Comments
Jan 2001 Jan 2002	Satellite Imagery Cooper Aerial	Vegetation Mapping and Wildlife Habitat evaluation	Stantec	Near Infra Red color
1, 5 Dec 1977	Cooper Aerial		JE Fuller	1:2,000 - Black and
3, 5 Jan. 1958	USDA	Agricultural Stabilization and	JE Fuller	1:20,000 Black and White
12 Feb. 1949 20 Feb. 1949 27 Mar. 1949	USDA		JE Fuller	1:20,000 Black and White

EL RIO OPEN WATER AREAS

The locations of the perennial open water habitat are critical to the survival of many plants and animals within the El Rio project area. Particularly dependent are the fish, waterfowl, and other obligate aquatic species. The vegetation types of Marsh 1 and Marsh 2, as defined in the vegetation survey section of the environmental resources report, are totally dependent on surface water, and many of the other plant and animal species are dependent on at least seasonal open water.

Table 2: Winter Season Open Water for the El Rio Project Area

Flight Dates	Open Water (acres)	Seasonally Dry Streambed (acres)	Industrial/Agricultural Open Water Area (acres) **	Comments: Source, Photo Quality
Dec. 2002 Feb. 2003	263	NA	103	Field Survey from ECOPLAN vegetation survey
Jan. 2001 Jan. 2002	263	70 *	78	Excellent
1 Dec. 1977 5 Dec. 1977	222	NA	27	Good
3 Jan. 1958 5 Jan. 1958	102	NA	NA	Fair
12 Feb. 1949 20 Feb. 1949 27 Mar. 1949	155	NA	NA	Fair

Notes to table

* Seasonally Dry Streambed was determined from aerial photos by white evaporite

** Industrial and Agricultural areas were constructed ponds and lagoons at dairies and sand and gravel plant sites

The results of the survey and analysis are shown on Table 2. The results show there is currently as much or more open water surface area in the EL Rio section of the Gila River as in prior years. The primary sources of this open water are from the outfalls of the 91st Ave municipal water treatment plant, agricultural return flows, and tailwater from the irrigation canals. For graphic portrayal of these historical water flow areas, the GIS overlay in the Appendix shows the location and extent of each of these data sets.

At the lower section of the project area, the permanent water flows are maintained by a combination of surface water discharges and a higher groundwater table. The quality of the water in these open water areas is dependent on the source of the water. Major surface discharges are shown on the GIS overlay for open waters.

OPEN WATER AREA SUMMARY

Historical aerial photos and field survey techniques were used to identify the extent of open water during the low water winter period for the El Rio project area. The analysis determined that over 200 acres of open water are present in the 17-mile reach of the project area. This open water habitat results from discharges of municipal wastewater, agricultural return waters, and irrigation tailwater, as well as natural groundwater expression at the downstream end of the project area.

These discharges of surface water form habitat for aquatic species of plants and animals that depend entirely, or seasonally, on these water sources. The quality of the open water is defined by the discharge water sources.

The analysis of aerial photographs determined that current open water areas are more extensive than in the past. There is roughly twice the open water acreage in the last few years, including the 2002-2003 drought year, as compared to data from the 1940-1960 period. Analysis of the historic aerial photographs shows that the stream bed of the El Rio section of Gila River was channelized during low flow periods. This channelization left long narrow ditches through the bottom of what appeared to be broad pond areas. This practice of ditching or channelizing the low flow stream bottom restricted historic aquatic habitat and drained pond areas. The photographs do not indicate whether this was done for vector control, water harvest, or agricultural drainage; this is not a current practice in the El Rio project area.

Recommendations for Open Surface Water Habitat

- Maintain or increase the amount of surface water available as aquatic habitat
- Restore or maintain adequate water quality for diverse fish and wildlife resources
- Reduce active waterfowl habitat near operating airports
- Maintain connections between surface water bodies to allow wildlife and fish migration
- Maintain continuous flows through the corridor to maintain dissolved oxygen levels
- Avoid stagnation and isolation of surface water
- Develop access for recreational fishing, while acknowledging challenges of health advisories for consumption of fish from the project area
- Improve water quality to allow removal of health advisories for consumption of fish
- Plan for beaver management and water level manipulation at selected open-water bodies

IDENTIFIED CULTURAL RESOURCES SITES

METHODOLOGY

The Flood Control District of Maricopa County retained James B. Rodgers of Scientific Archaeological Services, to conduct a cultural resource assessment of the El Rio project area. The resulting comprehensive assessment presented information about, and locations for, all known significant cultural resource sites in the El Rio locale. The maps contained within the assessment were utilized to produce the GIS layer presented in the Appendix, which depicts the known sites. Importantly, only approximately ten percent of the project area has been systematically surveyed for cultural resources. It is anticipated, therefore, that the overall site density is very high. As indicated in Jim Rodgers' excellent cultural resource assessment of the region, a variety of site types are represented by the known sites.

Rodgers identified several important cultural themes throughout the project area. These include canal irrigation, residential living, rock art production, and natural resource exploitation. These particular cultural themes are relevant based upon the site types known to exist. Although other themes may be determined in the future, we recommend that these themes be retained until a systematic survey of the project area has been conducted.

Rodgers makes very important recommendations in his assessment (Rodgers 2002). Prior to implementing any ground disturbing activity in the project area, any areas of potential effect should be systematically surveyed for cultural resources. Measures should then be taken to preserve those resources considered significant, either by physical protection or testing/data recovery. Of particular interest to our team in regard to cultural resources is the potential for interpretive development in a sustainable manner that protects and preserves the information potential of the resources.

The El Rio project offers a valuable opportunity to protect both the cultural and natural environment through proper resource management. We offer recommendations regarding the potential interpretive development of the El Rio project area. Of particular note is the absence of discussion regarding specific sites and their appropriateness or lack of appropriateness for interpretive development. The selection of specific sites, assuming interpretive development is to occur, will depend on a number of factors requiring the acquisition of additional data.

The primary theme that we would like to recommend is Rodger's "canal irrigation". This theme is tied directly to the river and its environment, and more importantly, runs through both the prehistoric and historic occupation periods. If the decision is made to pursue interpretive development at El Rio, we recommend the following general steps:

Site Investigation

Regardless of the many benefits of the multidisciplinary study in the El Rio project area, one important reason for interpretive development is again, the protection of the resource. Initial efforts might very well be successful with the use of volunteers, especially those connected with the existing Arizona Site Steward program. The El Rio project area of potential effect should be systematically surveyed in order that all existing archaeological sites are recorded. This will certainly increase the number of sites and options regarding selection of those sites relevant for interpretive development.

Initial Determination of Feasibility

After investigating the existing information regarding the sites in question, El Rio project planners must make a preliminary determination of goals. For example, who owns the land? Is the site accessible? Is it nearby or related to natural resources that should be interpreted? These questions must be answered to determine if the site is feasible for interpretative development.

Landowner Support

Support for the protection of the targeted sites should be pursued as soon as possible. The landowners should be approached regarding the future use of their property. As more and more attention is drawn to the area, increased traffic could present the possibility of adverse effects on the cultural resources.

Emergency or Interim Protection

If a site or sites are being impacted by collectors, erosion, vandalism or nearby land development, immediate measures should be taken to protect the resources. These measures might include fence construction, berming of access roads, water runoff control measures, etc. The establishment of regular monitoring is often difficult, but can be very valuable. Nearby residents might be encouraged to inspect the site or sites on a continuing basis.

Additional Support

The proposed effort at interpretive development should be presented to all stakeholders in the El Rio project. The potential benefits of tourism dollars, education, recreation, scientific significance, community pride and historic preservation should be described in detail to likely project supporters. Initial funding for further site protection measures may be possible to obtain at this point.

Formalized Project Support

Contacts should be established at the State Historic Preservation Office and one or more of the following depending upon jurisdiction; the town of Buckeye, the County Parks department, BLM, etc. Regardless of the agency or agencies involved, the intent is to formalize a concern for protection, and assuming it is warranted, a consideration of the feasibility of interpretive development. At this point, if necessary, initial inquiries should be made regarding the feasibility of transferring land ownership to the most appropriate jurisdiction.

Pre planning Efforts

Depending upon the level of perceived site significance, support should be sought for the interpretive goals and for establishing a planning committee comprised of archaeologists, the agency representatives involved in the El Rio project, and interested local citizens. The inclusion of elected officials will also enhance the likelihood of success. This input from volunteers and salaried professionals will temporarily postpone the need for funding. The size of the committee should be controlled, however, to include only the required expertise. Consideration should also be given to research in the long term. Is there an archaeologist or institution that is interested in the site(s) as the subject of research? If not, can the interest be generated? The early consideration of long term research requirements may help maximize continuity for the project. This step is critical as it will determine the level of needed contract work compared with that of long term institutional funding. The preferred objective may be to identify an interested research institution that may be willing to make a long term commitment.

A major chore will be deciding which site(s) to develop. Fortunately, a project such as this offers a great number of options. The nature of the resource, land ownership and accessibility questions are three of the prime criteria that must be considered.

Assuming a commitment has been made by the planning team, the project will benefit from formalizing the effort. A memorandum of agreement or some other binding document between all involved parties should be drafted to establish the efforts of continual coordination. The goals mentioned in the agreement may be, and probably should be, somewhat general at this stage of the process. The advantages of including a number of interested organizations in the effort cannot be overstated. The dangers of situations involving differences of opinion, personality conflicts and differences in objectives are overshadowed by the advantages of maximizing available resources.

The actual planning process must be discussed and agreed upon. The first major consideration is the scope of the project. The subject of interpretation will be overseen by a coordinating committee and involve a variety of disciplines. Therefore, cultural resources will be part of a much larger effort. Once the area is surveyed for cultural resources, the extent and significance of the cultural resources must be seriously considered in order to determine potential scale of development in a preliminary manner and how it fits in with the overall interpretive goals for El Rio. An early consideration of opportunities and constraints will minimize incremental decision-making later in the process. The planning process should be formalized in writing after an agreement is reached. Once goals have been established, the planning team should immediately identify data needs in both planning and in cultural resources. The expertise of the planning committee will be invaluable during this process.

It may be of value to develop an overall master interpretive plan, if it is determined that interpretive development will be an important focus of the future of El Rio. Once again it is critical for team members to collaborate with the biologists and ecologists so that potential functional relationships among the various resources in the El Rio project area are considered to the greatest advantage.

Facilities

A detailed discussion of types of interpretive facilities is beyond the scope of this discussion. A wide variety of facilities can be considered ranging from limited interpretive trails with appropriate signage to large scale interpretive centers with extensive park trail systems. The extent and significance of the resources as well as the scope of the overall project will suggest the level of facility development. Facilities' planning, therefore, is a function of the resource element and the interpretive element.

The Interpretive Element

The concept of interpretation is comprehensive in nature. The need for interpretation in locations such as El Rio is recognized by many people, but the subject usually does not receive adequate consideration early in project planning. It has often been treated as an afterthought, taking the form of simple explanations of past life ways based on existing data. Depending upon decisions made regarding the value of interpretation, the El Rio project may warrant a standalone interpretive plan. As with many other types of plans, the interpretive plan is a dynamic document. It results from input by archaeologists, interpretive specialists, the El Rio planning team, etc. It cannot remain static, however, as feedback from stakeholders and visitors must continually be sought. The resulting interpretive program will be a dynamic and innovative effort to maintain visitor interest and involvement, while at the same time providing maximum protection of the resources.

The concept of innovation is critical to interpretation of cultural resources. The passive recreation exhibits describing history and prehistory may appeal to a certain segment of visitors, but maximizing visitor enjoyment and involvement will broaden the visitor experience and eventually capture a wider variety of visitors. For example, the opportunity for visitors to assist archaeologists in actual excavations offers a feeling of accomplishment and may include the thrill of discovery.

In developing the interpretive program, serious consideration must be given to the means of communication. The effectiveness of different means of communication for varying types of information must be maximized. The interpretive specialist should work closely with the archaeologists in determining the most appropriate data to interpret, hopefully seeking the most interpretable data as part of the archaeological research effort. The challenge then becomes one of passing the information on to the visitor in an understandable and interesting manner. Signs with descriptive information are certainly part of this, but they are not enough. The full range of media must be explored including indoor and outdoor exhibits, written material in the form of brochures and reports, signs, labels, audio devices, lectures, living interpretation, guided and self-guided tours, etc.

EL RIO CULTURAL RESOURCE SITES

A total of 131 cultural resource sites were identified. Included were 57 prehistoric sites, two combined prehistoric/historic sites, and 72 historic sites (Rodgers 2002). Additional information regarding the prehistory and history of the project area is available in Rodger's report.

CULTURAL RESOURCES SUMMARY

In summary, the El Rio project area contains numerous known significant cultural resources, as well as an unknown number of significant cultural resources. Measures should be taken to record and mitigate any potential adverse effects to the cultural resources in the area. While well over 100 cultural resource sites are known to exist, only 10% of the project locale has been surveyed. In a multidisciplinary study of the El Rio project, the subject of cultural resources offers a major value, one that should be protected, but also one that offers numerous options for education, visitation and recreation.

Recommendations for Cultural Resources

- Avoid known cultural sites wherever possible
- Survey all potential disturbance areas for cultural resources
- Mitigate cultural resources where necessary
- Establish an interpretive center for educational purposes to show the rich cultural history of the area

HAZARDOUS MATERIALS ISSUES AND ENVIRONMENTAL RECORDS REVIEW

The Flood Control District of Maricopa County (District) is currently developing the El Rio WCMP to develop alternatives to alleviate flooding problems along the Gila River. The El Rio WCMP project area is a 17.5 mile reach of the Gila River west of Phoenix. Specifically, the project area boundaries are the Agua Fria river confluence on the east, MC 85 Bridge on the west, and the Gila River floodplain on the north and south.

Part of the planning process is to prepare an environmental resource report which identifies any environmental issues that the study team needs to be aware of during the planning process. Being aware of the potential environmental issues within the project area can help avoid delays, reduce unforeseen costs, identify multi purpose opportunities (e.g., ecological, educational, recreational, etc.), and ensure compliance with regulations in the project planning, design, implementation, and construction phase. The environmental records review is one section of the environmental resource report.

METHODOLOGY

The purpose of the environmental records review is to identify any known or potential hazardous waste sites or sites currently under investigation for potential environmental violations in or near the project area. To accomplish this task, District staff reviewed various environmental records from federal, state, county, and local agencies at the Arizona Department of Environmental Quality (ADEQ) library and by using the ADEQ online databases. Hundreds of sites were located near the project area, of which District staff searched through and determined if these sites were actually within project area or within the specified minimum search distances for the specific type of site (Table 3).

Due to the size and the needs of this planning study, site reconnaissance, historical uses review, interviews with property owners, and agency inquiries were not part of this task. However, a Phase I Environmental Site Assessment in accordance with the current American Society of Testing and Materials (ASTM) standards will be done for the specific locations of the final selected project alternatives during the design phase and prior to any property acquisition. A summary of the environmental records review follows.

NATIONAL PRIORITIES LIST (NPL)

The NPL is a list of the United States Environmental Protection Agency's (EPA) highest priority sites for remedial action (i.e., Superfund sites). The release date for this information is July 2002. The minimum search distance from the project area is one mile.

NPL sites were not found within the project area or within one mile from the project area. The Phoenix Goodyear Airport (PGA) South is a NPL site, however, the southern boundary of the PGA South groundwater contamination plume is Highway MC-85, which is approximately 1.4 miles from the Gila River.

Table 3: Environmental Records Searched and Corresponding Search Radii

Environmental Record	Search Distance – ASTM Standards
National Priority List (NPL)	1.0 Mile
CERCLIS	0.5 Mile
RCRA Generators	0.25 Mile
RCRA TSD Facilities	1.0 Mile
RCRA Corrective Action Database	1.0 Mile
Water Quality Assurance Revolving Fund (WQARF)/ Arizona Superfund Program List	1.0 Mile
Arizona CERCLA Information and Data Systems (ACIDS)	1.0 Mile
Underground Storage Tanks (UST)	0.125 Mile
Leaking Underground Storage Tanks (LUST)	0.5 Mile
Hazardous Materials Incident Logbook	Limited to Project area
Dry Well Registration	Limited to Project area

COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION AND LIABILITY INFORMATION SYSTEM (CERCLIS)

The CERCLIS list is a compilation by the EPA of sites that have been or are currently under investigation for releases of hazardous substances for possible inclusion on the NPL. The release date for this information is December 2002. The minimum search distance is one-half mile.

CERCLIS sites were not found within the El Rio project area or within one-half mile from the El Rio project area.

RESOURCE CONSERVATION RECOVERY ACT (RCRA) GENERATORS DATABASE

The RCRA generator database lists facilities that have notified the EPA that they generate hazardous waste. The release date for this information is September 2002. The minimum search distance is one-eighth mile.

One RCRA Generator was found in the Gila River at Tuthill Road, which is appropriately designated as the Tuthill Road Bridge Site. On the RCRA database, the information is vague and doesn't list the type of hazardous waste that was generated, the date, or any other pertinent information. The RCRA ID number is AZD982-035-644. This site was also listed on the hazardous material incident database, which indicates they could be referring to the same incident. No other RCRA generators were found within the El Rio project area or within one-eighth mile from the El Rio project area.

RCRA TREATMENT, STORAGE, AND DISPOSAL FACILITIES (TSDF) DATABASE

The EPA maintains the RCRA TSDF database which identifies facilities that have obtained either a final or an interim status permit for the treatment, storage or disposal of hazardous wastes, and known facilities operating without a permit. The release date for this information is August 13, 1999. The minimum search distance is one mile.

RCRA TSDFs were not found within the El Rio project area or within one mile from the El Rio project area.

RCRA CORRECTIVE ACTION DATABASE (CORRACTS)

The US Environmental Protection Agency lists corrective actions at hazardous waste handlers. The release date for this information is September 2002. The minimum search distance is one mile.

RCRA CORRACT sites were not found within the El Rio project area or within one mile from the El Rio project area.

WATER QUALITY ASSURANCE REVOLVING FUND (WQARF)/ARIZONA SUPERFUND PROGRAMS LIST (SPL)

WQARF is the Arizona state equivalent of the federal Superfund program. The program includes: WQARF priority list sites, Non-NPL Department of Defense sites, other WQARF sites, and voluntary clean-up sites. The release date for this information is July 2002. The minimum search distance is one mile.

WQARF sites were not found within the El Rio project area or within the one mile search distance. The Western Area PCE Plume in Avondale and Goodyear is near the project area, however, the southern boundary of the groundwater plume is 1000-feet north of MC-85 which is approximately 1.5 miles north of the Gila River.

POTENTIAL WQARF SITES ON THE ARIZONA SUPERFUND PROGRAMS LIST (ASPL)

The Arizona Superfund Programs List (ASPL) replaced the Arizona CERCLIS Information Data System (ACIDS) in July 2000. The ACIDS list was used by the ADEQ Superfund Programs Section (SPS) for the past decade in tracking WQARF sites and portions of sites, potential WQARF sites, referrals, and other cases of interest to the SPS. As of March 13, 2000, there were approximately 1,500 entries on the ACIDS list. While some of the cases on this list were relevant to Arizona's Superfund Program, others were not and their inclusion may have been misleading. For this reason, the SPS elected to archive the ACIDS list and no longer distribute it. In its place, the ACIDS list has been replaced by the Arizona Superfund Programs List (SPL). The ASPL is more representative of the sites and potential sites with the jurisdiction of the ADEQ SPS. The ASPL includes WQARF sites, potential WQARF sites, NPL sites, and Department of Defense sites requiring SPS oversight. The ASPL was searched to find sites that are listed as potential WQARF sites, which are cases that are awaiting or undergoing a WQARF preliminary investigation (PI).

One site listed as a potential WQARF site on the ASPL could be located in the El Rio project area, however, more research needs to be done to verify this. District staff contacted several people at ADEQ to find out more about this site, however, at the time this report was completed, no additional information was obtained. The District will continue to attempt to find out more information about this site. The site information is listed on the ASPL as:

Name: Middle Gila (formerly known as WQ-Gila River DDT and Lower/Middle Gila River)

Status & Status Date: Pending Preliminary Investigation; 4-29-97

Location: a specific location was not listed

UNDERGROUND STORAGE TANKS (USTS) LIST

The ADEQ maintains a database of registered USTs in the State of Arizona. The release date for this information is February 26, 2002. The minimum search distance is one-eighth mile.

There were no USTs listed within the El Rio project area or within one-eighth of a mile from the project area.

LEAKING UST (LUST) LIST

The ADEQ maintains a database of USTs that have been reported as leaking. The release date for this information is November 2002. The minimum search distance is one-half mile.

LUST's were not listed within the El Rio project area or within one-half of a mile from the project area. However, the study team did identify a leaking aboveground storage tank (AST) in the Gila River Floodway between Sarival Road and Cotton Lane alignments (Photograph 1; Latitude and Longitude: 33° 23' 14.77" N & 112° 25' 00.85"). The size of the tank was approximately 500 gallons. It is unknown who owns the tank or what the material is, but it appears to be diesel fuel or oil. There was significant surface soil contamination, however, it's not known what the depth of the contamination is and, consequently, if the groundwater is potentially contaminated unless sampling is conducted.

Photograph 1: Leaking AST in the Gila River floodway between Sarival Road and Cotton Lane alignments.

ACTIVE, INACTIVE, AND CLOSED SOLID WASTE FACILITIES

The ADEQ maintains a list of active, inactive, and closed municipal solid waste landfills, rubbish landfills, and solid waste dumps. The release date for this information is November 2002. The minimum search distance is one-half mile.

One closed solid waste landfill was listed as being located at Miller Road and the Gila River. The operator was listed as the town of Buckeye. No other closed, active, or inactive solid waste landfills were listed within the project area or within one-half mile search distance from the project area. However, throughout the Gila River and the project area, there are numerous illegal dumping sites (Photograph 2). Most of the solid waste appears to be general household waste, however, some suspect asbestos containing waste was observed.

Photograph 2: Example of the numerous illegal dumping sites throughout the Gila River

HAZARDOUS MATERIALS INCIDENT LOGBOOK

The Hazardous Materials Incident Logbook (HAZMAT Log) documents chemical spills and incidents referred to the ADEQ. The release date for this information is June 30, 2001. The search is limited to the project area.

Eleven listed HAZMAT sites are potentially located within the project area (Table 4). The first HAZMAT site listed below is definitely located within the project area. The other ten HAZMAT sites may be located within the project area, but specific information on the exact location of the sites was not provided. Regardless, when the chemical spills or other hazardous incidents are reported, ADEQ or the responsible party removes and remediates the hazardous materials. Therefore, even if a HAZMAT incident is located in the project area, it is not likely to affect the planning process or the project's final alternative selection.

Table 4: Hazardous Materials Incidents Potentially Within the El Rio Project area

Responsible Party	Incident Date	Incident Number	Listed Location	Chemical	Quantity
Unknown	4/9/00	00-116-E	Tuthill Rd. & Salt River	Drug Lab Chemicals	Miscellaneous
APS	12/8/97	98-086-E	Hassayampa Pump Station	Effluent Wastewater	4.5 million gallons
United Van Lines	10/11/89	89-320	SR 85, MP 116 Buckeye	Diesel Fuel	150 gallons
Unknown	6/4/97	97-054-E	SR 85W, S. of Canal Drive, Buckeye	Used Oil	6 55-gallon drums
Unknown	11/27/96	96-099-B	Miller Rd. Flood Control Dike, Buckeye	Unknown	>200 gallons
Unknown	5/11/93	93-013-E	Unknown, Goodyear	Unknown	Unknown
Unknown	6/20/94	94-035-A	100 yds. NE of Rainbow Valley & Elliot	Roofing Tar	3 drums
City of Goodyear	12/22/96	96-111-C	Well #3, Goodyear	Chlorine	15-19 pounds
Bill Funkenhouser	2/24/89	89-059	Goodyear	Unknown	50-60 drums
Fertizona	4/27/89	89-117	Field south of Goodyear	Anhydrous Ammonia	200 gallons

DRY WELL REGISTRATION

The ADEQ Dry Well Registration list was reviewed to identify any dry wells registered to the Property. The release date for this information is March 26, 2002.

No registered dry wells were located within the project area.

SUMMARY AND RECOMMENDATIONS

Various environmental records from federal, state, county, and local agencies were reviewed by the District to identify whether hazardous material sites or potential hazardous material sites are located within the El Rio WCMP project area or at offsite locations within the specified minimum search distances. The sites that were located in or near the project area are listed below. Significant hazardous materials sites within the El Rio project area are shown on the map attached to this report in the Appendix.

- A RCRA generator site was located at the Gila River and the Tuthill Road Bridge. The type of hazardous material was not listed.

- The Arizona Superfund Program List (ASPL) listed one potential WQARF site, known as the Middle Gila site, which may be located in or within 1-mile of the project area. The location description for the Middle Gila site was not listed, however, more research is currently being done to determine where this site is. The status of the site was listed as "pending preliminary investigation" in April 1997.
- A leaking aboveground storage tank (AST) was identified in the Gila River Floodway between Sarival Road and Cotton Lane alignments. The tank owner and leaking substance are unknown, however, the substance appears to be oil or diesel fuel. Depending on the extent of the soil contamination, the groundwater could be impacted as well.
- One closed solid waste landfill was listed as being located at Miller Road and the Gila River. The operator was listed as the town of Buckeye.
- Eleven Hazardous Material Incident sites were listed in the HAZMAT logbook and potentially occur in the project area. One site, located at the Tuthill Bridge and the Gila River, is definitely in the project area, however, the other sites did not have clear location information. Regardless, when the hazardous material incidents are reported, the ADEQ or the identified responsible party removes the hazardous materials immediately or shortly after.

If any of the El Rio WCMP alternatives include land near the sites listed above in the summary, then more research will be conducted to find out information such as the type and extent of contamination or environmental hazards associated with these sites. Likewise, if the District determines that the potential WQARF site, known as the Middle Gila River site, is within the project area and project alternatives are in the vicinity of this site, then more research will be conducted. Otherwise, based on a search of the environmental regulatory records, the planning team should not be concerned with other hazardous material sites within or near the project area for planning purposes at this time.

As a final point, this report discusses sites that the local, state, and federal environmental agencies are aware of, however, unknown hazardous sites potentially exist anywhere in the project area. Thus, a Phase I Environmental Site Assessment, which includes site inspections, must be done for the final selected project alternatives and alignments prior to any property acquisition and project implementation.

Recommendation for Management of Hazardous Material Sites

- Avoid all sites with known history of hazardous materials
- Conduct site assessments to identify problem areas early in the planning process

SIGNIFICANT SOLID WASTE SITES

Planning for the El Rio WCMP includes consideration of unauthorized present and past solid waste disposal activity. The effort included compilation of a solid waste inventory of wildcat dumpsites in the El Rio project area identified during field reconnaissance. In conjunction with the compilation of the inventory of wildcat dumpsites, a GIS-compatible map showing areas of low, medium, and high solid waste densities was prepared and a copy of the map is contained in the Appendix to this report.

METHODOLOGY

Representatives of Stantec Consulting Inc. conducted reconnaissance of the El Rio project area in December 2002 and January 2003. The purpose of the reconnaissance was to confirm the locations of significant accumulations of solid waste in the project area noted during other surveys and, to the extent possible without laboratory testing, categorize the waste accumulations for management recommendations.

EL RIO UNAUTHORIZED SOLID WASTE SITES

Future development of the area surrounding El Rio project area is anticipated to be suburban residential as the Phoenix and Maricopa County metropolitan area expands to include the formerly remote agricultural community of Buckeye. Currently, the El Rio project area and its surroundings are and have been predominantly rural and agricultural. Access to the Gila River bed from adjacent roadways is limited and the sandy nature of the river channel makes travel with conventional two-wheel drive vehicles difficult.

Reconnaissance of the El Rio project area indicates that the undeveloped areas within and adjacent to the channel of the Gila River downstream from its confluence with the Agua Fria River to the SR 85 bridge have been utilized by the public for the illicit disposal of household trash, appliances, and construction debris. The largest accumulations of these waste materials are located where road access is easiest and surrounding development is either nonexistent or screened from view by topography and/or vegetation. During reconnaissance, major accumulations of construction debris and waste soil were observed west of the north end of the Estrella Parkway Bridge crossing of the Gila River and within an abandoned sand and gravel mine located at Miller Road and the Gila River south of the Town of Buckeye. Smaller accumulations of construction debris were observed beneath the Bullard Avenue Bridge and within the channel of Waterman Wash.

Isolated but significant accumulations of household trash and appliances were observed along a dirt road on the north bank of the Gila River between Miller Road and SR 85. Smaller household trash and appliance dumpsites were observed within the abandoned sand and gravel pit at Miller Road and the Gila River and north of Vineyard Avenue.

Large perennial ponds within the river channel have been utilized for recreation (fishing, overnight camping, and picnicking) and areas adjacent to water access have accumulated litter, trash, and clothing items discarded by the recreants.

Generally, wildcat dumping within and adjacent to the channel of the Gila River in the El Rio project area is limited to areas readily accessible to vehicles transporting significant volumes of material to be disposed. Wildcat dumpers are not interested in transporting rubbish any farther than is necessary to surreptitiously dispose of it. Consequently, the overall concentration of refuse in the El Rio project area is low, rising to medium and high only in those areas frequented for recreation or amenable for the clandestine deposition of construction debris and household waste.

Construction Debris

The heaviest concentrations of construction debris were observed in the power line right-of-way west of Estrella Parkway at the north end of the Estrella Parkway Bridge (Photographs 1 through 6; Appendix). A significant volume of construction debris was also observed in the abandoned sand and gravel pit at Miller Road and the Gila River south of Buckeye (Photographs 17, 18, 23, and 24; Appendix). A small load of asphalt roofing shingles, possibly containing asbestos, was observed in Waterman Wash near its confluence with the Gila River (Photograph 9).

Abandoned Appliances and Household Trash

The highest concentrations of abandoned appliances, furniture, and household trash were observed along a dirt road leading from Miller Road at the abandoned sand and gravel pit to SR 85 (Photos 25 through 30; Appendix). Abandoned appliances and household trash are also common, though not as prevalent, in the abandoned sand and gravel pit at Miller Road and in the power line ROW west of the north end of the Estrella Parkway Bridge. Photograph 7 shows abandoned appliances north of Vineyard Avenue on the south bank of the Gila River.

Litter

Litter is ubiquitous throughout the El Rio project area. Some litter may be blown into the project area by wind or washed into the project area by stormwater flows. The highest concentrations of litter occur near the ponds in the Gila River channel west of Waterman Wash. These appear to be refuse left by recreants fishing, picnicking, or camping in close proximity to open water access. Photos 10 through 16 in the Appendix show litter in the vicinity of the two ponds in the Gila River channel west of Waterman Wash.

Closed Solid Waste Landfill

A closed municipal solid waste landfill is located at the junction of Miller Road and the Gila River. The facility was operated by the Town of Buckeye and, according to Mr. Manuel Alvarez, Water and Wastewater Superintendent and Acting Director of Public Works, was closed in the mid 1970's. The accumulated refuse, consisting primarily of common domestic refuse, was buried inplace.

SOLID WASTE SUMMARY

Solid Waste appears to be ubiquitous in the El Rio project area. However, significant concentrations are limited to areas of easy and frequent public access. The areas of significant solid waste accumulation are west of the north end of the Estrella Parkway bridge crossing of the Gila River; within an abandoned sand and gravel mine located at Miller Road and the Gila River south of the Town of Buckeye; and along a dirt road on the north bank of the Gila River between Miller Road and SR 85. A municipal solid waste landfill site formerly utilized by the Town of Buckeye and located at the intersection of Miller Road and the Gila River is also considered to be significant because the waste was buried in place when the facility was closed in the 1970s and the facility could be susceptible to exhumation by flooding.

Recommendations for solid waste considerations:

- Avoid sites with known history of solid waste disposal
- Remove and relocate solid wastes to legitimate landfill sites
- Conduct Phase I site assessments to identify problem areas early in the planning process
- Initiate a public education or enforcement program to eliminate illegal dumping

OTHER ENVIRONMENTAL CONSTRAINTS OR OPPORTUNITIES

METHODOLOGY

An ownership/surface management map of the El Rio project area was prepared to identify parcels within the project area that may, by virtue of their ownership or surface management, be encumbered by environmental constraints or offer environmental opportunities.

ENVIRONMENTAL CONSTRAINTS

Modification of land use may be impeded by the ownership of certain parcels. Land ownership within the project area is divided between public and private ownership at a ratio of approximately 2:1. Within the El Rio project area the following agencies manage the public land: U.S. Bureau of Land Management, Arizona Department of Game and Fish, Arizona State Land Department for the Arizona State Trust, Maricopa County Department of Parks and Recreation, and the Flood Control District of Maricopa County. In addition, other agencies have influence over parcels in the El Rio project area. For example the airspace around airports has planning and management constraints for minimizing bird strikes. Collectively, the administrative procedures and regulatory requirements of all agencies and the expectations of private land owners and the approval of their development projects must be achieved to implement a complex project such as the El Rio WCMP.

Each of the agencies discussed above have different environmental standards, siting guidelines, administrative requirements, public review protocols, planning requirements, and decision making procedures. Some of these agency decisions are subject to full analysis of impacts through environmental impact analysis, endangered species reviews, long term and short term cumulative effects analysis, and aesthetic considerations such as visual impacts. Other agencies are driven by single resource or single purpose protection, such as evaluation of cultural resources, or wildlife habitat protection. The critical evaluation of approaches and creative development of project alternatives in the next phase of the El Rio WCMP will have to consider all of the requirements of each landowners or regulating agency.

U.S. Bureau of Land Management

The U.S. Bureau of Land Management (BLM) is responsible for managing surface and minerals of federal lands throughout the United States. Planned uses and modifications to surface managed by BLM will require prior approval of that agency. As a federal agency, BLM lands are subject to federal administrative procedures that may not apply to state, county, or private lands.

Arizona State Land Department (State Trust Land)

The Arizona State Land Department is responsible for the management for the benefit of the State Trust of approximately 9 million acres of land in the State of Arizona. State Trust land is eligible for lease or purchase at public auction for development for highest and best use. It is the responsibility of the Land Department to obtain maximum value for the State Trust from the lease or sale of State Trust land. Planning or development of State Trust land in the El Rio project area will require the permission of the Arizona State Land Department.

Arizona Department of Game and Fish

The Arizona Game and Fish Department (AGFD) is responsible for management of a significant land area within the El Rio project area. AGFD manages this land to maximize habitat for wildlife. Planning and development within the El Rio project area will be constrained where proposed development requires the disturbance of existing or planned wildlife habitat on land managed by AGFD. Portions of the AGFD administered lands are entrusted to AGFD by federal agencies. These lands may be subject to deed or interagency agreements that are more limiting that state owned lands.

Maricopa County Department of Parks and Recreation

The Maricopa County Department of Parks and Recreation (MCDPR) controls land within the El Rio project area at its eastern end. It is part of a large tract set aside for preservation as a public park for the people of Maricopa County. Planning and development of the El Rio Project involving MCDPR land will require MCDPR input and approval.

Flood Control District of Maricopa County

The Flood Control District of Maricopa County (District) controls a 1000 foot wide corridor that traverses the length of the El Rio project area. It is the intent of the District to maintain this corridor as a primary watercourse for the unimpeded flow of floodwater within the channel of the Gila River. Planning and development of the El Rio Project will require input and approval from District to ensure that proposed development does not interfere with or impede the flow of floodwater within the 1000 foot corridor controlled by the District.

Private Land

Use and development of private land within the El Rio project area can only be controlled through planning and zoning regulations. If regulations by the adjacent municipalities or Maricopa County are not sufficiently stringent, development and use of private land within the project area cannot legally be controlled unless it is acquired by a government agency from the current private owners.

Environmental Constraints Summary

Use and development of land within the project area for the purposes of the El Rio Project will require coordination with public agencies and private owners. Certain types of development and use may be constrained by the management goals of public agencies. It may be difficult to prevent certain uses and development on private land without the cooperation of the land owners and the assistance of county and municipal planning and zoning authorities.

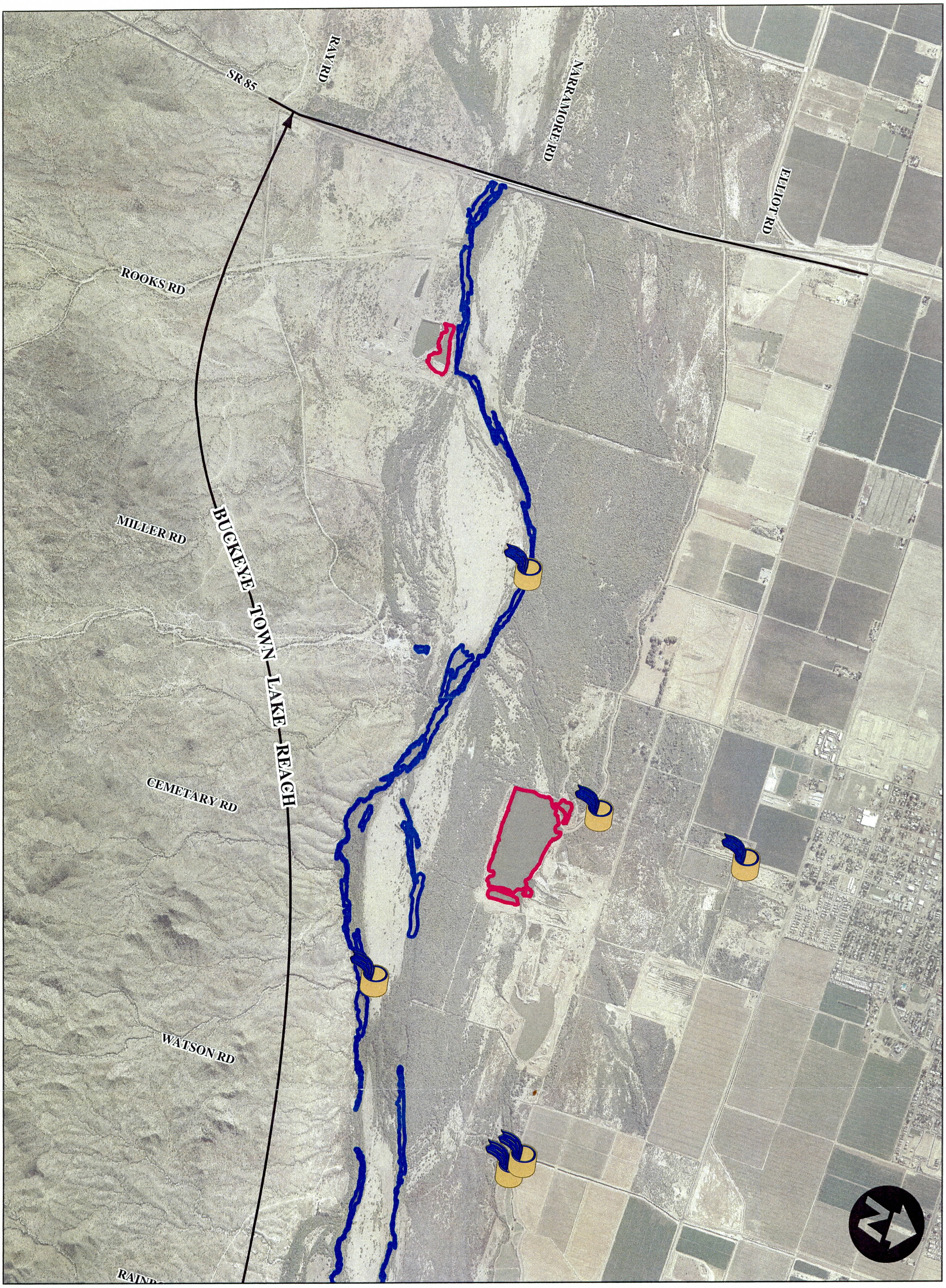
ENVIRONMENTAL OPPORTUNITIES

Opportunities to enhance the planning and development of segments of the El Rio Project may exist on the public lands where the development goals of the project can be matched with those of the surface owners to take advantage of existing conditions or plans for future development. To the extent that the plans and development of the El Rio Project can be successfully matched with the existing conditions and plans of owners of public and private land in the project area, opportunities for environmental development or enhancement will be realized.

Recommendations for project implementation:

- Detailed recommendations from landowners and agencies that would apply to specific parcels are included in technical sections to this report
- Structural controls should be kept to a minimum and used only if non-structural controls are not an option
- Increase conveyance capacity with vegetation maintenance
- Provide increased law enforcement presence if public access in increased
- The floodplain should be protected from encroachment from noncompatible uses

Open Water Areas
Within the El Rio Project Area



Flood Control District
of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Stantec Consulting Inc.
8211 S. 48th St.
Phoenix, AZ 85044

Inflow Points

Water Type
Industrial
Non-Industrial

1 2 3 4

N

EL RIO WATERCOURSE MASTER PLAN

OPEN WATER AREAS
SHEET 1 OF 4 (BUCKEYE TOWN LAKE REACH)
11 NOV 2005

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1 Inch = 2000 Feet

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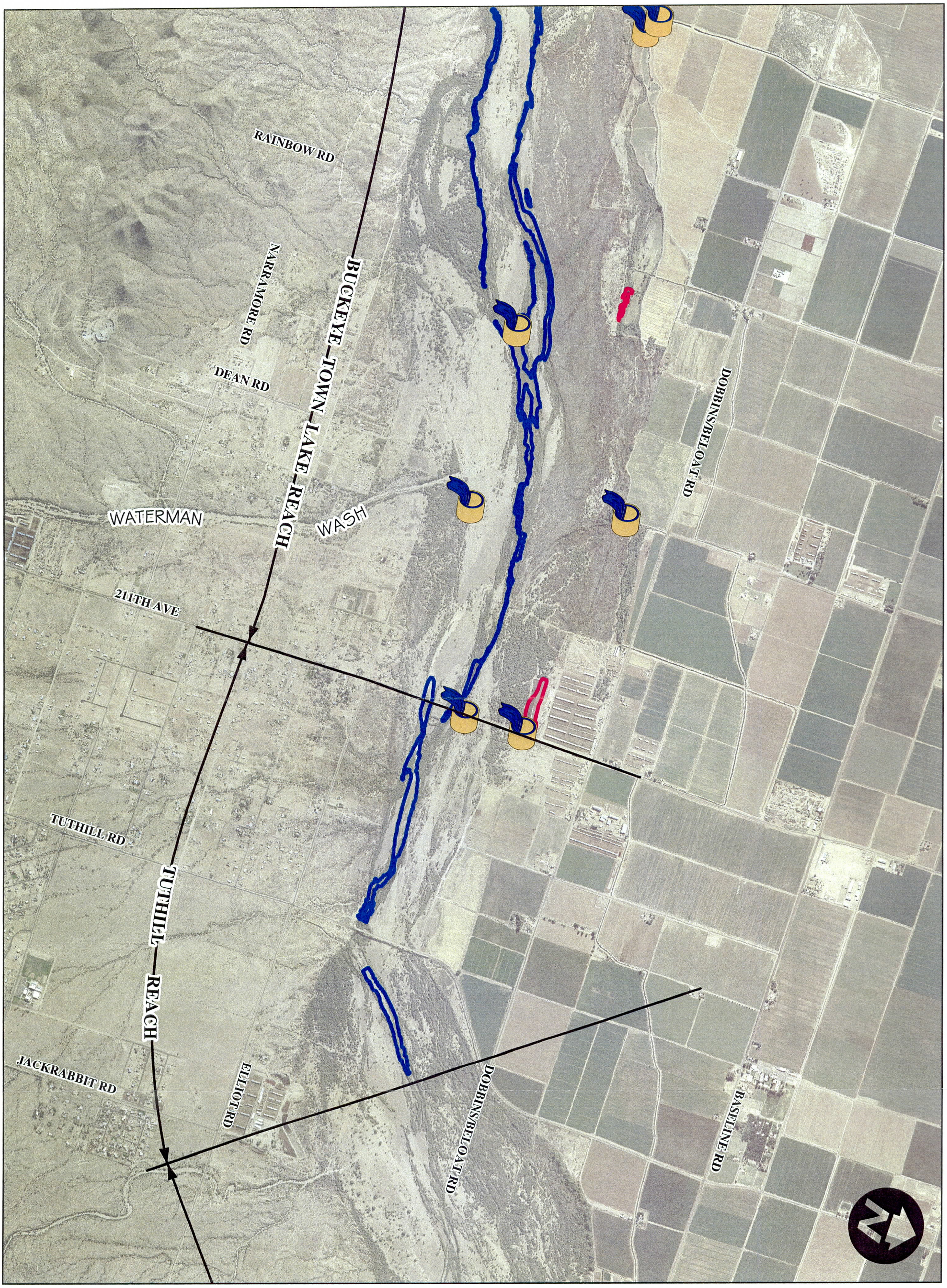

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Stantec Consulting Inc.
8211 S. 48th St.
Phoenix, AZ 85044

Inflow Points

Water Type
Industrial
Non-Industrial

1 2 3 4

N

EL RIO

EL RIO WATERCOURSE MASTER PLAN

OPEN WATER AREAS
SHEET 2 OF 4 (TUTHILL REACH)
11 NOV 2005

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1 Inch = 2000 Feet

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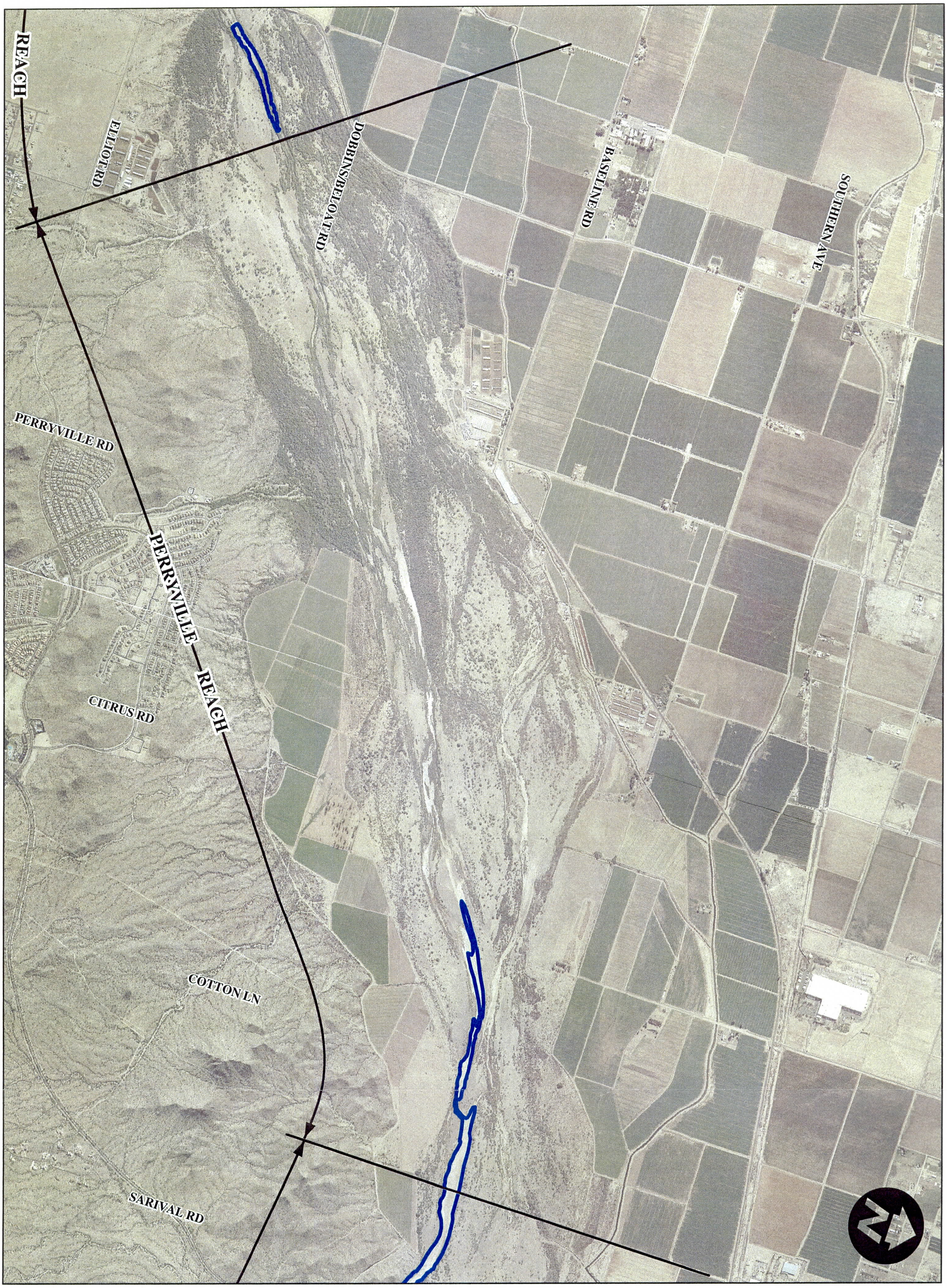

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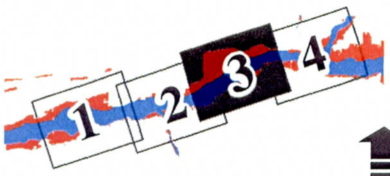
Non-Industrial



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EL RIO WATERCOURSE MASTER PLAN

OPEN WATER AREAS

SHEET 3 OF 4 (PERRYVILLE REACH)

11 NOV 2005

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1 Inch = 2000 Feet

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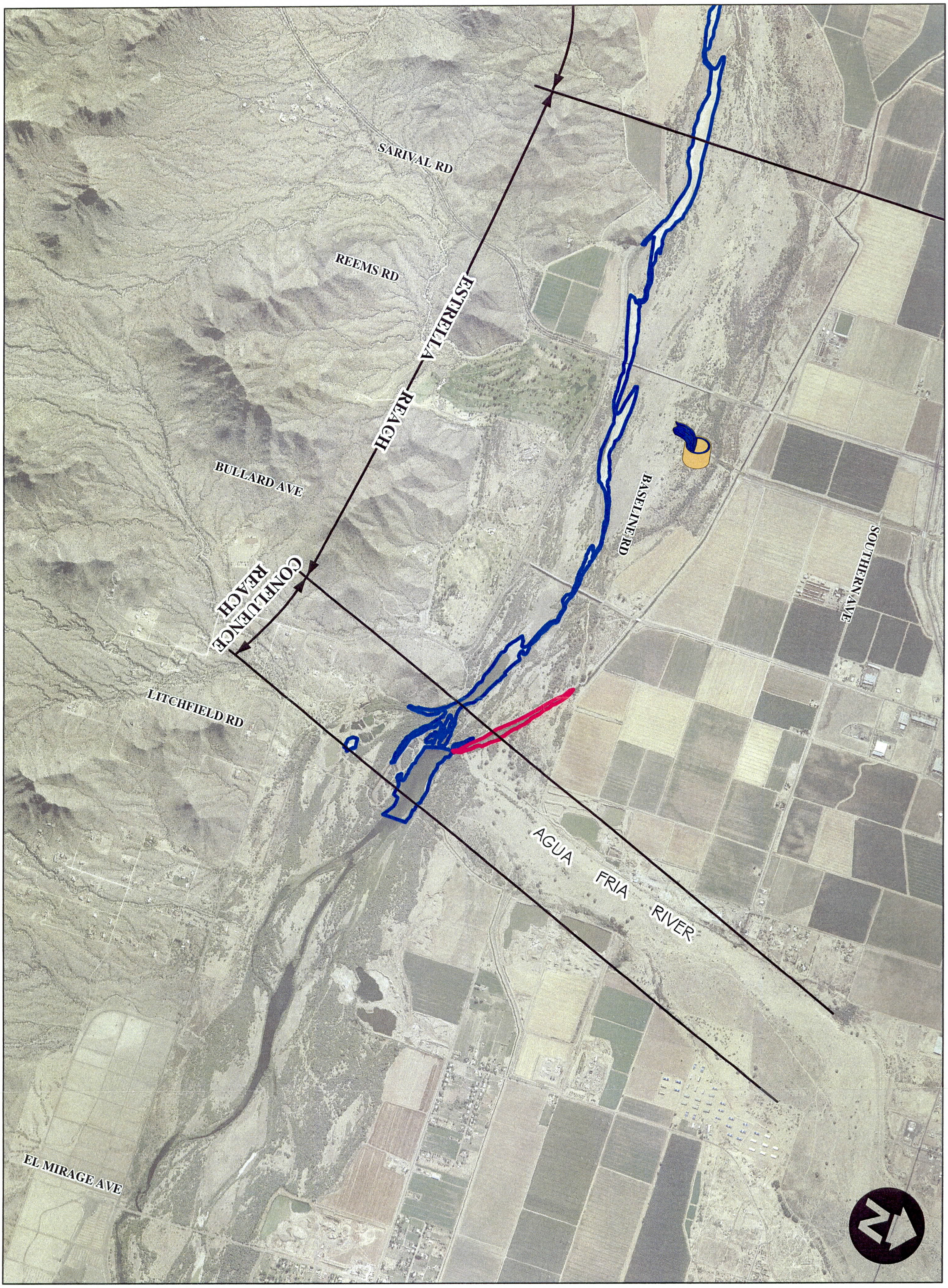

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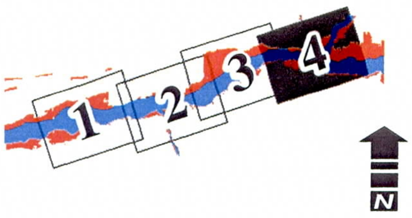

EL RIO WATERCOURSE MASTER PLAN

OPEN WATER AREAS

SHEET 4 OF 4 (ESTRELLA REACH)

11 NOV 2005

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1 Inch = 2000 Feet

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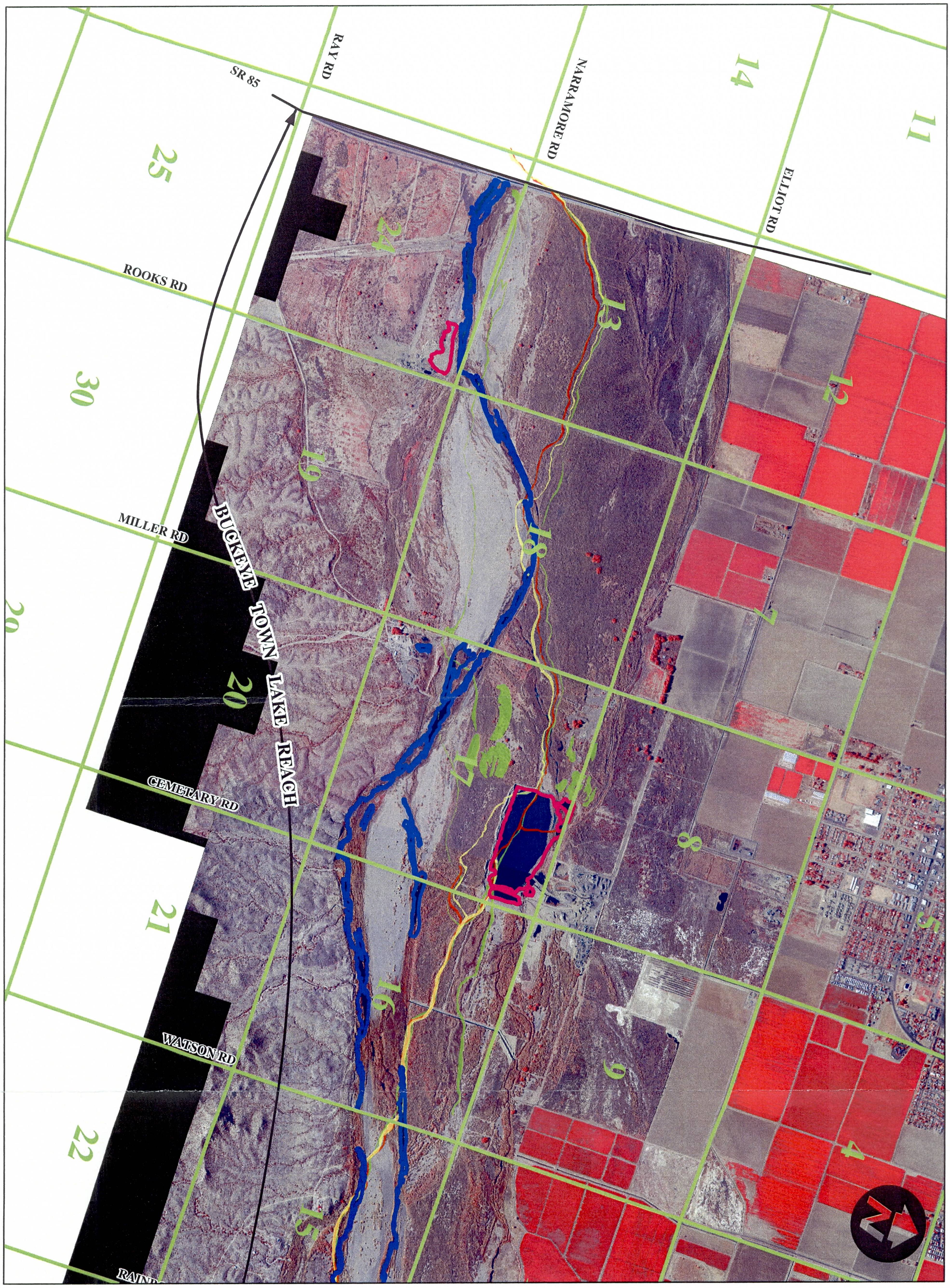
Historical Open Water Areas Within the El Rio Project Area



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2801 W. Durango St.
Phoenix, AZ 85009

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8211 S. 48th St.
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Open Water Areas - 2002
- Industrial
- Non-Industrial

Historical Open Water Areas
- 1949
- 1958
- 1977

EL RIO WATERCOURSE MASTER PLAN

HISTORICAL OPEN WATER AREAS
SHEET 1 OF 4 (BUCKEYE TOWN LAKE REACH)
11 NOV 2005

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1 Inch = 2000 Feet

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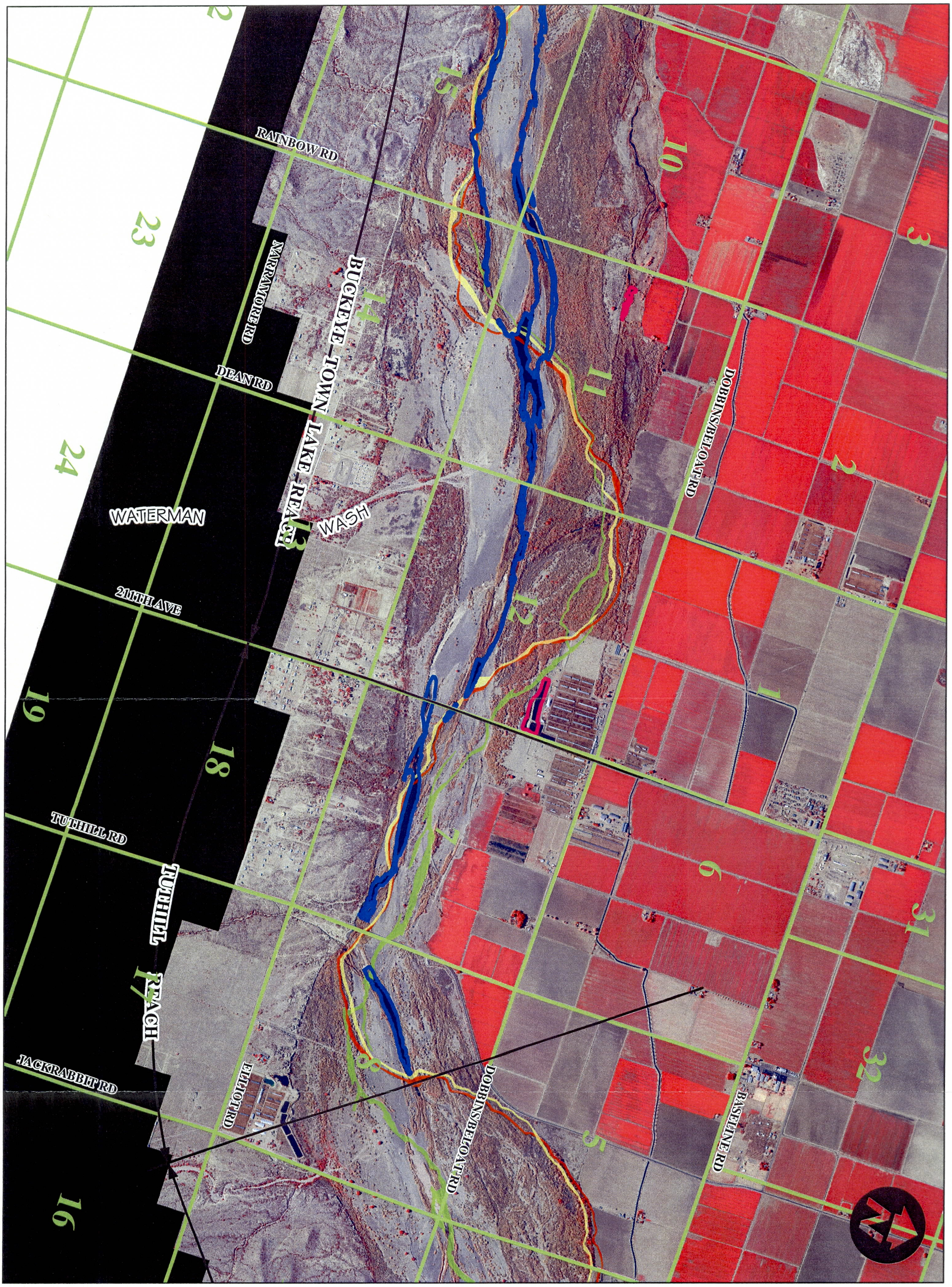

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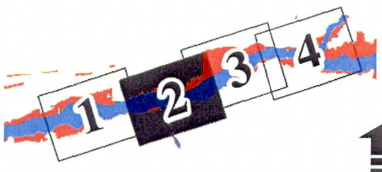

EL RIO WATERCOURSE MASTER PLAN

HISTORICAL OPEN WATER AREAS
SHEET 2 OF 4 (TUTHILL REACH)
11 NOV 2005

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1 Inch = 2000 Feet

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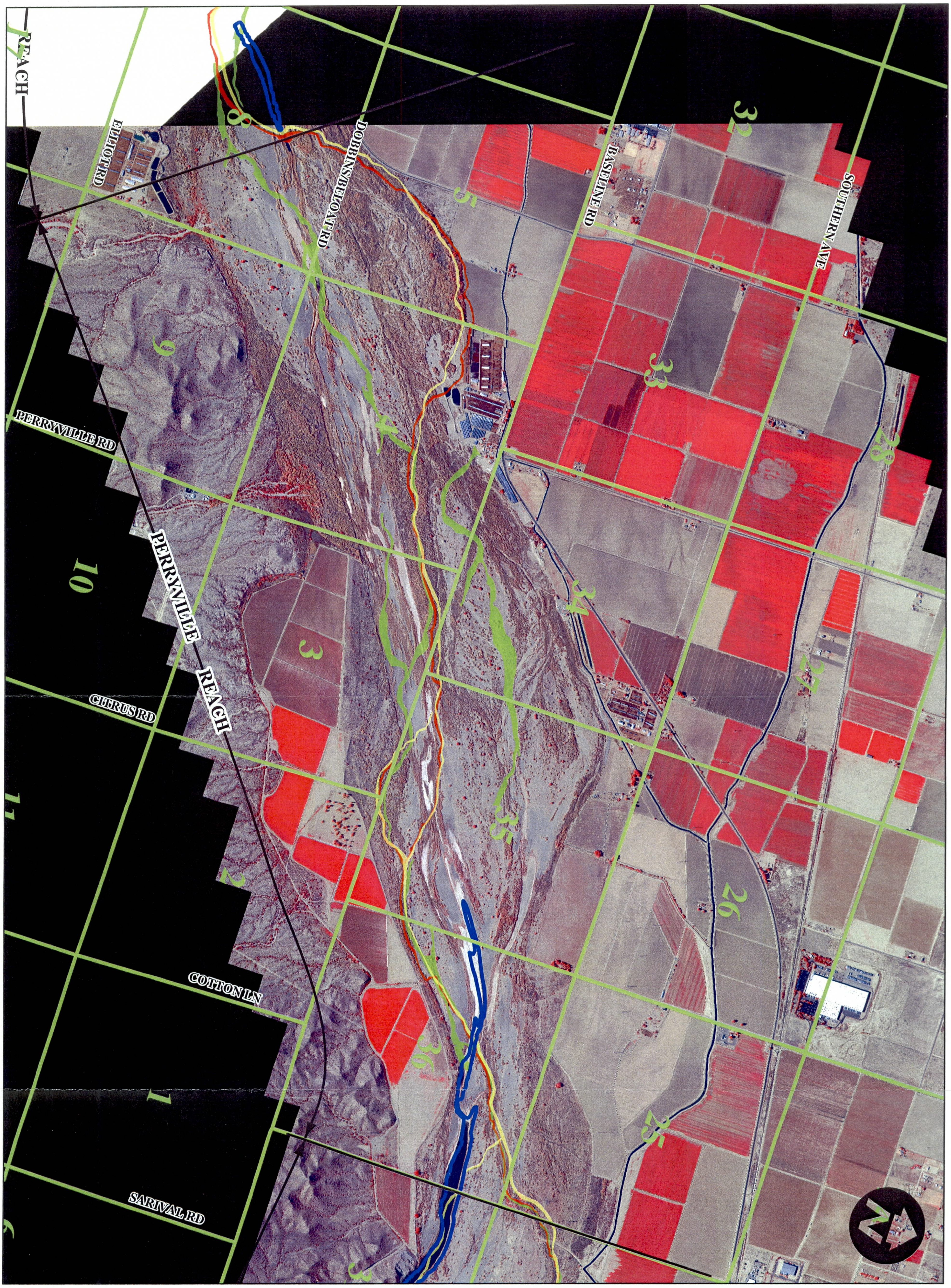

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EL RIO WATERCOURSE MASTER PLAN

HISTORICAL OPEN WATER AREAS
SHEET 3 OF 4 (PERRYVILLE REACH)
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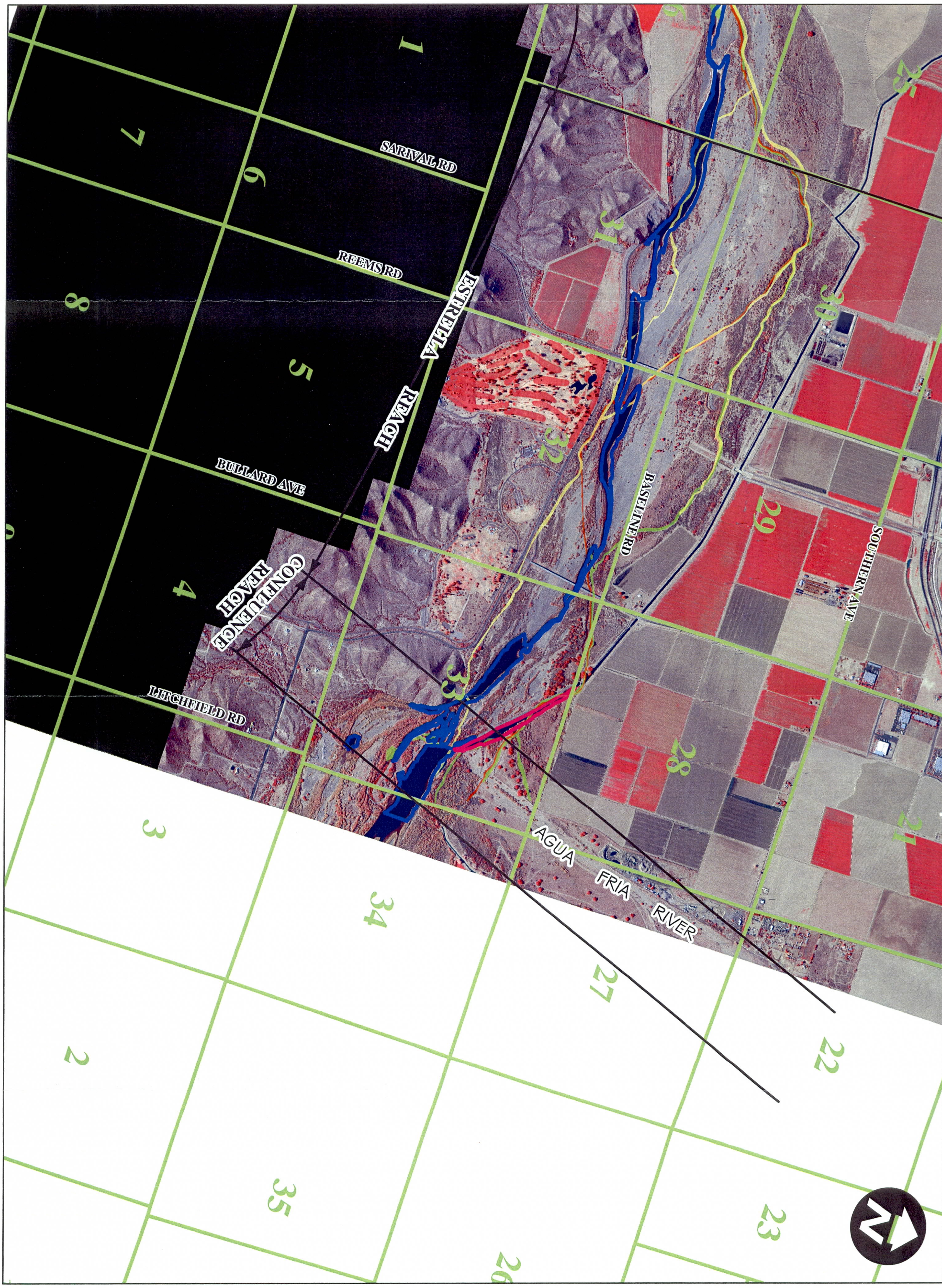

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SHEET 4 OF 4 (ESTRELLA REACH)
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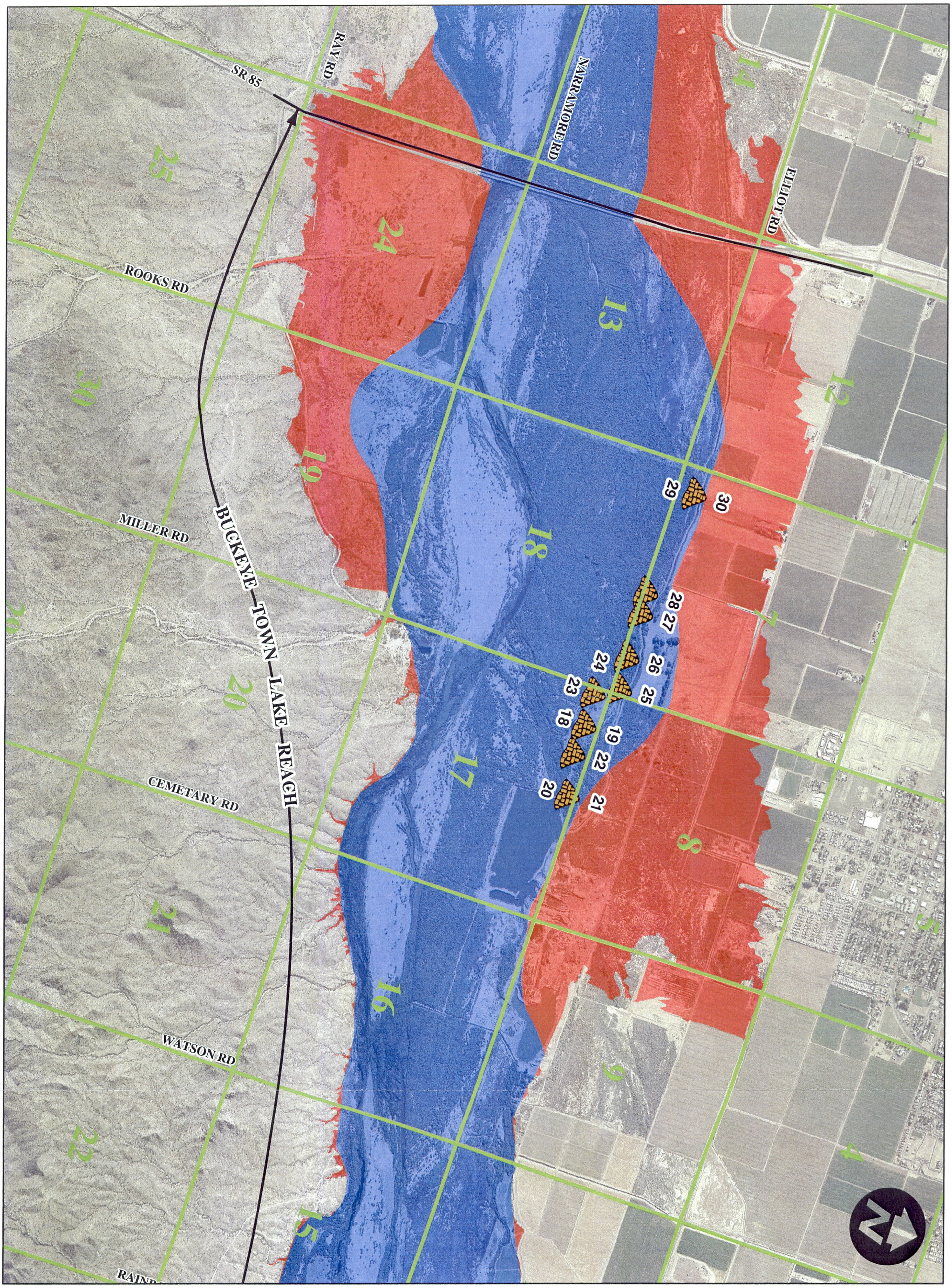
Identified Cultural Resource Sites Within the El Rio Project Area

Significant Waste Sites
Within the El Rio Project Area

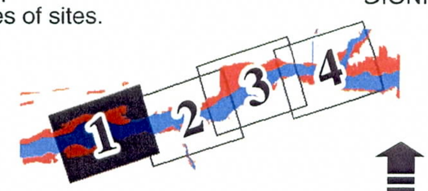


Flood Control District
of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Stantec Consulting Inc.
8211 S. 48th St.
Phoenix, AZ 85044

See "Photograph Log -
El Rio Trash Reconnaisance (1/30/03)"
in Environmental Resources Report for
descriptions and grid coordinates of sites.

8 Solid Waste Site



EL RIO WATERCOURSE MASTER PLAN

SIGNIFICANT SOLID WASTE SITES WITHIN EL RIO PROJECT AREA

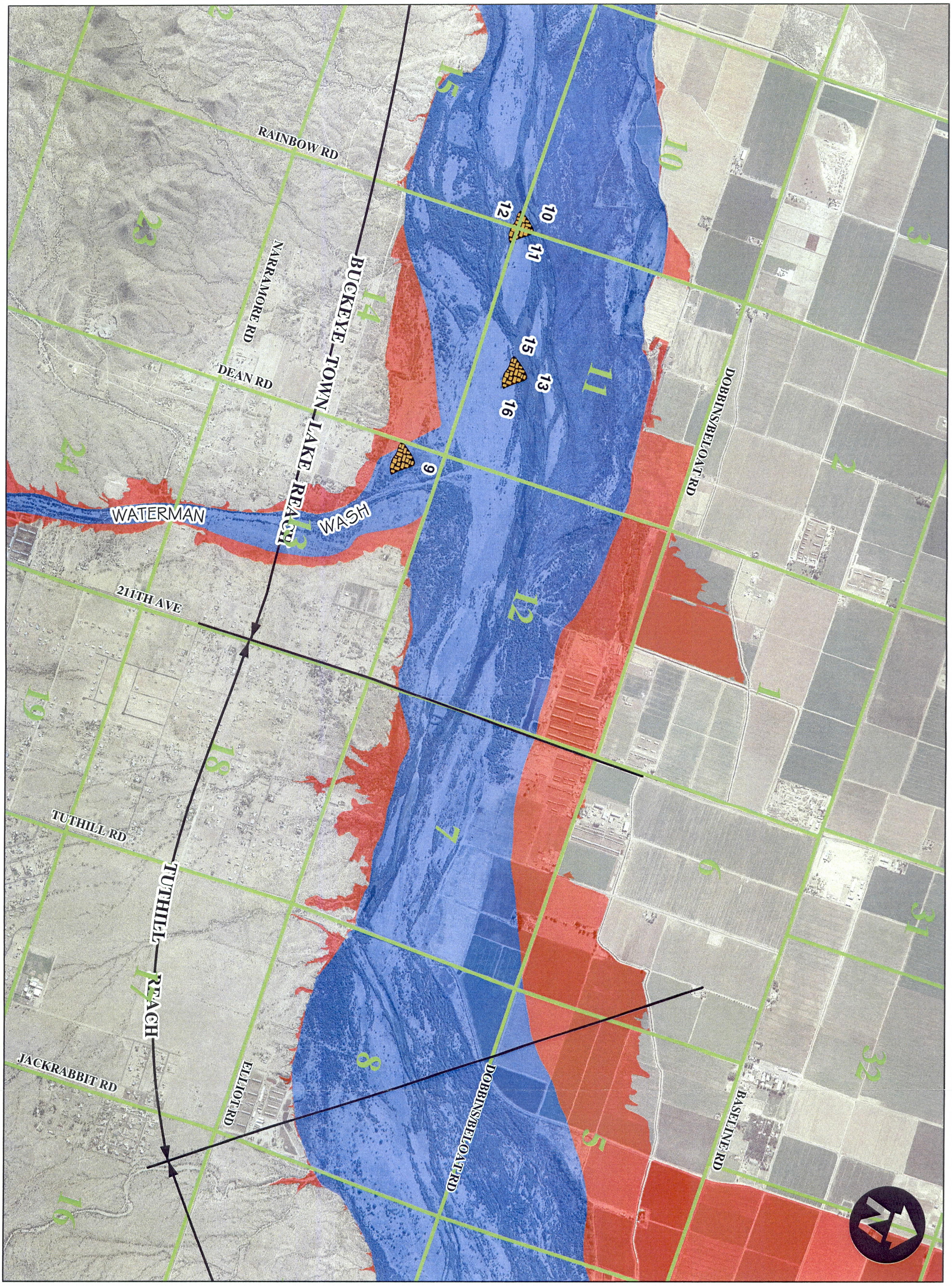
SHEET 1 OF 4 (BUCKEYE TOWN LAKE REACH)

11 NOV 2005

0 1,000 2,000 4,000

1 Inch = 2000 Feet

W:\active\82000240\GIS\env res report\solidwaste

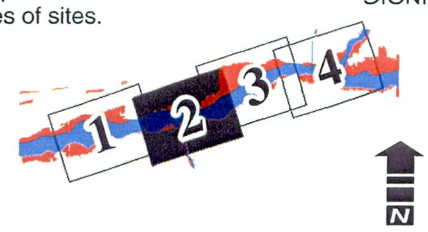


Flood Control District of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Stantec Consulting Inc.
8211 S. 48th St.
Phoenix, AZ 85044

See "Photograph Log - El Rio Trash Reconnaisance (1/30/03)" in Environmental Resources Report for descriptions and grid coordinates of sites.

8 Solid Waste Site

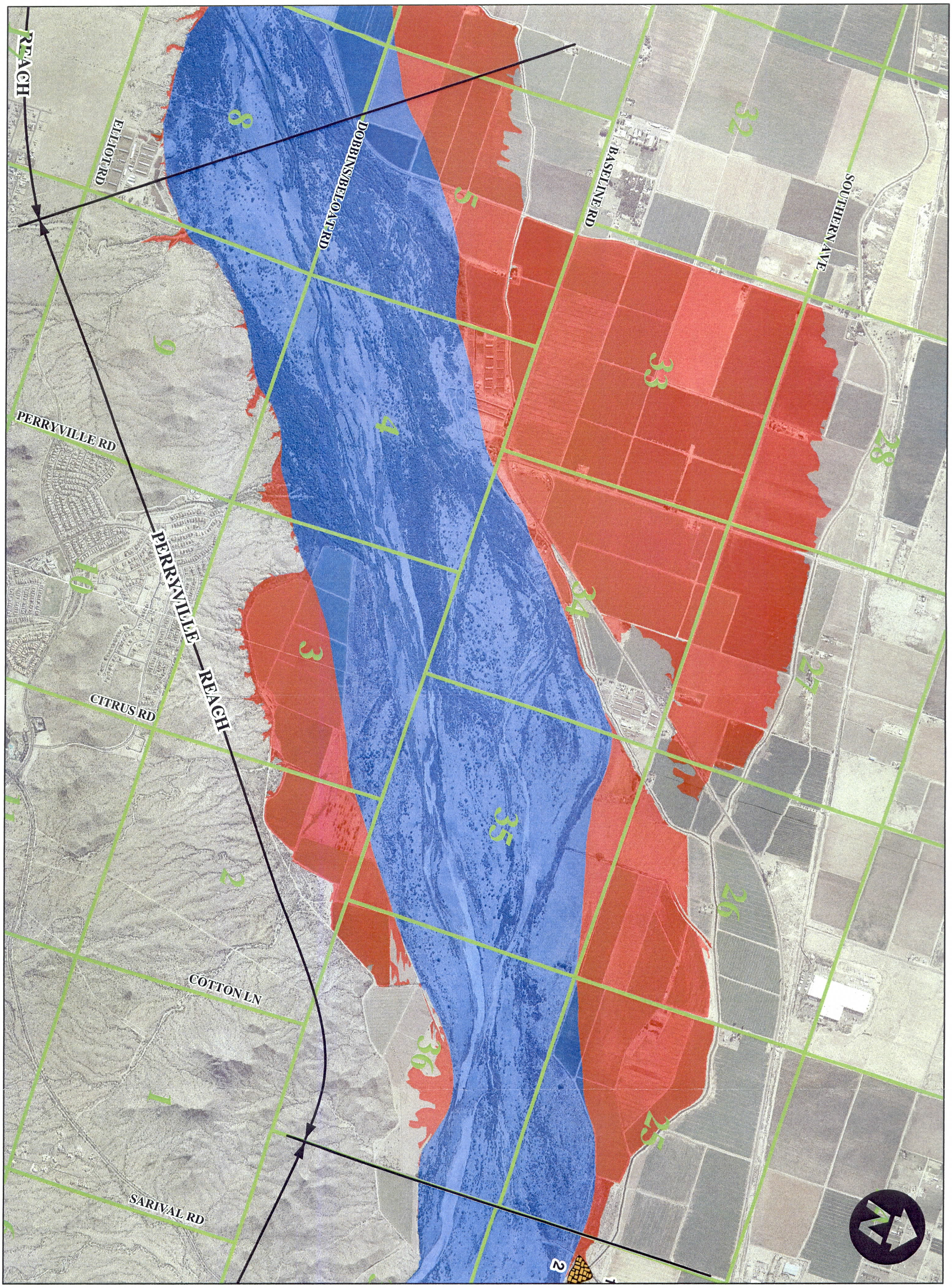


EL RIO WATERCOURSE MASTER PLAN

SIGNIFICANT SOLID WASTE SITES WITHIN EL RIO PROJECT AREA
SHEET 2 OF 4 (TUTHILL REACH)
11 NOV 2005

0 1,000 2,000 4,000
1 Inch = 2000 Feet

W:\active\82000240\GIS\env res report\solidwaste



Flood Control District
of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

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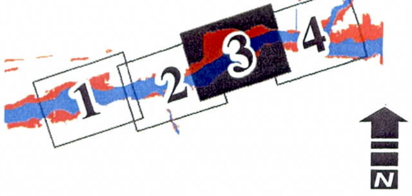
Stantec

See "Photograph Log -
El Rio Trash Reconnaisance (1/30/03)"
in Environmental Resources Report for
descriptions and grid coordinates of sites.

8 Solid Waste Site



EL RIO WATERCOURSE MASTER PLAN

SIGNIFICANT SOLID WASTE SITES WITHIN EL RIO PROJECT AREA

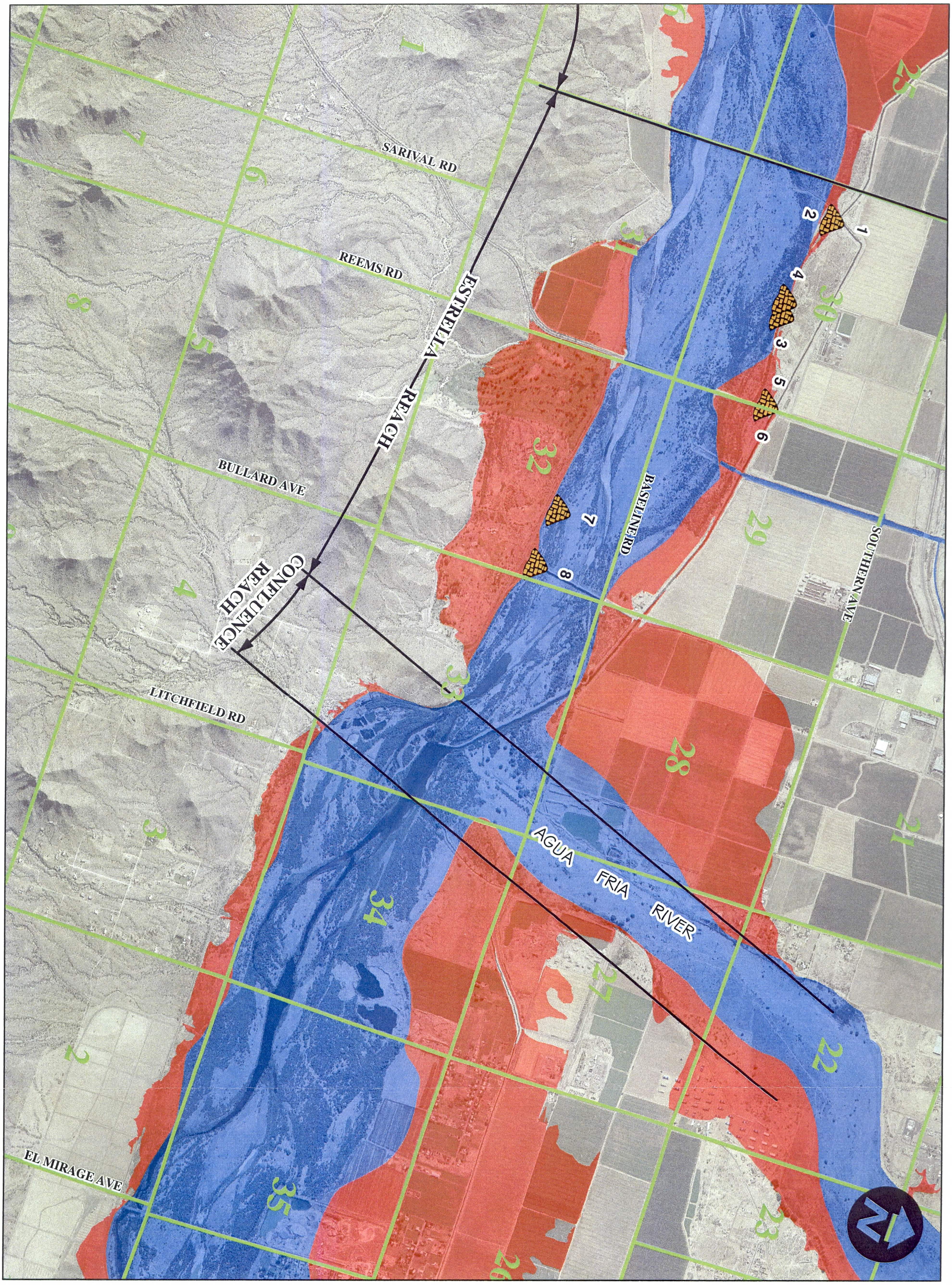
SHEET 3 OF 4 (PERRYVILLE REACH)

11 NOV 2005

0 1,000 2,000 4,000

1 Inch = 2000 Feet

W:\active\82000240\GIS\env res report\solidwaste



Flood Control District
of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Stantec Consulting Inc.
8211 S. 48th St.
Phoenix, AZ 85044

See "Photograph Log -
El Rio Trash Reconnaisance (1/30/03)"
in Environmental Resources Report for
descriptions and grid coordinates of sites.

8 Solid Waste Site

EL RIO WATERCOURSE MASTER PLAN

SIGNIFICANT SOLID WASTE SITES WITHIN EL RIO PROJECT AREA

SHEET 4 OF 4 (ESTRELLA REACH)

11 NOV 2005

0 1,000 2,000 4,000

1 Inch = 2000 Feet

W:\active\82000240\GIS\env res report\solidwaste

Photographs of Solid Waste Sites Within the El Rio Project Area

Photo 1: East view of discarded tires and construction debris in powerline ROW west of Estrella Pkwy.

Photo 2: North view of dumped gypsum board (possible ACM) in the powerline ROW west of Estrella Pkwy.

Photo 3: South view of discarded tires, abandoned appliances, and construction debris in powerline ROW west of Estrella Pkwy.

Photo 4: North view of construction debris, discarded tires, and household trash in powerline ROW west of Estrella Pkwy.

Photo 5: North view of waste soil, construction debris, discarded tires, and concrete-filled blue plastic drums in powerline ROW west of Estrella Pkwy.

Photo 6: West view of waste soil and construction debris in powerline ROW west of Estrella Pkwy.

Photo 7: Abandoned appliances (water heater and refrigerator) north of Vineyard Ave. and west of Bullard Ave. on the south bank of the Gila River.

Photo 8: North view of bathtub and dumped landscape material under the Bullard Ave. Bridge.

Photo 9: East view of discarded roofing shingles (possible ACM) in Waterman Wash.

Photo 10: Litter and household trash in the Gila River, 2nd pond west of Waterman Wash.

Photo 11: Litter, household trash, and discarded clothing in Gila River, 2nd pond west of Waterman Wash.

Photo 12: Litter, household trash, and discarded footwear in Gila River, 2nd pond west of Waterman Wash.

Photo 13: Litter and household trash in Gila River, 1st pond west of Waterman Wash.

Photo 14: Litter and household trash in Gila River, 1st pond west of Waterman Wash.

Photo 15: Litter and household trash in Gila River, 1st pond west of Waterman Wash.

Photo 16: Litter and household trash in Gila River, 1st pond west of Waterman Wash.

Photo 17: Abandoned sand and gravel pit/closed landfill at Miller Rd. & Gila River, abandoned sand and gravel processing equipment.

Photo 18: West view of abandoned sand and gravel processing equipment in abandoned sand and gravel pit/closed landfill at Miller Rd. & Gila River.

Photo 19: Discarded appliances, furniture, and construction debris in abandoned sand and gravel pit/closed landfill at Miller R. & Gila River.

Photo 20: White pelicans on pond east of abandoned sand and gravel pit/closed landfill at Miller Rd. & Gila River. Active sand and gravel pit in distance.

Photo 21: West view of white pelicans on pond east of abandoned sand and gravel pit/closed landfill at Miller Rd. & Gila River.

Photo 22: Litter and household trash in abandoned sand and gravel pit/closed landfill at Miller Rd. & Gila River.

Photo 23: Waste concrete and construction debris dumped in abandoned sand and gravel pit/closed landfill at Miller Rd. & Gila River.

Photo 24: Waste concrete and construction debris dumped in abandoned sand and gravel pit/closed landfill at Miller Rd. & Gila River.

Photo 25: Dumped furniture and appliances along north bank of Gila River between Miller Rd. & SR 85.

Photo 26: Dumped tires and household trash along north bank of Gila River between Miller Rd. & SR 85.

Photo 27: Household trash dumped along north bank of Gila River between Miller Rd. & SR 85.

Photo 28: Landscape debris, household trash, and appliances dumped along the north bank of the Gila River between Miller Rd. & SR 85.

Photo 29: Landscape debris and temporary grave marker dumped along north bank of Gila River between Miller Rd. & SR 85.

Photo 30: Household trash, abandoned mattresses and bedding dumped along the north bank of the Gila River between Miller Rd. & SR 85.