City of Phoenix
Tres Rios
Constructed Wetland

Full-Scale Project

Visioning Workshop

Report

June 2003

WASS Gerke and Associates, Inc

Tres Rios Constructed Wetland
Full-Scale Project
Visioning Workshop
Report

EXECUTIVE SUMMARY

The Tres Rios Constructed Wetland Project conducted a visioning workshop on November 19, and 20, 2002, at the 91st Avenue Wastewater Treatment Plant. The objective of the workshop was to bring together wetland experts from across the country, federal, state, and local officials, and field staff to develop specific visions for the full-scale wetland project.

The City of Phoenix and workshop team presented their goals and objective for the Tres Rios Project. Visions included long term sustainability, compatible wildlife habitat, flood control, water quality improvements and adaptive management for the life of the project.

Key findings of research at the Tres Rios Demonstration Constructed Wetland Project in relation to hydraulic operations, wildlife, and vector monitoring and control strategies, were presented. Water quality improvements have been achieved. However, the full-scale project should carefully consider operations and maintenance during the design phase. Designs should be improved for influent flow, flow measurement, larvicide application, and access/site security.

The team discussed design elements for the management of hydraulics, water quality, and vectors. Several hydraulic designs were suggested for the regulating wetlands to meet the extreme range of potential influent flows. The basis of design is a consumptive water use of 28,000 acre-feet per year. Regulating wetlands must discharge above the 100-year flood level. Regulating wetlands shall have an average design capacity of 230 mgd, and handle peak capacity of 460 mgd.

Vector control strategies were discussed in depth. Presentations by Arizona Department of Health and Maricopa County Vector Control, addressed the imminent threat of the West Nile Virus, as early as summer of 2003. The *Culex* mosquitos, which breed in stagnant water, are likely carriers of the disease, in Arizona. Design elements of the wetlands should consider prevention strategies, monitoring methods, and management techniques. Improved water level control, encouragement of natural predators, and larvicide application systems, were identified as primary management techniques.

The visioning document concludes with specific recommendation for facility and basin layout, wetland hydraulics, wetland vegetation, habitat, operations and maintenance, public use, and vector control.

Tres Rios Constructed Wetland
Full-Scale Project
Visioning Workshop
Report

TABLE OF CONTENTS

Introduction....1
Project Background....1
Tres Rios Demonstration Project Summary....2
Visioning Workshop Summary....13
Performance Goals & Objectives....15
Basis, Guidelines, and Constraints of Design....18
Basis of Design....18
Vector Control and Public Use....19
Constraints....20
Design Variables....22
Hydraulics....22
Water quality....22
Habitat....23
Operations and maintenance....23
Sustainability....23
Recreation, public use, and safety....23
Data gaps....25
Recommendations....26
Facility and basin layout....26
Wetland hydraulics....26
Wetland vegetation....26
Habitat....27
Public use....27
Vector control....27
Summary of Wetland Design Recommendations....27

Appendix A – Demonstration Basin Redesign and Revegetation
Appendix B - Agenda and List of Attendees
Appendix C - Results from Visioning Workshop Questionnaire
Appendix D - Visioning Goals and Field Trip Comments
Appendix E - Wetland Visioning Graphics

Tres Rios Constructed Wetland
Full-Scale Project
Visioning Workshop
Report

INTRODUCTION

The purpose of this report is to document and describe the visions that were formulated during the Tres Rios Constructed Wetland Visioning Workshop.

Project Background

The Tres Rios concept was first identified in a U.S. Army Corps of Engineers (USACE) Reconnaissance Report. At that time, the USACE could not justify a project based upon flood damage benefits. However in 1992, the United States Bureau of Reclamation (USBR) was authorized by Sections 1605 and 1608 of Public Law 102-575 to participate in the development of a demonstration wetland project to be located at the 91st Avenue facilities. In 1995, the City of Phoenix, SROG and the USBR entered into an agreement to construct and operate the Tres Rios Demonstration Constructed Wetlands Project.

In 1994, the USACE mission was modified to include environmental protection and restoration in addition to their traditional mandate of flood damage reduction in House Resolution 2425 dated May 17, 1994. Such authorization opened the way for the USACE to conduct the Tres Rios, Arizona Feasibility Study which was completed in April 2000. The results of the Feasibility Study indicated the need for two wetland complexes in the preferred alternative. The first wetland complex would be located immediately across 91st Avenue from the 91st Avenue Wastewater Treatment Plant (WWTP) and serve to polish effluent discharges from the conventional treatment facilities and dampen diurnal flow variations that result from variations in water usage, long travel times in the City's collection system, and the contractual demands placed upon the effluent by the Arizona Nuclear Power Plant (ANPP). These basins are termed the regulating wetlands for their role in controlling discharges to the Salt River and other downstream features. The second series of wetlands are located south west of the regulating wetlands on the north bank of the Salt/Gila River. These are termed the overbank wetlands, and they will receive seasonally constant water flow from the regulating wetlands. Their primary role is habitat enhancement.

The current project schedule indicates that design will likely begin in August of 2003. Design of these systems is estimated to be between 18 and 24 months. If this target is met, construction could begin as early as January 2005. Some of the insight that will be used to design the full scale wetland facilities was developed through efforts expended at the Tres Rios Demonstration Constructed Wetland Project facilities. The following section provides a brief summary of the demonstration project, its facilities, and selected findings.

Tres Rios Demonstration Project Summary

Location
The Tres Rios Demonstration Constructed Wetlands occupy approximately 14 acres in and around the 91st Avenue Wastewater Treatment Plant (WWTP) in Phoenix, Arizona. The plant itself is located on the north bank of the Salt River, just east of 91st Avenue. The WWTP is a conventional activated sludge plant currently treating approximately 180 MGD of municipal wastewater using six distinct treatment trains: 1A, 1B, 2A, 2B, 3A, and 3B. The source water for the demonstration treatment wetland sites is Plant 3A. Plant 3A contains secondary treatment with nitrification and denitrification, and produces a high quality effluent, low in BOD and nitrogen species. Recent upgrades at the WWTP have improved all Plants such that they now produce a similarly high quality effluent.

Cobble Site
The Cobble Site consists of two elongated wetland cells whose flow-paths are oriented from east to west and possess identical surface areas (Figure 1). They are located within the Salt River floodway and as such, are subject to flood flows. Adjacent to the cells on the north and west are Cottonwood (*Populus fremontii*) and Willow (*Salix spp.*) galleries and some fairly dense stands of Salt Cedar (*Tamarix spp.*). To the south is the main channel of the Salt River, which is braided and only vegetated in discrete areas.

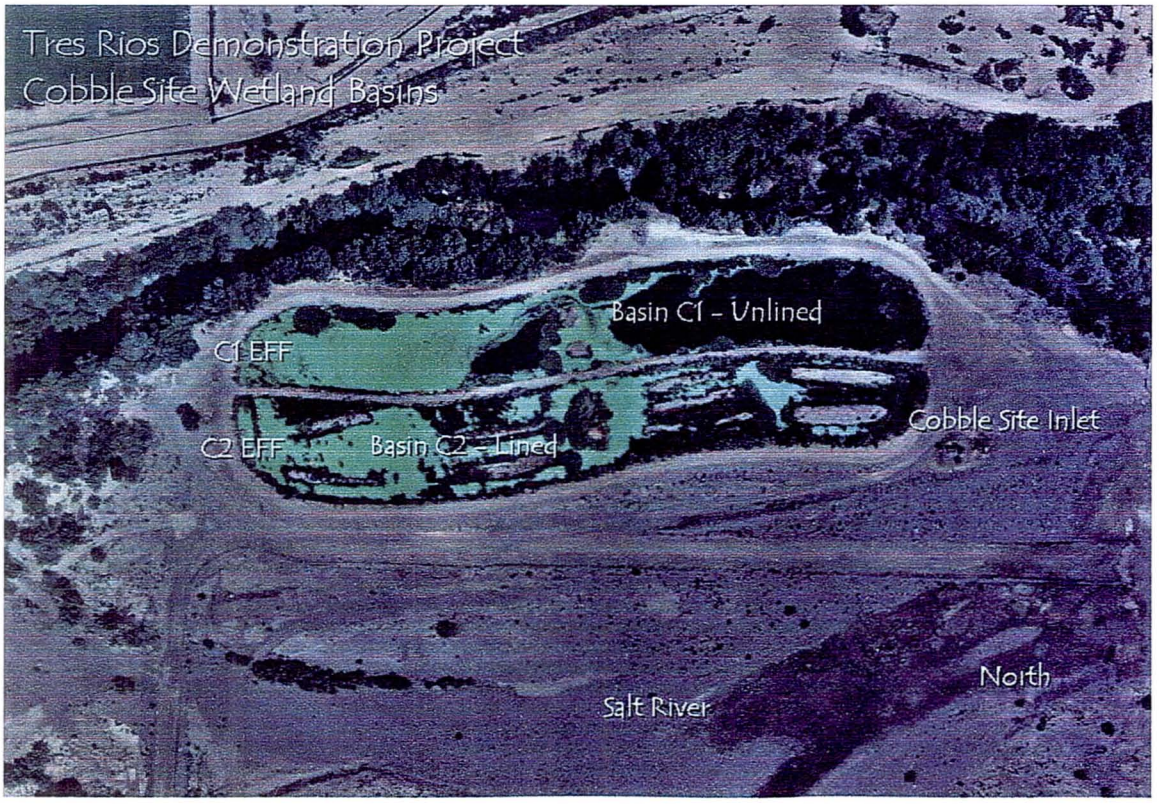


FIG. 1. The Reconfigured Tres Rios Cobble Site Facilities Located in the Salt River Immediately Downstream of the 91st Ave. WWTP Showing Sample Points.

The northern basin, C1 is unlined, the river run (cobble gravel, and sand) is used as a substrate. The southern basin, C2 is lined with 6 to 8" (15 - 20 cm) of top-soil obtained from an agricultural field in the proximity of the project site. Flows enter the site by means of a two-way splitter-box outfitted with 60° V-notch weirs. These cells can only be operated in parallel and flows exit each basin through another 60° V-notch weir, which spills into an underground conveyance system that discharges to the river bed, combining with water discharged from the 91st Avenue WWTP effluent channel.

Each basin is approximately 900 ft (275 m) long and 115 ft (35 m) wide, which results in a wetted surface area of approximately 2.2 acres (0.9 ha) when a depth of 1.0 ft (0.3 m) is maintained in the emergent marsh areas. This produces an aspect ratio (length/width) of almost 9:1 and at design hydraulic loadings results in a design theoretical hydraulic retention time between 0.5 and 5 days.

All of the Tres Rios Demonstration cells are considered two-phase free water surface wetlands because they incorporate both shallow emergent areas and deep-water zones. The shallow emergent areas were planted with two native species of bulrush: soft-stem bulrush (*Schoenoplectus tabernaemontan* formerly *Scirpus validus*) and three-square bulrush (*Schoenoplectus americanus* formerly *Scirpus olneyi*). The soft-stem was obtained from the Kingman, AZ wetlands while the three-square was transplanted from the Casa Grande, AZ area. These two species constituted between 70 and 80% of the vegetation in each basin. Emergent vegetation is restrained to the shallow areas by design of deep zones (approximately 3.3 ft (1.0 m)) too deep to allow for emergent vegetation establishment.

As originally constructed, both C1 and C2 have inlet, outlet, and interior deep zones, which together comprise roughly 20% of their surface area. These deep areas serve multiple purposes; 1) they allow remixing of waters after they transition a shallow vegetated emergent zone where short-circuiting is likely to occur; 2) they tend to enhance the habitat value for waterfowl; 50% "open-water" in multi-purpose constructed wetlands is thought to provide optimal waterfowl habitat; and 3) they can alter the water chemistry because they will typically have an aerobic water column and an anoxic bottom layer (both important for nutrient transformations, metals attenuation and decomposition of organic compounds). As the open water percentage was increased, so did bird use, water use water quality measurements made in open-water zones also demonstrated higher D.O. levels then found in densely vegetated emergent areas.

Hayfield Site

The Hayfield Site is located on what was once an agricultural field, which is in contrast to the sand, gravel and cobble of the Cobble Site. The Hayfield site includes two kidney-shaped wetland cells whose flow-paths are oriented from west to east (Figure 2). The emergent areas of each basin were originally planted with the two species of bulrush, soft stem and three-square, used at the Cobble Site. The site is situated on a level terrace

above the Salt River floodway and would be subject to inundation by flows in excess of a 100 year return interval flood. Located along the south side of the site is an established riparian corridor which has mature stands of cottonwoods, willows, elderberry and numerous other deciduous trees and shrubs. Just east of the site there exists a Mesquite Bosque, which occupies roughly 3 acres, while to the north are sludge drying beds of the WWTP.

The two Hayfield basins each have approximately 20% open water deep zones but the northern basin H1 has a different configuration than the southern basin H2. Both cells have inlet and outlet deep zones, but H1 has five narrow (top width approximately 30 ft (9 m)) interior deep zones, while H2 has only 2 (top width 75 ft (23 m)). Within each interior deep zones of H2, three waterfowl islands were constructed.

Hydraulic control over this site is slightly different than the Cobble Site. The Hayfield basins can be operated either in parallel or series. Flows entering the Hayfield are split between the two basins by means of 60° V-notch weirs housed within a three-way splitter box. An additional splitter box was added to this site at the east end, which allows effluent from H1 to be routed to the inlet splitter box and ultimately into H2 when the site is operated in series. Flows leaving the Hayfield are combined underground and discharged into a pool, riffle system which conveys the flows into a riparian corridor. Salt cedar is not much of an issue in this riparian corridor because of mature cottonwood and willow canopy.

Each Hayfield cell is approximately 3 acres (1.2 ha) in surface area (assumes a 1.0 ft (0.3 m) depth in emergent areas), and including the surrounding terrestrial vegetation provides a total site area just under 7 acres (2.9 ha). Each Hayfield basin is approximately 750 ft (228 m) long and 200 ft (60 m) wide, which results in an aspect ratio of 3.8. The theoretical design hydraulic retention times for this site range from 2.0 to 20 days. The range was established to test the performance under a wide range of conditions, anticipated for the full scale project. However, recent and planned future expansions of the 91st Avenue WWTP will likely produce more effluent than initially anticipated. As such, flow rates at the full scale wetlands will likely exceed the ranges investigated at the Hayfield Site.

FIG. 2. The Tres Rios Demonstration Constructed Wetland Hayfield Site Facilities Located at the City of Phoenix, AZ 91st Avenue Wastewater Treatment Plant

Research Cell Site

The Tres Rios Research Cells were a collection of twelve (12) 1200 m^2 wetland basins occupying two abandoned sludge drying basins of the 91st Avenue WWTP. Each basin was identical with respect to surface area, inlet, and outlet deep zone.

Research Cells 1, 2, and 3 had no internal deep zones. They have inlet and outlet deep zones which corresponded to roughly 12.5 % of their surface area as open-water. Cells 4, 6, and 12 had one internal deep zone, while 7, 8, and 10 had two, and 5, 9, and 11 had three. This resulted in a range of open water from 12.5 % to 35 %.

The vegetation used in the Research Cells was identical to that used in the larger Demonstration Basins. The primary vegetation consisted of soft-stem and three-square bulrush. Vegetation thrived in all cells for the first 18 months; however, during the spring of 1997, neither species came back after winter senescence in Cell 12.

Source water to this site was dechlorinated effluent supplied from the Plant 3A chlorine contact channel. Once at the site, flows are split by means of two splitter-boxes, each of which housed six (6) 22.5° V-notch weirs. Outlets also used 22.5° V-notch weirs, and water from this site was discharged into the Plant 2A/2B chlorine contact channel where it mingled with the main plant flow and was ultimately discharged to the Salt River at the plants' NPDES point of compliance. In 2000, the Research site was taken out of service

and the 6-cells located on the east side of the site were decommissioned and those on the west side of the site were combined to establish one flow path. Minimal monitoring of the site was conducted after that time.

Demonstration Basin Redesign and Revegetation
Vegetation management is needed for the demonstration and full-scale Tres Rios wetland basins. Vegetation failures in the demonstration basins began in 1997. By the summer of 1998, conditions were unacceptable with regards to vector control. Several reasons for this failure were investigated including herbivore pressures, excessive chlorine loading, and/or a micro-nutrient deficiency that may have stressed the vegetation. However, no conclusions were able to be made, and the Cobble basins were redesigned and reconfigured during the summer of 1998. Hayfield Basin 1 was reconfigured in the spring of 2004. Subsequent and ongoing research at the Hayfield site it testing the theory that operating depths used in the Demonstration Project were too deep for the plant species.

Cobble Basin 1 was reconfigured by removing bottom material so all shallow emergent areas were surrounded by open water. The purpose of the redesign was to improve access for *Gambusia sp.* (mosquito fish) to prey on mosquito larvae. The reconfigured basin became dominated almost exclusive by *Hydrocotyle*. Mosquito management has been improved by replacing the dense emergent plant, with *Hydrocotyle* in this basin.

Cobble Basin 2 was reconfigured by adding the material removed from C1, as gravel bars within the emergent zones. The new bars were planted with Cottonwood and Willow trees to provide shade. The bulrush (soft-stem and three-square) were replanted with a lower density and additional aquatic species, cattail and *Hydrocotyle*, were added to increase diversity. The purpose of the redesign was to reduce bulrush densities, improve species diversity and to promote a more balanced ecosystem. The reconfigured basin developed and has maintained about 50% vegetation cover since reconfiguration.

Hayfield Basin 1 was not reconfigured, however in July 1999 above-ground dead vegetation was removed. The purpose of the redesign was to investigate whether dead material may have been the causing vegetation stress (indicated by very little new growth in the spring of 1997). Since the removal, emergent vegetation has grown to 32% coverage. Above-ground vegetation removal appears to have improved the sustainability of emergent vegetation.

In Hayfield Basin 2, the dead vegetation was left to decay. H2 was used as a control site to assess the impact of the changes made in H1. In 1997 and 1998, H2 had emergent vegetation in over 70 % of the wetted surface area. By 1999, the basin coverage was down to 15 %. Suggesting that without vegetation management system was not sustainable for more than three growing seasons.

In the spring of 2003, H1 was nearly devoid of vegetation, and a reconfiguration study was begun. The emergent areas were reconfigured to study if the planting depth was too deep to sustain emergent vegetation.

Detailed descriptions of the redesign and revegetation efforts and findings are included in **Appendix A.**

Hydraulic Parameters
Over the course of the study period hydraulic readings and water quality parameters were measured at the inlet and outlet of each of the four demonstration wetland basins. Hydraulic parameters included the influent flow rate, effluent flow rate, and depth in the emergent area.

The Demonstration Project wetland basins evaluated inlet-based hydraulic loading rates that ranged from close to 0.60 m/d to less than 0.10 m/d. The average daily flow rate to the full scale wetlands will be on the high side of that range with proposed maximum having never been tested in the Demonstration facilities. It is currently estimated that flows to the regulating wetlands will be in the range of 180 to 230 mgd, which translates into hydraulic loading rates in the range of 0.55 to over 0.70 m/d.

Evapotranspiration was not measured at the site(s); rather an approximation was obtained from the Arizona Meteorological Network (AZMET) weather station located 1 mile North of McDowell road on Cotton Lane in Litchfield Park, Arizona. AZMET provides reference evapotranspiration values (ETO) which are determined using a weather-based model known as the Penman Equation. Due to work done by Dr. Kadlec, it was found that the basins were not reaching equilibrium with respect to temperature, as such, the ETO values need to be converted to adjusted evapotranspiration using a multiplicative factor based upon the hydraulic loading rate and temperature.

Infiltration losses were calculated by for using a water balance. At both the Hayfield Site Basins and Cobble Basin 2, infiltration losses were reasonably stable from 1995 through 1998. In the unlined Cobble Basin C1, infiltration rates during this time period fluctuated on an annual basis coincident with emergent macrophytic growth and senescence, but the pattern was consistent during those years. In 1999 and 2000, infiltration rates became more variable and were likely a function of a lack of steady state hydraulic operations. Several reasons exist for this including the influence of beavers (breaching the berm(s) at basin H2), periodic pump malfunctioning, water level fluctuations to facilitate mosquito management, and a lack of hydraulic measurements made by researchers. In 2000, there were occasions when only one hydraulic measurement was made for a basin during a month. Over the duration of the demonstration project, infiltration losses from basins C2, H1, and H2 ranged from 0.03 – 0.08 m/d, while the long term infiltration rate in the unlined Cobble Basin C1 was 0.15 m/d.

Water Quality
A primary goal of the Tres Rios Demonstration project was to determine if a constructed wetland system could treat discharges from the conventional treatment plant to a level that would satisfy future National Pollutant Discharge Elimination System Permit (NPDES) requirements. The following section provides a summary of the performance achieved in the wetlands for selected water quality parameters. To date, water quality

data suggest that the wetlands produce water capable of satisfying requirements for the permitted constituents: Total Nitrogen, cBOD, TSS, and toxicity. Bacterial levels are not within permit guidelines, but are likely due to wildlife input, not from human origins.

Nitrogen

Total Nitrogen in the source water averaged 6 mg/L. It was delivered primarily in the form of NO_3-N, which is more readily removed in the wetlands than NH_4-N. After denitrifying conditions developed in the wetland basins, total-nitrogen levels exiting the Tres Rios wetlands have averaged approximately 3.0 mg/L. Denitrifying conditions result as the microbial populations and wetland systems themselves mature. As vegetation grows, portions begin to senesce and fall into the water column. On the wetland floor, the dead vegetation is decomposed by aerobic bacteria. This microbial decomposition provides an environment where microbial denitrification can occur, e.g. anoxic conditions develop and carbon by-products are produced. At Tres Rios, development of denitrifying conditions took from 5 to 9 months, depending upon basin substrate and vegetation fitness (Figure 3). It is likely that this can be reproduced in the full-scale system.

With respect to a Full-Scale system, a decision will have to be made as to how rapid denitrifying conditions will be established and what type of maintenance schedule will be necessary so that a sustainable system is achieved. Although it is possible to achieve denitrifying conditions in as few as 5 months e.g., plant vegetation on 3-foot centers and fertilize, this technique may cause substantial vegetation failure in subsequent years. Even though the failure does not deleteriously impact the water quality exiting such systems, vegetation die-off and large amounts of standing, senesced material may exacerbate mosquito breeding and other nuisance conditions.

Nitrogen concentrations exiting the wetlands via infiltration are also lower than incoming wastewater nitrogen levels. Evidence collected at the "Leaky" Cobble Site Basin C1 indicates that a very active microbial layer exists in the first one-foot of bottom material. Sampling from subsurface well-points indicates detectable NO_3-N in the water column and at the soil-water interface, but non-detectable in a well-point located 1-foot below the surface. These data were collected in a basin where up to 70% of the incoming water exits via infiltration. Considering these findings, lining the full-scale wetlands to prevent contaminating groundwater with nitrate is probably an unnecessary consideration.

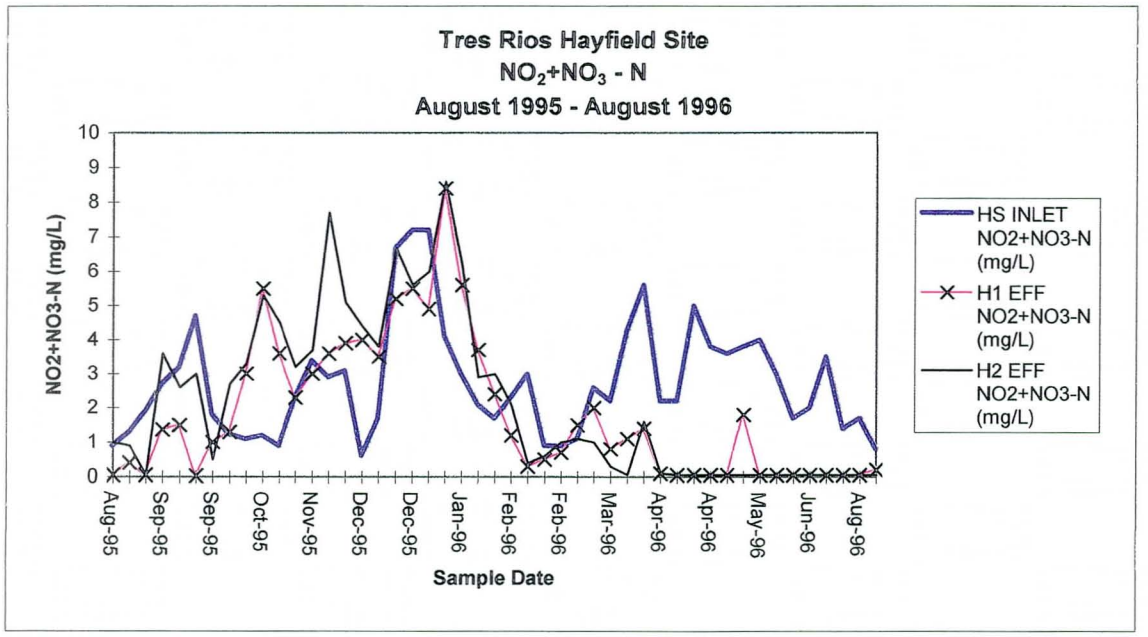


FIG. 3 This plot shows the startup with respect to denitrification of the Hayfield Basins. One can see a build-up of NO_2+NO_3-N from 8/95 through 1/96. After that time, anoxic conditions and excess carbon were available for microbial denitrification and both nitrite and nitrate concentrations dropped.

Nitrogen Conclusions

1) Planting bulrush on 3-foot centers and fertilizing results in 90-95% basin coverage in 90-120 days.
2) Densely planted bulrush can develop denitrifying conditions in as little as 5 months, however it may take up to two years.
3) Densely planted bulrush may cause vegetation sustainability problems and exacerbate mosquito breeding and nuisance conditions.
4) Denitrification is occurring in the top 1-foot of basin sediments as water exits through the wetland bottom.

Dissolved Oxygen and Oxygen Demanding Substances

The Tres Rios Demonstration Wetlands have also tended to remove most of the oxygen demanding substances present in the source water and those contributed through internal loading. Reaeration is accomplished at the Hayfield site by spilling the wetland discharge over a gravel filter after completing a vertical drop of approximately 9 feet. This provides a post-discharge dissolved oxygen (DO) level of between 3 and 6 mg/L, depending upon the time of year. Elevated DO still persist 200 meters downstream (Figure 4).

It is envisioned that the full-scale Tres Rios wetlands will be located upon the north bank of the Salt/Gila rivers so that a similar discharge to the river could be accommodated. Using the configuration at the Hayfield site, it is likely that outlets for the full-scale will consist of steep, rip-rap lined channels where a turbulent reaerating flow regime could be

accomplished from the top of the north bank to the channel invert. The ultimate goal is to produce an oxygenated discharge to the river bottom to encourage a more diverse aquatic wildlife.

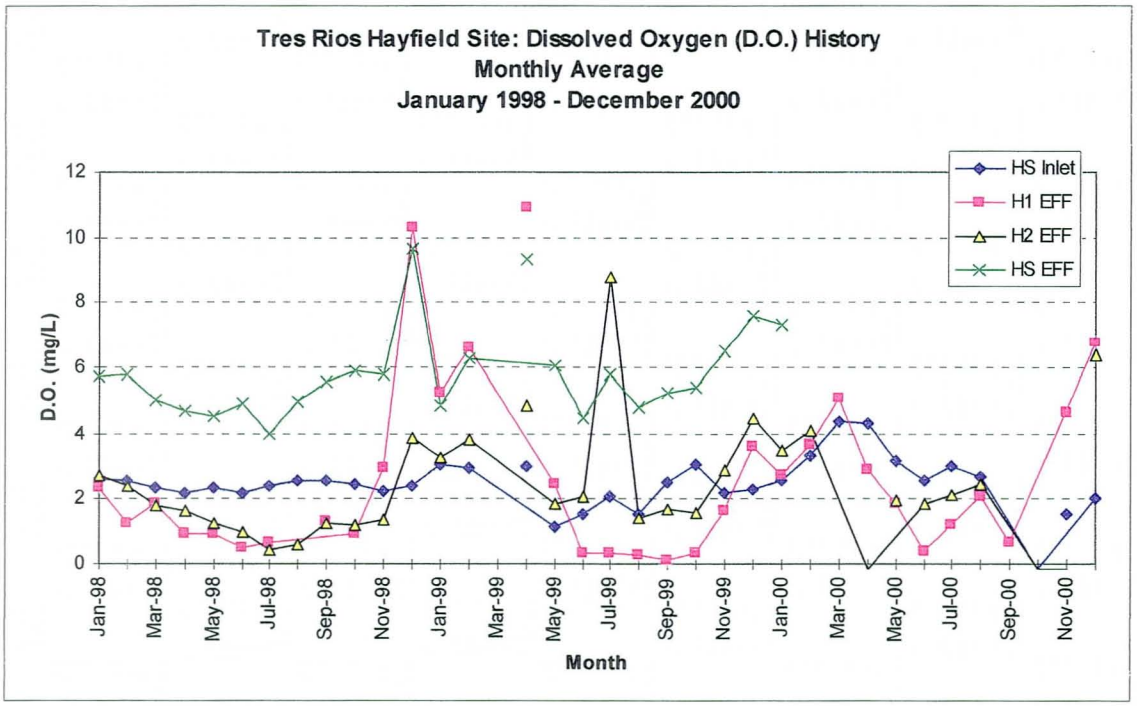


FIG. 4 Tres Rios Hayfield site dissolved oxygen summary. Note the increase in D.O. exhibited at HS EFF which was due to turbulent mixing as the effluent cascaded from the Hayfield site into the river bottom.

D.O. Conclusions

1) Wetland treatment provides water that is easy to reaerate.
2) Wetland treatment provides water that maintains its D.O. for many meters downstream.
3) Full-scale treatment systems should attempt to configure outlets such that reaeration is optimized prior to joining flows in the river bottom.

Reduction in Toxic Compounds

Biomonitoring of the wetland discharge has been ongoing since startup. At Tres Rios, the method employed is a 7-day static renewal test using *Cerriodaphnia dubia* as the test organism. (Methods include EPA/600/489/001, its supplemental EPA/600/489/001a, and the update EPA/600/489/002) Using this method, no toxicity has been found associated with the wetland effluents, except during the 1996 fogging event. Interestingly, diazinon, an unregulated organophosphorous (Organo-P) pesticide, has been found in the discharged water. Organo-P pesticides are designed to degrade relatively rapidly in the environment, primarily through photolysis and decomposition by bacteria. Both removal mechanisms are prevalent in a free water surface wetland system, and as such, a full-scale

wetland system should have in its design; areas of open-water where high exposure to sunlight can be optimized.

Interestingly, researchers from the United States Geological Survey (USGS) did identify some toxicity in the wetland effluents using the MicroTox assay method. Indications were that herbicide and pesticide application and or a cationic species, such as a heavy-metal in the incoming wastewater, or one of the cationic polymers used in the conventional treatment process was the likely culprit.

Toxicity Conclusions

1) Conventional Biomonitoring has shown no toxicity associated with wetland effluents.
2) MicroTox testing does indicate toxicity in wetland effluent, but at this date cannot be attributed to specific class or compound.
3) Drift from aerial application of pesticides and herbicides on agricultural fields may impact the full-scale system.

TDS

Since the onset of the project, TDS has shown to be increasing. This can likely be attributable to a change in water supply in the region from local surface and groundwaters to Colorado River water transported via the Central Arizona Project canal. This increase is shown in Figure 5 as electrical conductivity and indicates current effluent values are in the range of 2000 μS/cm. This level is approaching the threshold level for some riparian species such as cottonwood and willow and should be considered in the design of full-scale facilities.

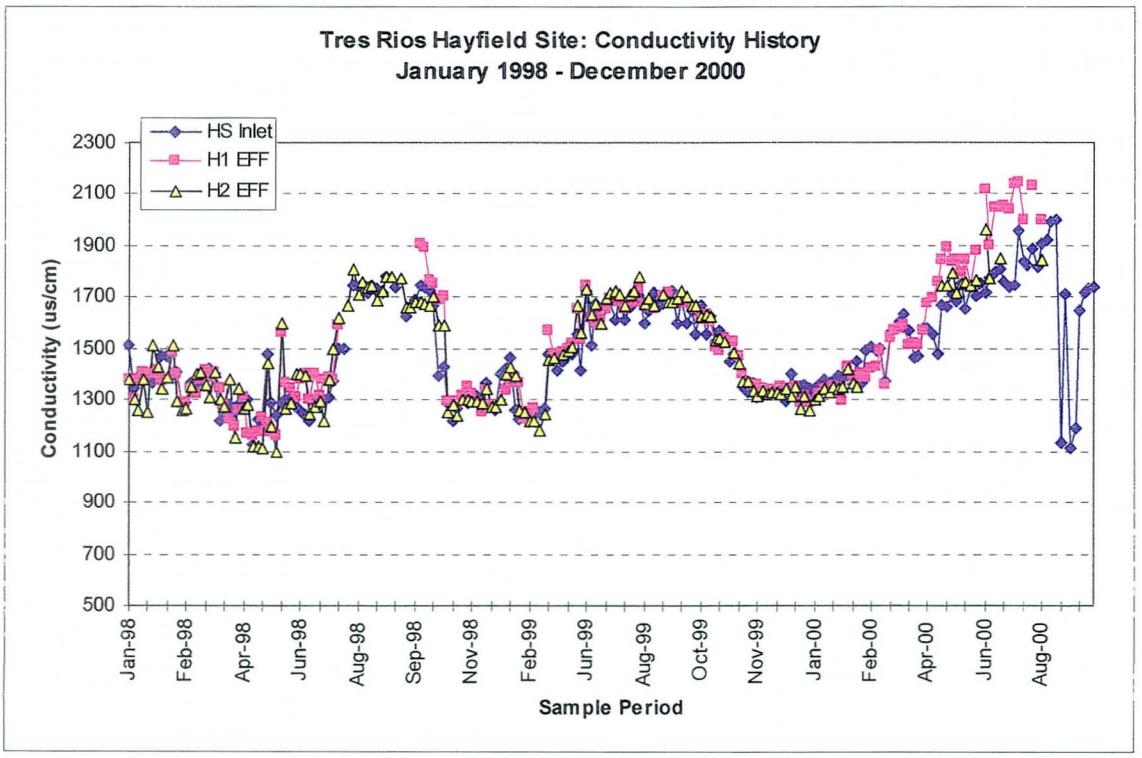


FIG. 5 Electrical conductivity history showing an increasing trend over time that is likely associated with increasing TDS in the water supply.

Bacteria / Pathogen

Chlorinated effluent (2.5 – 3.0 mg/L) is supplied to the Tres Rios Demonstration Wetlands, as such, bacterial loading to the wetlands from the influent water has been minimal. Although loading to the wetlands have been small, the wetland effluent consistently has very high numbers (> 20,000 cfu/100mL) of bacteria associated with it. This impact is believed to be attributed to wildlife. During startup from August 1995 through early December 1995, very little bacteria were noted in the wetland effluent. After that time however, a large sustained increase has occurred and continues to occur some 6 years later. The initial increase of bacteria measured in the wetland effluents coincided with the appearance of large numbers of birds, in particular the Yellow-Headed Blackbird. At times, this species has been observed in numbers close to 1500 roosting in a wetland over night. When considered with the enormous population of muskrats, beavers, and waterfowl frequenting the sites, it is easy to attribute the rise in bacteria to wildlife.

This result raised several questions such as; are bacteria in the wetland effluent due to wildlife or re-growth of human bacteria from the conventional treatment plant? Is there a public health risk by contacting these waters?

University of Arizona researchers conducted a preliminary study in 2000 and 2001 to start to answer the above questions. They found that the source of observed *Escherichia coli* blooms in the outlet of the Tres Rios wetlands was from both human and animal sources. Antibiotic resistance profiling and biochemical fingerprinting was performed on 325 *E. coli* isolates collected from key points in the wetlands and the avian population. Multivariate statistical analysis was used to interpret the data from samples collected on October 3, 2000, December 12, 2000 and January 16, 2001. It was found that the passerine population was the major source of fecal contamination in October and December whereas regrowth of the treated wastewater was the main source in January. Further research is needed to confirm seasonal patterns for the sporadic *E. coli* blooms and to determine the potential for disease transmission.

Implications can be made based on the research at the Tres Rios Demonstration Constructed Wetlands. Key implications regarding water quality are listed below:

- Wetland pond may not require liner to prevent groundwater contamination
- Further research is needed regarding vegetation sustainability
- Open water areas for more sunlight exposure facilitates degradation of some compounds
- Drift from aerial application of pesticides/herbicides on adjacent agricultural fields adjacent may increase toxicity of wetland effluent to some indicator species

Summary

The Tres Rios Demonstration Project has been on-going since August 1995. Much information has been obtained that can be directly used to design and operate the Full-

Scale Tres Rios Wetlands in the future. This information can also be transferred to other wastewater issues in the Phoenix Active Management Area (AMA) and likely, the entire State of Arizona under certain conditions. Namely, the wetlands at Tres Rios receive a high quality wastewater, e.g. nitrified and disinfected. For other systems receiving higher strength wastewater, results from the Tres Rios Demonstration Project are still valid, but loading rates and hydraulic retention times will probably need adjustment.

A balanced ecosystem approach should be used, one where emergent marsh, deep pools, and riffles are combined and support riparian and upland areas. The Tres Rios Demonstration Constructed Wetlands uses aquatic, wetland, and terrestrial features, which maximizes wildlife benefits, improves water quality. The balance ecosystem approach also goes a long way towards reducing vector and nuisance conditions typical of unbalanced systems.

Visioning Workshop Summary

On November 19 and 20, 2002 a team of concerned stakeholders, design professionals, agency officials, and experts from across the country gathered at the 91st Avenue Wastewater Treatment Plant conference room to discuss their vision for the full scale Tres Rios Constructed Wetland.

The event began with a welcome address from City of Phoenix Wastewater Engineering Superintendent, Paul Kinshella, and introductions from the group. Aimée Conroy of the City of Phoenix Wastewater Engineering Division moderated the two-day session. The overall goal of the workshop was to solicit input from project stakeholders and experts in the fields of treatment wetland design and operation, ecosystem restoration, vector control, environmental education, and recreation. This input would be formulated into a "Vision" of the future Full-scale Tres Rios Constructed wetland facilities. **Appendix B** contains the agenda and list of workshop participants.

In order to begin to define a vision, workshop participants were asked to fill out a questionnaire answering the following questions:

- Speaking from your own personal and professional background: In general, what elements should be included in the Tres Rios Wetlands for them to be "successful"?
- What is your vision for the Tres Rios Wetlands related to the following: water quality, water supply, habitat enhancement, fish and wildlife restoration, recreation and education, and flood control?
- Any other comments or suggestions?

Appendix C contains the participants' responses to the questionnaire.

Summary of Activities

The two day event consisted of presentations, a field visit, discussions, and group design time. Presentations were given on the following topics: lessons learned from the Demonstration Project, treatment wetlands and mosquito control issues, and county and state view of vectors.

Dr. Roland Wass presented the lessons he has learned from his tenure leading operations and research at the Demonstration Project. A review of the research facilities was presented first, followed by a performance summary of selected water quality parameters. Issues regarding the wetland vegetation used in the demonstration basins were then presented including a summary of the vegetative cover as estimated from aerial photography. Vector control issues were then summarized and the presentation ended with comments of public access and site safety issues.

Dr. Robert Knight, co-author of *Treatment Wetlands*, presented on treatment wetlands and mosquito control issues from his extensive experience with wetlands across the United States, including the Tres Rios Demonstration Wetland facilities. Dr. Knight discussed the success of the Indian River County, Florida's 165-acre wetland project. He credits the scarcity of mosquitoes to excellent water quality, presence of numerous mosquito predators, and an ongoing aquatic plant management program. He pointed out the importance of vegetation selection and management, including plant harvesting or controlled burning. Dr. Knight concluded that "wetland design and vegetation management in concert with year-to-year environmental conditions might be more important in determining mosquito populations than conventional mosquito management techniques (biological agents and pesticides).

John Townsend from the Maricopa County Vector Control Division and Craig Levy from the State of Arizona Health Department spoke together on the issues of mosquito and public health with a focus on the West Nile Virus (WNV). Arizona was among 6 states in the contiguous United States to not detect the West Nile virus in humans during the summer of 2002; the outlook for 2003 is not so bright. The virus was first detected in the United States in New York in 1999, since then it has infected over 4,000 and killed 284 people. The virus is transmitted to humans by mosquitoes. However infected birds and horses are major hosts of the virus. Migratory birds may be the cause of the virus's rapid spread across the United State.

The County and State are actively sampling sentinel chicken flocks as well as testing dead birds for presence of the virus. To date WNV has yet to be detected in Arizona. However, with the number of birds anticipated at the full scale wetland project, the management of potential mosquito breading sites, such as wetlands is critical to public health. Water quality improvement and habitat enhancement values of the Tres Rios wetland must be secondary to protection of human health.

After the presentations were concluded, the team took an hour to visit the demonstration wetlands and reacquaint themselves with the facility, its successes, failures, and ongoing challenges.

Upon returning from the field visits, three moderated discussions were conducted on the following topics:

- Brainstorming – Aimée Conroy
- Constraints – Alice Brawley-Chesworth
- Vector Solutions – Juliet Johnson

Treatment wetland experts: Dr. Kadlec, Dr. Knight, and Dr. Gearheart, shared their design concepts for lead the group was given design time and instructed to develop design concepts for the following elements in regards to both the regulating and overbank wetlands:

- Habitat/species of importance
- Recreation/education
- Hydraulic controls/discharge options
- Water quality
- Basin layout and berm design
- Wetland access

Comments from the field trip and discussion are contained in **Appendix D**.

The workshop wrapped up with a final discussion moderated by Roland Wass.

Performance Goals & Objectives

In the first order of business, the team was asked to describe their vision of the Tres Rios Project Goals. Their responses were recorded on flip charts during the workshop and subsequently sorted into 6 categories that include: Project Theme, Water Supply, Water Quality, Wetland Design/O&M, Ecosystem/Habitat, and Public Use (Recreation, Education, Access, and Safety). The following section will present a summary of the participants' "visions" that were recorded during the initial visioning workshop task. After each summary, the specific comments are provided for review. In a couple of instances the same comment has been repeated when the vision addressed multiple categories.

Project Theme

Five vision statements did not address specific project components, instead they encompassed ideals, and were more like global visions that provide a holistic view of the overall project. In all, five general statements were provided which addressed the overall vision of the project.

- The full scale project should be a "naturally functioning river system"
- Adaptive management should be provided and expected through the life of project

- Tres Rios is more than a "construction" project, and needs to be a long-term cooperation between agencies
- The project should provide a discharge that is "best" for the river
- The project should encompass the ideal that we want "the water to work harder"

Water Supply

- Water supply is an important aspect of the project. The wetlands will provide water conveyance to downstream project elements and satisfy contractual obligations like that of the Buckeye Irrigation District
- The full scale project needs to recognize the responsibility to reliably transport the treated effluent

Water Quality

- The project must continue to strive for the "best" water quality
- To the extent possible, meet habitat and water quality goals simultaneously
- It is desirable to use the regulating wetlands for chlorine removal
- The project should be designed to improve (polish) the quality of the 91st Avenue WWTP effluent

Wetland Design, Operation, & Maintenance

- The full scale design of project features should be readily adaptive
- To the extent possible, meet habitat and water quality goals simultaneously
- It is desirable to use the regulating wetlands for chlorine removal
- The project should be designed to improve (polish) the quality of the 91st Avenue WWTP effluent
- The design should encompass the ideal of long term sustainability
- The design should facilitate adaptive management through the life of project
- The design should be one that requires the least amount of maintenance
- The design should consider/encompass future conditions and or other opportunities downstream, e.g., flexibility in piping and plumbing (maximum effluent from regulating wetlands may be as high as 920 mgd in future scenarios)

Ecosystem/Habitat

- Full scale design and operational strategies should be compatible with wildlife
- Flood control and habitat need to be carefully designed and balanced
- Consider the potential to provide flood event(s) of the appropriate scale that could stimulate the regeneration of favored plant species
- The full scale project facilities should provide a safe region for people and animals
- To the extent possible, the project should enhance existing habitat, especially in the proximity of future interpretive center(s)
- Full scale facilities should have non-public areas that are secluded for habitat reasons including seasonal breeding
- Remember it is a sensitive ecosystem

- To the extent possible, the design should support a naturally functioning river system
- Adaptive management should be planned now to last through the life of project

Public Use (Recreation/Education/Access)

- Recreation would be a good project component, but it should be limited so as not to impact primary functions
- The design should consider protection, project security, and access, including the exclusion of ATV access
- The design of facilities should provide a "safe" region for people and animals
- Project features should be included that provide opportunities to educate public, politicians, and legislators about the economic benefits of the project
- Take the time in design to make it "beautiful" for the people
- Use the project to provide education about the rich cultural history of area
- Development of project site security should include coordinated patrols from assorted agencies under an Inter-governmental Agreement among the City of Phoenix, Maricopa County, and Gila River Indian Community (GRIC).

Tres Rios Constructed Wetland
Full-Scale Project
Visioning Workshop
Report

BASIS, GUIDELINES, AND CONSTRAINTS OF DESIGN

Basis of Design

During the Workshop, information was provided that, once verified, could be used to support the basis of design for both the regulating and overbank wetland systems. This information included 91st Avenue WWTP design and operating flow information as well as, wetland design flows and the amount of water to be lost in the systems via "consumptive use". It is unclear as to whether this estimate of "consumptive use" includes seepage loss or losses to associated riparian vegetation, as such this value needs to be verified. With respect to the facility layout and operation, it was generally agreed that the wetland systems be designed with some number of individually controlled cells which would provide system redundancy and operational flexibility.

Specific information regarding the regulating wetlands included that the average daily fluctuation in water surface elevation will be approximately 1-ft per day. Further, the outlet(s) from the regulating wetlands should allow for discharge at or above the 100-year flood water surface elevation in the Salt River.

The comments as recorded at the workshop regarding the basis of design for the overbank and regulating wetlands are provided below:

- 91st Avenue Plant Flows
    - Plant design flow: 210 mgd
    - Seasonal inflows: 180 - 210 mgd
    - Summer Flow to Wetlands: 80 mgd
- Flow capacity of regulating wetlands (conceptual estimate)
    - Average design capacity: 230 mgd
    - Peak treatment capacity: 460 mgd
- Flow capacity of overbank wetlands
    - Average design capacity: 100 mgd
    - Peak treatment capacity: 120 mgd
- Maximum allowable consumptive use of water for Tres Rios Wetlands is 28,000 acre-feet per year (25 mgd)

- There shall be a minimum of six of more individually controlled cells in regulated wetlands to allow flexibility of operations and maintenance.
- The regulating wetlands must discharge above the 100-year flood level
- Water level fluctuation in regulating wetland < 1 foot on an average day

Vector Control and Public Use

Vector control and public use issues generated much discussion. Vector control issues relate to the management of both larval and adult mosquito populations and encompass basin design, vegetation selection and maintenance, larvicide application and fogging. The desire exists to minimize the use of larvicide and adulticides in lieu of vegetation selection, density, and water level management.

Vector control issues include the following questions:

- Can the plant communities be managed such that we don't require larvicides/fogging?
- If mosquitoes are controlled without larvicide, can wider basins be designed?
- Should we consider maintaining optimal plant density with controlled burning?
- It may be more expensive to build lots of roads versus the cost to implement other mosquito control techniques? Cost/benefit of chemical control versus plant community management needs to be assessed.
- Could we use an airboat for larvicide application in large cells?
- Given the vector control costs of the demonstration project, 1,000 – 2500 $/acre/yr, the anticipated annual costs for the full-scale project will range from $250,000 to 1,200,000 $/yr. Are other methods more cost effective in the short or long term?

The City of Phoenix Parks and Recreation Department estimates that over 500,000 visitors will potentially visit the project facilities on an annual basis. This amount of visitation will present a challenge with respect to protecting the habitat and wastewater treatment components of the project while still providing a safe recreational/educational experience. Criteria need to be established to address the hours of public use and specific picnic and staging area facilities. Travel to the Project Facilities must also be considered from the standpoint of existing transportation corridors. Finally, decisions should be made regarding the frequency and magnitude of public access provided in the Wetland areas. The specific questions raised by workshop attendees are provided below.

Many recreation, public use, and safety questions need to be considered

- Public uses
  - Will use/visitation be allowed after dark?
  - Will picnic areas with barbeque grills be provided for individuals and/or group events?
  - Will campfires be allowed if overnight use is permitted?
- Do existing streets have the capacity to safely handle increased traffic to the area?
- Public access to wetlands

- Will vehicle guided tours be provided?
- Will horse traffic be allowed in all project areas or will it be restricted to only overbank areas?
- Will there be seasonal shut down of portions of the project in wildlife breeding habitat areas?

Constraints

Alice Brawley-Chesworth and Aimée Conroy led a discussion of the project's constraints. The four major physical constraints identified were concerned with utilities and associated facilities such as:

1) Arizona Nuclear Power Plant (ANPP) cooling water pipeline crosses the site and will not be relocated.

2) City of Phoenix gas pipeline is located under the regulating wetland site.

3) Project storm water collection and drainage needs to coordinate with the Durango Area Drainage Master Plan (Flood Control District of Maricopa County)

4) El Paso Natural Gas pipeline is located under the overbank wetland site.

5) City of Tolleson 30" effluent pipeline crosses the regulatory wetland site.

The team was asked to discuss the potential impact of these constraints as well as identify additional possible constraints on the project. Issues that need to be addressed included the following:

- ANNP pipeline may not be an issue since topography of the land and its depth below ground surface may allow construction on top of the line.
- There is a potential that loads applied by structures and/or vehicles may compromise the integrity of the ANNP pipe line.
- El Paso Natural Gas pipeline may be located at a point conducive for dividing wetland cells.
- Provide drainage from horse trails away from wetlands or collect horse path run-off separately.
- Use gravity to convey water through the wetlands from south to north or southeast to northwest.
- Construct the wetlands at a level grade and contour with gates.
- Divert storm water around the regulating wetlands.
- A seepage control canal may need to be constructed along west edge of regulating wetlands to protect property to the west, especially during storms.
- Consider a by-pass channel along the eastern boundary of the regulating wetlands site that would convey both effluent and storm water runoff.

- Do not design 90° angles in the wetland basins.
- Scour criteria of the river sediment will limit the amount of water through the overbank wetlands.
- Provide a riparian corridor channel down the middle of the site and place the wetland cells down the sides.
    - The riparian corridor would likely convey water more quickly to the Salt River and be used during times of extremes.
- When the pump station was moved away from discharge channel, it took away option to pump to river during 100-year flood event
- Some seepage is good for water quality (reducing the buildup of salts), but how much leakage is allowable without impacting neighbors or buried utilities?

Tres Rios Constructed Wetland
Full-Scale Project
Visioning Workshop
Report

DESIGN VARIABLES

On Day 2 workshop attendees were tasked to focus on specific issues related to the Regulating and Overbank wetland systems. National wetland experts Bob Knight, Bob Kadlec, and Bob Gearheart, led a discussion of wetland design topics that included: Habitat Value/Species Selection, Recreation/Education, Hydraulic Controls/Discharge, Water Quality Improvement, Basin Layout and Berm Design, and Wetland Access. Out of that discussion, the team developed concepts for hydraulics, water quality, habitat, operations and maintenance, and sustainability. Their efforts were recorded on Flip-Charts and the leaders presented the design concepts. The team also developed several alternative designs for the layout of the regulating and overbank wetland basins. Many designs were discussed and opinion often conflicted. All results of the discussions are presented below while the graphical depictions are provided in **Appendix E**. The concepts presented do not reflect the opinions of all participants.

Hydraulics

- Scour criteria is needed to design the depth, capacity, and flow velocity for the overbank wetland basins.
- Discharge structures from regulating wetlands to the Salt River could consist of a plunge pool.
- Channels should be designed to allow by-pass of flows for flexibility of operations.
- No more than 1-2 feet elevation drop should occur within each cell.
- High head loss will limit the length of overbank wetlands.
- Longer detention times should be sought in the overbank wetland basins.
- Little waterfalls between overbank wetland basins are needed to improve hydraulics.
- Maintain a relatively consistent discharge rate to the river on monthly basis.

Water quality

- The use of plunge pool or similar discharge structure will improve water quality by increasing dissolved oxygen levels.
- Use vegetation density of emergent plants and/or floating plants to improve water clarity (floating plants shade algae and emergent plants capture particles).
- Storm water can be collected and treated with independent wetland systems. Pre-treatment is needed prior to commingling with project water to protect downstream uses of project water.

Habitat

- Vegetation diversity is needed for aesthetics and to increase habitat values.
- Seasonally limit access to protect prime habitat sites.
- Multiple discharge points from wetland basins can be used to supply water for habitat stringers consisting of cottonwood and willow dominant canopy species.
- Pennywort provides shade to reduce algae and protection of fish from avian predators.
- Pennywort has been shown at other wetland projects to harbor mosquito larvae.
- Trees are excellent for habitat value, but can reduce views and destabilize banks.
- Cottonwoods can get too dense for optimum habitat values to be achieved.
- Basins with majority (60 to 80%) open water and proximate to wooded river bank, may increase herbivore damage by beaver populations. Potential damage may include holing of levees and short circuit channelization of the wetlands.

Operations and maintenance

- Flexibility in operations is necessary and can be provided by designing excess capacity in freeboard and hydraulic control structures.
- Design of facilities should facilitate flexibility in monitoring and implementation of adaptive management actions.
- Basins need pipes or other means connecting deep zones to facilitate initial filling and quick draining of all wetland areas including deep zones.
- Drainage from horse paths should be routed away from wetland features.
- At least two trains of parallel basins are needed for the overbank wetlands facilities.
- Elimination of the existing mosquito breeding problems at 113th Avenue is needed.
- The design of wetland facilities needs to consider access for maintenance and/or monitoring activities.

Sustainability

- Long-term sustainability of project should be the major focus of design elements.
- Over the course of the project life, continued monitoring is necessary so that appropriate adaptive management measures can be employed.

Recreation, public use, and safety

- No public vehicle access should be allowed to the wetland facilities.
- Keep public away from all water control structures.
- Need to control: shooting, dumping, and automobile activity in and adjacent to the wetland basins.

- It is anticipated that the new development in the area will result in bigger problems with illegal dumping in and around the project area.
- More eyes and ears in project area may hopefully mitigate the pressure of increased local population and result in less dumping.
- Consider circular/loop trails with distance labeled as people tend to like this feature at other City outdoor facilities.
- "Dirt" roads would be better for bikes, horses, walking/jogging, while boardwalks could be used for less active recreation needs.
- The wooden bridges and boardwalks mentioned above reduce the impact of human visitors on the delicate wetland environment, but still allow people to get the feeling of being in the wetland
- Pathways need to be designed with dust control in mind.
    - Decomposed granite
    - Slippery when wet
- Because of safety concerns, no cross street trails should be designed.

Tres Rios Constructed Wetland
Full-Scale Project
Visioning Workshop
Report

DATA GAPS

The team identified several data gaps, during discussions of design variables:

- Seepage should be considered to ensure lateral migration and mounding are not a problem to the west.
- Examples of stormwater conveyance through regulated wetlands. (i.e. Estrella Lakes)
- Constraints of the hydro-seeder for applying larvicides.
- Information is lacking regarding the performance of hummocks in treatment wetlands.
- More information is needed on the use of internal deep-zones for mitigating short-circuiting in treatment wetlands.

Tres Rios Constructed Wetland
Full-Scale Project
Visioning Workshop
Report

RECOMMENDATIONS

The two day workshop produced the following recommendations for design elements in the full scale Tres Rios Constructed Wetland Project. Many of these recommendations are likely applicable to both the regulating and overbank wetland systems although several are system specific such as the need to provide for water level fluctuations in the Regulating portion.

Facility and Basin Layout

- Use multiple cells for system redundancy and operational flexibility
- Use a combination of open water deep zones and emergent marsh areas (60 to 80% of surface area to be configured as open-water deep zones)
- Provide all weather access to perimeter of wetland cells
- Hummocks or other means of contouring the emergent marsh areas to:
    - Provide variable hydraulic regimes
    - Allow for rapid dewatering of vegetated areas
    - Facilitate fish access into densely vegetated areas

Wetland Hydraulics

- Provision of bypass channel to the Salt River
- Incorporate beaver resistant control structures
- Water surface control should be readily attainable in each cell
- Incorporate self-cleaning outlets
- Allow for adequate discharge or storage during 100-year flood event

Wetland Vegetation

- Use a diverse assemblage of aquatic plants
    - Emergent
    - Submerged
    - Floating
- Specify plant material adapted to the wetland design hydro-period
- Use emergent species with densities ≤ 200 stems/m^2

Habitat

- Design discharge(s) from wetlands to Salt River to sustain existing riparian and riverine habitat.
- Include transitional and riparian vegetation leading from the wetland shoreline to the upland area(s) of the project. These should be multi-canopy communities that include: ground cover, mid-story vegetation, and dominant canopy species.
- Place terrestrial riparian species to shade the water surface and assist in control of macrophyte densities while considering bank stabilization issues.

Public Use

- Include interpretive signage on trails
- Provide parking area for visitors
- Provide viewing opportunity points
- Public visitation during daylight hours only
- Provide ramadas and picnic areas

Vector Control

- Monitor weekly for larval and adult mosquitoes
- Manage vegetation densities
- Develop/explore vegetation management methods:
    - Mechanical
    - Burning
    - Varying hydro-period
    - Water depth regulation
- Encourage development of robust macroinvertebrate population by providing a diverse assemblage of aquatic and terrestrial plant species.
- Stock all wetland cells with *Gambusia sp.* and ensure adequate breeding populations are maintained
- Design the wetland basins to facilitate the introduction of mosquito larvicides.
- Develop in-house capability to apply larval mosquito control agents
- Ensure the City has the ability to apply adulticides either using in-house staff or an outside contractor

Summary of Wetland Design Recommendations

Diurnal fluctuations in treated effluent result from long travel times in the City of Phoenix collection system, diurnal fluctuation in water usage, and from contractual flow

obligations to supply effluent to the Arizona Nuclear Power Plant (Palo Verde). The regulating wetland complex should be designed to accommodate these diurnal flow fluctuations via changes in depth. This will permit a constant discharge(s) to be delivered to existing aquatic and riparian habitat located in the Salt River channel. The goal is to provide relatively constant depth and velocity profiles which in turn will increase the habitat value in this reach of the river. Further, since the regulating wetland complex will be located on the bank, this will provide an opportunity to design outfalls that utilize the change in elevation to re-oxygenate the wetland discharge. Experience at the Tres Rios Demonstration Project indicates that a turbulent drop of 9-ft increased the dissolved oxygen content 3 to 4.5 mg/L. Since the wetland treatment processes use available oxygen for the degradation of organic compounds and nutrients, re-aeration of wetland effluent provides better fish habitat and lessens mosquito production in the downstream areas. (Note, however, the 91st Avenue WWTP effluent is high quality and therefore does not have a high oxygen demand. However a substantial oxygen demand can be produced internally through the heterotrophic decomposition of macrophytic biomass.)

A constant discharge from the regulating wetland complex should also be supplied to the overbank wetland complex. The overbank system of wetland basins will be designed and operated primarily for habitat value and will be located as linear systems parallel to the Salt River channel along the top of the north bank.

The regulating wetland complex will be located upon agricultural fields that exist due west of the 91st Avenue WWTP. The site has been "leveled" in the past for agricultural activities and in general slopes to the center and to the southwest. The design should incorporate the existing topography to the extent practical, e.g. placement of open water deep zones and the orientation of flow paths and direction(s). A minimum of 3 and likely a maximum of 12 wetland cells should be designed to ensure flexibility in operation and to provide system redundancy. Individual basin morphometry should be balanced by the need for access for O/M activities, habitat value, construction cost, and ease of maintenance. All-weather access should be provided immediately adjacent to the regulating wetland basins to facilitate monitoring, operation, and maintenance activities.

The regulating and overbank wetlands may have common grading features including open-water deep zones and shallow level planting areas. Although not completely tested, consideration should also be given to the configuration, known as hummocks, which is being tested in the 2003 revegetation of the Hayfield Basin H1. The hummock configuration refers to the creation of shallow mounds that have a broad flat planting surface at the top and then taper surrounded by deeper waters. Although these features may exacerbate short-circuiting within the wetland basins, they may also result in better plant diversity and increased sustainability.

Open water areas are important from the standpoint of mixing, hydraulic efficiency, water quality, and wildlife habitat. Tracer testing and physical modeling of the demonstration scale basins indicated that internal deep zones oriented perpendicular to the flow path can mitigate, to some extent preferential flow paths formed in the shallow emergent areas due to high hydraulic loading rates (HLR), vegetative growth patterns,

and/or animal activity by increasing the amount of mixing. Dr. Kadlec looked at this aspect in the smaller Research cell basins and could not support the former statement. The issue of short-circuiting needs resolution prior to full scale implementation because the proposed average daily flow rates result in large hydraulic loading rates (≈ 70 cm/d). Hummocks will assist in aspects like mosquito management, but they will also likely result in short circuiting that may or may not be addressed through the use of deep water zones. Deep water zones will also be essential at the basin inlets and outlets. At the inlet areas, deep water should be used to distribute flows over the entire width of the wetland which will increase the hydraulic efficiency of the basin. Outlet deep zones should be configured in a similar manner, which will also enhance beaver resistant and anti-fouling outlet control structures. In any open water zone, the hydraulic retention time (HRT) should be less than the time needed for the development of algal blooms. Open water deep zones should also be designed so that they create areas within the wetland where wind induced mixing and re-oxygenation of the water column can occur. These areas should be on average 3 – 5 feet deeper than the emergent marsh areas so that when such vegetated areas are dewatered, a refuge will exist for aquatic macroinvertebrates and fish.

Based upon past and ongoing wetland vegetation research at the Tres Rios Demonstration facilities, emergent marsh to open water ratios should be in the 2:3 range. Past guidance indicated that 80% vegetated was needed in order to realize water quality goals. Research at Tres Rios and at a similar system in Hemet, California indicate that water quality goals can be met with lower emergent marsh to open water ratios. From a habitat standpoint this will likely provide systems more attractive to waterfowl (1:1 has been purported as optimum) and less likely to develop nuisance conditions, especially mosquito breeding. In areas where emergent marsh vegetation is desired, hummocks could be utilized as a platform for their establishment. The proposed hummocks would be mounds that taper with slope (horizontal run: vertical rise) 3:1 to 10:1 to a depth of 3 to 4 feet. Such a feature allows a tremendous amount of diversity to be achieved in a small area. Hummocks have several potential advantages over emergent areas that are graded to a single elevation in that they may allow for more variations in wetland hydroperiod (e.g. how long and to what extent areas are inundated), which in turn will support a diverse assemblage of macrophytes. Further, since they are surrounded on all sides by "deep-water", they facilitate access by mosquito predators into the vegetated areas. Finally, such a configuration may allow for more rapid dewatering of the vegetated areas for operational and maintenance activities.

Hydraulic control structures should be designed to meter and distribute flows into, between, and out of the regulating wetland and overbank wetland complexes. Special attention will be focused upon the design of structures that can pass the wide range of proposed flow rates while permitting very accurate measurements. Further, as was clearly shown at the Tres Rios Demonstration wetlands, the inlets and outlet structures must be beaver resistant, allow for absolute control of the water surface elevation, resist fouling due to vegetation, be redundant, and automated to the extent practicable. Passive hydraulic connections should also link internal deep zones so that initial filling can be accomplished without the head-cutting problems that arose at the Demonstration facilities. (Note: the size and/or configuration of connections should be limited since

these features will likely promote short circuiting of emergent zone.) Consideration should also be given to managing storm water runoff emanating from both within the project features and from adjacent lands. It is likely that runoff and run-on can be managed in dual-service structures such as a potential wetland by-pass channel running along 91st Avenue or even routed through the wetland basin complex. Consideration should also be given in the wetland system design to the opportunity for treating and utilizing storm water and dry-weather nuisance flows in future project features or for future regulatory compliance.

Design of the vegetative components of the project will be integral to the success and efficient operation over the course of the 50-year project life. Both wetland and terrestrial plants play an integral role in water quality enhancement, habitat value, vector control and project sustainability. From a water quality standpoint the vegetation is used to provide an environment conducive to epiphytic and bacterial colonization, assist in the mechanical straining and capture of particulates, shading of the water column, and providing gas exchange.

The wetland vegetation should be comprised of several classes of aquatic plants to provide diversity, which increases the overall habitat value of the system. In many instances diversity also makes it easier to operate and maintain the system. Emergent macrophytes will be used in the emergent marsh areas. Emergent plants native to Arizona include cattail (*Typha spp.*) and bulrush (*Schoenoplectus spp.*) species. Each species has specific life-cycle requirements, benefits, and detriments. For example, *Schoenoplectus americanus*, common name three-Square bulrush, requires moist muds to approximately 4" of inundation. It was found during the Tres Rios Demonstration Project that this species grows at up to 800 stems/m^2. Such a density, coupled with the propensity to lodge and thatch provided areas within the wetland that were ideal for mosquito breeding. Conversely, *Schoenoplectus acutus* (formally *Scirpus acutus*) thrives in 12 inches of water or deeper and grows at densities of 200 – 300 stems/m^2, making it much easier to maintain and to effect mosquito control. At this time, up to 7 emergent marsh species could be considered.

Floating aquatic plants such as pennywort (*Hydrocotyle sp.)* should be used in both open water and emergent areas to increase diversity and provide habitat. In the open water areas the pennywort supports zooplankton, which in turn provides forage for mosquito fish. On many occasions while "dipping" for mosquito larvae in pennywort at the Tres Rios Demonstration Wetlands, juvenile mosquito fish (*Gambusia affinis*) were caught, which indicated that this plant served as a nursery for this fish. Additional habitat value was noted in that muskrats, American Coots, and other water fowl appear to forage on the pennywort at different times of the year. Spreading/Floating aquatic plants grown in conjunction with the emergent marsh species also improved access by mosquito predators into densely vegetated areas.

Submerged aquatic plants should also be established in some of the open water deep zone areas. At the Demonstration Project, coontail (*Ceratophyllum demursum)* was used in similar areas. Submerged aquatic plants assist in re-oxygenating the water column,

provide surface area for the attachment of bacteria, and serve as a nursery for zooplankton. Further, they block sunlight from penetrating the entire water column, reducing algal growth.

Terrestrial riparian vegetation adds to the success of the Regulating and Overbank wetland systems habitat value as well as operations. It was when the Demonstration Project facilities lacked this component that many of the nuisance conditions were at their worst. Facultative wetland plants should be used to serve as a transition from the wetland to the hydro-riparian habitat to be located immediately adjacent to the wetland facilities. Such vegetation will consist of grasses, forbs, and rushes immediately adjacent to the wetland perimeter to serve as ground cover for slope stabilization and cover for wildlife accessing or exiting the wetland ecosystem. Shrubs will serve as the mid-story vegetation with species such as Seep Willow, Quail bush, Mexican Elderberry serving in wildlife habitat and slope stabilization roles. The dominant canopy species will include Gooding's Willow and Freemont Cottonwood. Various establishment and recruitment techniques including seed, pole, and containerized planting will be used to establish and sustain this multi-story riparian complex.

In summary, the Regulating and Overbank wetland systems are complex and will require the expertise of a multi-discipline design team. Most importantly, the hydrology and hydraulics must be thoroughly investigated and systems designed to accommodate the high flow rates the full-scale system is expected to receive. This includes inlet, outlet, and intra-basin hydraulic structures, as well as location and configuration of deep zones. Also, there is a need to continue to research emergent area bottom configurations so that diverse and sustainable marsh areas are provided in the full-scale facilities. Further, in order for the project to be a success, the design must include consideration of the costs and operation and maintenance issues the wetland systems will undergo over its 50-year life, including vegetation maintenance and especially vector control costs.

Appendix A – Demonstration Redesign and Revegetation

Tres Rios Demonstration Constructed Wetlands Project

Demonstration Basin Redesign and Revegetation

Vegetation failures in the demonstration basins began in 1997. By the summer of 1998, conditions were unacceptable with regards to vector control. Vegetation management is needed for the demonstration and full-scale Tres Rios wetland basins. Several reasons for this failure were investigated including herbivore pressures, excessive chlorine loading, and/or a micro-nutrient deficiency that may have stressed the vegetation. However, no conclusions were able to be made, and the Cobble basins were redesigned and reconfigured during the summer of 1998. Hayfield Basin 1 was reconfigured in the spring of 2004. Subsequent and ongoing research at the Hayfield site it testing the theory that operating depths used in the Demonstration Project were too deep for the plant species.

Reconfiguration efforts consisted of removing approximately 1865 m^3 of bottom material from the unlined basin (C1) such that all shallow emergent areas are surrounded with open-water deep zones on at least three sides. The goal was to provide better mosquito fish access to potential breeding areas located within vegetated zones.

Bottom material removed from C1 was placed as gravel bars within the emergent zones of the lined Cobble Basin C2. This effectively reduced the amount of wetted area by approximately 0.3 acres. These bars were then planted with riparian vegetation such as cottonwood and willow trees to shade the water surface. Further, the amount of the two species of bulrush originally used was reduced and augmented with additional species. To provide surface area lost to the less dense emergent zone plantings, floating aquatic plants were added. The primary species used was Water Pennywort (*Hydrocotyle* sp.).

Although the Cobble Site basins were the only ones reconfigured, above-ground dead vegetation was removed from basin H1 during July 1998, while standing dead vegetation was left to decay in basin H2.

Percent Vegetative Cover

Estimates of the amount of vegetative coverage was developed from color adjusted infrared aerial photographs taken pre and post reconfiguration during the time period 1995 through 2000. Two flights dated February 1997 and January 2000 were available where vegetated areas were delineated based upon areal coverage and species. Estimates of vegetative coverage were developed from aerial photographs taken quarterly in 1997, 1998, and 1999 for each of the four basins H1, H2, C1, and C2. Prior to 1997, all basins exhibited over 80% vegetated coverage. As seen in Table 1 emergent macrophytic-based vegetative cover in the four wetland basins varied over the four-year period. Much of the variance is associated with the reconfiguration activities conducted during 1998.

Table 1. The Percent Vegetative Cover
Estimated from Aerial Photographs Taken

Before and After Vegetation Removal Activities

Year	H1	H2	C1	C2
1997	69%	77%	84%	90%
1998	40%	46%	47%	58%
1999	10%	15%	10%	25%
2000	32%	12%	53%	54%

The reconfiguration activities involved basin dewatering and some degree of biomass removal in all of the wetland basins with the exception of Hayfield Basin H2. The following describes the changes in vegetative cover each wetland basin experienced during the course of this study.

Hayfield Basin 1

During 1997 basin H1 exhibited full vegetative coverage (≈ 70%) in emergent areas, 54% *S. americanus*, 46% *S. tabernaemontani*. Normal growth and senescence cycle occurred. However, in the winter and spring of 1998, very little new growth was apparent.

By June of 1998 virtually all macrophytes (≈ 90%) had died and the biomass developed in 1997 was undergoing decay. In July 1998 the basin was dewatered and the above ground biomass was removed. A layer of detritus approximately 5-10 cm was left in place to the extent possible and the basin put back into service September 1998.

During 1999, volunteer cattail and root stock left in-place after the June 1998 removal produced sparse above ground emergent macrophytic biomass. By August 1999 basin H1 exhibited approximately 32% emergent vegetative cover. This coverage persisted throughout the year 2000.

Hayfield Basin 2

Maximum vegetative cover occurred in basin H2 during 1997 and 1998 overlying ≈ 77% of the wetted surface area. The species present included *S. tabernaemontani*, *S. americanus*, and *Hydrocotyle*. Normal vegetative cycles were observed through 1997 and the first quarter of 1998. Between May and September 1998, close to 65% of the vegetative cover was lost due to plant death and subsequent decay. Unlike basin H1, the vegetative biomass was not removed during reconfiguration activities, rather it was allowed to undergo decomposition within the wetland basin H2.

In 1999, emergent macrophytic biomass continued to decline, but *Hydrocotyle* persisted in H2. Using aerial photographs taken in January, April, and August 1999 as a basis, the basin coverage was estimated to be approximately 15%. As of January 2000 the amount of vegetative cover in basin H2 had reduced to 12%, almost all of which was *Hydrocotyle* associated with the perimeter of two islands located in the downstream open-water deep zone. Subsequently, cattail has invaded the basin and currently a little more than 50% of the basin is vegetated.

Signs of vegetative stress were already occurring by February 1997 in basin C1. The vegetation present, *S. validus* and *S. olneyi* covered approximately 84% of the wetted area. By June 1997 both species of bulrush exhibited obvious stress and very little new

growth was observable with this trend continuing through the end of summer and into the fall.

Much of the vegetation was dead and undergoing decomposition by January 1998. In March 1998, the basin was dewatered in anticipation of reconfiguration activities planned for July and August 1998.

Cobble Site 1

Because Basin C1 was out of service from March through August 1998, percent vegetative coverage was estimated as the average between pre and post reconfiguration activities. This resulted in basin coverage of approximately 47% during 1998. The post reconfiguration vegetation in C1 was almost exclusively *Hydrocotyle*.

During 1999 *Hydrocotyle* started to spread over the basin resulting in roughly 27% vegetative coverage in January 2000. That amount of cover was used for the entire year of 1999. *Hydrocotyle* continued to spread and by the end of 2000 it is estimated that coverage represented close to 53% of the wetted area.

Ninety percent of the wetted surface area of C2 was vegetated with *S. tabernaemontani* and *S. americanus* in 1997. Similar to C1 the vegetation showed signs of stress and little new growth had occurred by June 1997. By January 1998 close to 50% of the vegetation was submerged and likely undergoing decomposition.

Vegetative cover continued to decline in the first quarter of 1998 until the basin was dewatered for reconfiguration activities. The reconfiguration resulted in a loss of approximately 1214 m^2 of wetted surface area. Approximately 58% of the remaining available emergent area was vegetated.

Cobble Basin 2

During 1999 *S. validus*, *S. olneyi*, *Typha*, and *Hydrocotyle* all contributed to a 25% vegetative coverage in C2. The bulrush re-grew from root stock that remained viable during the reconfiguration, cattail volunteered in small areas, and *Hydrocotyle* was introduced in both deep zones. By January of 2000, the aerial coverage in C2 was estimated from aerial photographs to be approximately 54% which did not significantly change through the end of 2000.

Appendix B – Agenda and List of Attendees

Tres Rios Wetlands Visioning Workshop
Day 1: November 19, 2002

Time	Topic	Presentor/Moderator
8:00-9:00	Welcome and Introduction	Aimée Conroy and Paul Kinshella
9:00-10:00	Lessons learned from the Demonstration Project	Roland Wass and Sara Gerke
10:00-10:15	break	
10:15-11:30	Brainstorming	Aimée Conroy
11:30-12:30	Lunch Wetlands Panel Discussion	Bob Knight, Bob Kadlec, Bob Gearhart
12:30-2:00	Walk around the Demonstration Site	
2:00-2:30	Discussion about ideas/thoughts from the visit to the Demonstration Site	Aimée Conroy and Roland Wass
2:30-3:00	Constraints	Alice Brawley-Chesworth
3:00-3:30	Discussion of constraints	Alice Brawley-Chesworth
3:30-4:00	Presentation of plan for tomorrow	Aimée Conroy
4:00	Adjourn	

Tres Rios Wetlands Visioning Workshop
Day 2: November 20, 2002

Time	Topic	Presentor/Moderator
8:00-8:30	Recap and Summary of Key Items Review today's Agenda	Aimée Conroy
8:30-9:00	Vectors	Bob Knight
9:00-9:30	County and State View on Vectors	John Townsend and Craig Levy
9:30-10:00	Discussion of Vector Solutions	Juliet Johnson
10:00-10:15	break	
10:15-11:30	Design Groups - Regulating Wetlands	Juliet Johnson
	Topics: Habitat/Species, Recreation/Education, Hydraulic Controls/Discharge, Water Quality, Basin Layout and Berm Design, Wetland Access	Group leaders: Bob Knight, Bob Kadlec, Bob Gearhart and Bob Bastian
11:30-12:30	Lunch Habitat Considerations	Julie Stromberg
12:30-2:00	Design Groups - Overbank Wetlands	Juliet Johnson
	Topics: Habitat/Species, Recreation/Education, Hydraulic Controls/Discharge, Water Quality, Basin Layout and Berm Design, Wetland Access	Group leaders: Bob Knight, Bob Kadlec, Bob Gearhart and Bob Bastian
2:00-2:15	break	
2:15-3:15	Presentation of Group Ideas	Bob Knight, Bob Kadlec, Bob Bastian and Bob Gearhart
3:15-4:00	Synthesis and Wrap-up	Roland Wass

TRES RIOS RIVER MANAGEMENT PLAN

Sign-In Sheet
Tres Rios Wetlands Visioning Meeting

November 19, 2002

Name	*Affiliation*	*Phone*	*E-mail*
CHRIS OCHS	CITY OF GLENDALE	623-930-2702	cochs@ci.glendale.az.us
Paul Kinshella	City of Phoenix	623 534 6928	paul.kinshella@phoenix.gov
William Doyle	BOR	602 216-3843	wadoyle@lc.usbr.gov
Sara Li	Greeley and Hansen, LLC	602-275-5593	jli@greeley-hansen.com
Mark Lutman	USDA/Wildlife Services	602-870-2081	Mark.W.Lutman@APHIS.USDA.gov
Frank Turek	PBS&J	602 943 1003 ex 110	fturek@pbsj.com
DICK PERREAULT	FCDMC	(602) 506-4774	rgp.@mail.maricopa.gov.
Don Perrier	FCDMC	602 506.4878	DTP@MAIL.MARICOPA.GOV
Max Enterline	ADEQ Watershed Mngmt Unit	602 771-4580	jme@ev.state.az.us
Wendy Wonderley	City of Phx - Env. Prog.	602 534-1775	wendy.wonderley@phoenix.gov
Aimee Conroy	City of Phoenix - Water	602 534-2576	Aimee.conroy@phoenix.gov
Roland Wass	WGA, Inc.	480-994-4542	rlwass32@aol.com
Wes Camfield	COP Tres Rios		—
Crystal Cotter	COP - Tres Rios	602-206-4176	Crystal.Cotter@phoenix.gov
[illegible]	COP P&R	602 534 1870	
Maria Blake	COP	602 261 8232	maria.blake@phoenix.gov
Marvin Murray	BOR	602-216-3839	mmurray@lc.usbr.gov
George Brooks	GRIC	520-562-6706	gbbrooks@gilariver.com

TRES RIOS RIVER MANAGEMENT PLAN

Sign-In Sheet
Tres Rios Wetlands Visioning Meeting

November 19, 2002

Name	*Affiliation*	*Phone*	*E-mail*
Bill Werner	Az Game & Fish	602-789-3607	bwerner@gf.state.az.us
Bob Kadlec	WMS	734-475-7256	rhkadlec@chartermi.net
Bob Gearheart	Humboldt State Univ	707 826 3135	rag2@humbdat.edu
Bob Knight	Wetland Solutions	386-462-1003	bknight@wsi.us.com
ADRON KEICHERT	HOLLY ACRES	623.936.1154	
Sara Gerke	WASS Gerke + Associates	602-454-0678	sara@wetlandsbywass.com
Mike Ternak	Corps of Engineers	602 640-2004	MTERNAK@SPL.USACE.ARMY.MIL
Mike Martinez	U.S. Fish & Wildlife	602 242 0210	Mike_Martinez@fws.gov
LARRY HANSON	91ST AVE WWTP	(602) 534-7108	Larry.Hanson@Phoenix.gov
Alice Brawley-Chesworth	COP	602-262-1828	alice.brawley-chesworth@phoenix.gov
Debbi Rodfl	COP WWED	2624595	Debbi.Rodfl@phoenix.gov
TOM SAGE	COE	213-452-3707	tsage@spl.usace.army.mil
Bob Koplin	COE	213-452-3629	robert.e.koplin@usace.army.mil

TRES RIOS RIVER MANAGEMENT PLAN

Sign-In Sheet
Tres Rios Wetlands Visioning Meeting

November ~~19~~ 20, 2002

Name	Affiliation	Phone	E-mail
Bill Werner	Az Game & Fish	602-789-3607	bwerner@gf.state.az.us
Aimée Conroy	COP-Water Services	602-534-2976	aimee.conroy@phoenix.gov
Bob Knight	Wetland Solutions, Inc	386-462-1003	bknight@wsi.us.com
Bob Kadlec	WMS	734-475-7256	rhKadlec@charter mi.net
Adron Reichert	Holly Acres	623-936.1154	
Sara Gerke	Wass Gerke + Assoc.	602-454-0678	sara@wetlandsbywass.com
Bob Gearheart	Humboldt State Univ	707-826-3735	rag2e humboldt.edu
John Townsend	Maricopa County Vector	602-506-0703	jtownsen@mail.maricopa.gov
Craig Levy	Az Dept. Health Serv.	602-230-5918	clevy@hs.state.az.us
Frank Turek	PBS & J	602 943 1003 x110	fturek@pbsj.com
William Doyle	BOR	602 216 3843	wdoyle@lc.usbr.gov
Sara Li	Greeley and Hansen	602-275-5595	jli@greeley-hansen.com
Bob Koplin	COP	213-452-3225	robert.e.koplin@usace.army.mil
Tom Sage	COE	213-452-3707	tsage@spl.usace.army.mil
Wendy Wonderley	COP-Env. Programs	602 534-1775	wendy.wonderley@phoenix.gov
Tom Fitzgerald	COP-Parks+Rec	(602)534-5252	tom.fitzgerald@phoenix.gov
Ray Ashley	GRIC-Environmental Health	(602) 528-1226	rayashley_oeh@hotmail.com
Mark Lutman	USDA/WS	602-870-2081	mark.w.lutman@APHIS.USDA.gov
Bob Bastian	U.S. EPA	202-564-0653	bastian.robert@epa.gov
Alec Gentield	COP Tres Rios		

TRES RIOS RIVER MANAGEMENT PLAN

Sign-In Sheet
Tres Rios Wetlands Visioning Meeting

November ~~18~~ 20, 2002

Name	*Affiliation*	*Phone*	*E-mail*
Alice Brawley-Chesworth	COP	602-262-1828	alice.brawley-chesworth@phoenix.gov
Mike Ternak	COE	602 640-2004	MTERNAK@SPL.USACE.ARMY.MIL
George Brooksdr	GRIC	520-562-6706	gbrooks@gilariver.com

Appendix C – Results from Visioning Workshop Questionnaire

Tres Rios Constructed Wetlands Project

Visioning Questionnaire

1. **Speaking from your own personal and professional background: In general, what elements should be included in the Tres Rios Wetlands for them to be "successful"?**
   - Vegetation, wildlife, people. Quality control on water levels and water quality.
   - Water quality enhancement, treatment processes involved such as nutrients removal. Recreation and education
   - Public and government buying sustainability by partners in project. Design to incorporate features that allow the project to be adequately maintained and "policed" to protect the progress already made and the success of future plans.
   - Meet water quality treatment goals, provide flood control protection, provide wetland/marsh habitat for native species; provide passive recreational activities, efficient to operate (low O & M costs), provide educational opportunities re water treatment and wildlife, attractive.
   - Hydraulic and hydrologic integrity and operability, positive public perception, biological richness, and diversity
   - Five years after implementation a new arrival to the valley visits the wetland and exclaims what a wonderful human and wildlife sanctuary with no idea that the system runs of treated effluent.
   - Restoration of lost river habitat, protection of downstream water quality, creation of a world-class ecological classroom, self-design for passive recovery after inevitable flooding
   - The #1 critical element is water supply other important elements: native vegetation reestablishment, consideration of wildlife in O&M
   - Easy to adapt should it be necessary to make minor changes to the completed project of for operational, "flow through" or gradient should minimize detention time, consideration for operation and maintenance, consideration for operation and maintenance
   - Ability to transfer flow in parallel not series, keep some discharge to river at current WWTP discharge, blinds for secure wildlife viewing, and long-term sustainability.
   - East to operate and maintain – helps improve wildlife in the area - beaver proof.
   - Community and professional ownerships
   - The elements in the feasibility study
   - Public access and safety, controlled and directed; education and integrate on all levels (K – PhD) tell the technical – biological story, and aesthetically pleasing.
   - Primary purpose should be for wildlife, yet available to be enjoyed by man. Must be compatible with the natural functioning of the river; conveyance of flood flows, recharge, natural water quality improvement and varied aesthetics in a desert environment.

- Most important aspect – **education**. Since the Tres Rios is on the fringe of an urban/rural interface, educating the public and government officials is an extremely important function of the Tres Rios Project. An interpretive center would be a crucial step towards meeting the public's need for riparian/wetland ecosystem education. Since this project is considered to be a demonstration, then this project should be used as a blueprint/boilerplate across other regions of the desert southwest.
- Education is important
- Sustainability, naturally, functioning, incorporating maintenance of natural processes, incorporating adaptive management through the life of the project, and incorporate into a river management framework so that we continue to collaborate on operations maintenance, and identify roles and responsibilities.
- Safe, pleasing in appearance, provide the best water quality possible, least amount of maintenance possible, secure bird and animal habitat compatible with area lasting.
- Primary purpose should be for wildlife, yet available to be enjoyed by man. Must be compatible with the natural functioning of the river; conveyance of flood flows, recharge, natural water quality improvement and varied aesthetics in a desert environment.
- All of the items below, you might want to add a research component as well.
- Natural riparian transition zones, bird watching, family enjoyment, seamless operation and control without looking like a machine, appreciate that water is water, and no beaver damage to built-up berms,

2. **What is your vision for the Tres Rios Wetlands relative to the following:**

   a. **Water Quality**
      - Constant control
      - Better quality to feed the habitats in this area
      - Tertiary treatment, polishing
      - Meet or exceed water treatment goals
      - Buffer and polish, with respect to several parameters
      - That the natural background levels of "NPDES" and TMDL inputs define the effluent release to the river out to potential reuse options
      - Meeting applicable water quality standards and protect designated use
      - Effluent is acceptable to meet wildlife habitat needs, through probably not human recreation contact
      - Maximum water quality for polishing
      - Keep agricultural tail water and stormwater (future urban and current CAFO) out of wetlands.
      - Improve metal and nitrate removal maintains low turbidity – discharge looks like a river
      - The best water quality possible
      - Remove chloride, polishing

- Clean and safe
- Improve water quality through natural processes with minimum artificial manipulation by man.
- Monitor the before and after water quality parameters. Use this info to justify creating more projects with a cost/benefit and fiscal impact to better connect the projects efficacy.
- Polishing step, not the most critical part, but try to get all we can.
- Water quality sufficient to support mutual ecosystem, and habitat values which would be naturally found in the area.
- Body contact
- Improve water quality through natural processes with minimum artificial manipulation by man.
- Improve it
- Excellent not just meet NPDES requirement, but important to go beyond so that the effluent from the wetlands can be used as an addition to local water supplies

b. Water Supply

- What happens in water restrictions or droughts
- Continuous supply to downstream habitat, avoid dry seasons of the rivers.
- Potential for groundwater recharge
- Provide clean water for downstream users, including the Agua Fria Linear Recharge Project, supply water for habitat
- That the system is designed to be able to store and release on a seasonal basis – minimize ET losses.
- Reuse effluent for environmental enhancement
- Supply is questionable. Long term commitment to discharge effluent into river is needed.
- Remove diurnal variations, discharge-frequency return flow into river for best 'ecosystem' result in river
- Define the quantity required so the commitment to river can be established, control diversions by ANPP so Sunday summer mornings are not almost zero flow.
- Maintain flow in the river and helps as met our water supply objectives including Agua Fria Recharge
- Once started, cannot stop
- Transport water to downstream segments of project and BIC
- Reliable and predictable
- Recharge and sustained growth in a riverine environment.
- Maintain an adequate supply of water to sustain habitat. Consider naturally functioning ecosystems processes and carious elements of natural hydrograph which support and drive those processes. Dedicate water supply long-term.
- Recharge and sustained growth in a riverine environment

- Useable – needed to support current economic uses. Wanted for future water supply to satisfy growing community's demands.
- Keep it

c. Habitat Enhancement

- What type of vegetation to plant? Invasive species? Will there be control and management for vegetation, endangered species and diseases? If New Castle spreads in the wetlands. It would wipe out most of avian communities.
- Biodiversity
- Return to riparian 'native' habitat
- Provide 'islands' of functional native habitat to support the existence and restoration of native species. Also provide habitat for passive recreation.
- Well balanced communities of flora and fauna
- That habitat enhancement is the starting point – determine these communities you want to support and design around that
- Create maximum sustainable area of wetland and riparian habitat
- Provide for establishment and regeneration of native vegetation communities that provide habitat for a diversity of wildlife species.
- Design habitat area for specific species. Provide nesting sites for osprey, hawks, and bald eagles. Establish flowing water reaches.
- We have to be able to sustain what we plant, keep out saltcedar – use 'flood events' to stimulate desired species growth
- More beavers
- Provide a major wetlands in west valley
- A mosaic of vegetative types, classification and function sustainable
- Provide for varied (diverse) wildlife found in natural southwest rivers.
- Continue expanding project for increased benefits.
- Try to get as diverse as possible – some areas 'off-limits' to visitors and very dense vegetation.
- Maximize diversity of habitat to maximize diversity of native wildlife which would be naturally found in area.
- Provide for varied (diverse) wildlife found in natural southwest rivers
- Species diversity
- Desirable to incorporate habitat enhancement, fish and wildlife restoration and recreation and education as overlays that can and should be included in this wetland project.

d. Fish and Wildlife Restoration

- "If you build it they will come," Migratory stop-over-sites are essential. This could be a permanent site for migratory birds.
- Biodiversity
- Biodiversity, once prevalent in the area, a demonstration project, becoming a viable project and world renown
- Provide habitat to support the recovery of threatened, endangered, and sensitive species
- Consider wildlife needs during construction phase and O & M phase.
- Use native species in wetlands and upland area. Use native species for vector control. Establish habitat for specific species to aid in de-listing.
- Attract species but have a way to maintain them
- As diverse as possible
- Provide opportunities for Fish and Wildlife
- Focus on balanced native and migratory –viewable in a natural setting
- Create good habitat and see what comes
- Maximize diversity of native wildlife which would be naturally found in the area
- Valuable and important
- Bring back some riparian habitats

e. Recreation and Education

- Public assess on foot only, patrolled by security
- Parks trails around the wetlands
- A gemstone for public use and education tool that crosses many boundaries. Not only for primary and secondary education for that of the public, specialists in the field.
- Provide opportunities for passive recreation (bird watching, hiking) and environmental education.
- Availability balanced with operational goals
- Allow public access to a maximum extent, form an organization to support and deliver education programs 'Friends of Tres Rios Wetlands'
- Make area accessible for interested in public for passive recreation only: hiking, birdwatching, etc.
- Provide amenities that benefit the public but do not result in habitat degradation of wildlife disturbance
- Allow recreation access and opportunities to enjoy the resource, limit recreation to ensure it is not excessive and negatively impacts the primary purpose.
- Passive recreation for wildlife viewing. Control illegal activities in river. Provide an education center with small examples of all

habitat types for enhanced education. This provides opportunities to experience Tres Rios for those who can not hike the area.

- Continue to be a leader in environmental education
- No swimming – should be reserved for viewing and educational purposes only.
- Passive recreation – the whole thing is educational facilities will allow focus
- Accessible, safe, fun, and a clear message targeted to many education levels.
- Non-intrusive interaction by man on the natural environment
- Interpretive center needs to be built to educate public, children, municipal officials, and legislators. Build on the 'Carnegie' concept towards education and outreach.
- Need to encourage school groups – reach out to community
- Include recreation to the extent it doesn't reduce primary habitat objectives. Incorporate education through construction of facilities. Incorporate recreational fishing in overbank area if feasible and can use water without contamination issues.
- Separated for animal and human users.
- Necessary
- Learning experience/interpretive signs
- Hiking/meditation areas

f. Flood Control

- What are the history and record high water level/floods? Will there be a chance of erosion from river that may damage the wetland in 50 years?
- Capability to store all the water and discharge to the river
- Allow the project to grow within the natural course of river and perhaps alleviating man made 'boo boos' of years past.
- Provide a reasonable level of flood control for the Tres Rios facilities and local business and residents.
- Do not make anything worse
- Design pretreatment system for stormwater
- Maintain pre-development flood control only
- Minimize structural provisions and maximize opportunities to allow for overbank flooding, to the extent practicable.
- Works in conjunction with flood conveyance considering scour and erosion.
- Do not use wetlands for flood control in an active process. Construction should increase channel capacity but not be a flood control feature.
- Allows the river and the community to co-exist
- Invisible

- Already proven by project as safe
- Need for local population but should not constrain river too much.
- Manage flood impacts through design, operation, and maintenance of the project.
- 100-year a minimum and maintenance free within cost.
- Provide for 'natural' functions of the river, limit 'non-natural' development in the river.
- Essential
- No new problems from interior drainage

3. **Any other comments or suggestions?**
   - The security should definitely be considered during the design of wetlands. The operation mode should be flexible to accommodate difference scenarios.
   - Overlay all of the above
   - Perform and economic analysis
   - "Is there and economist in the house"
   - Move project to completion as soon as possible
   - Evaluate project from a holistic river landscape perspective, considering how the project fits in with other projects up and down stream.
   - In that most of the water flows through the regulating and overbank wetlands – opportunities will be created or lost or what we decide – some vision of the downstream flow requirements needs to be clarified.
   - We need to create a committee to have jurisdiction over what goes into the wetland after we finish so inappropriate plants and animals are controlled.
   - This is a very complex undertaking that should be explained in clear and elegant ways to scientist, students, lay people, and children
   - This team is overloaded with technician and engineers needs to bring on designers, landscape architects, education and recreation professionals – the earlier the better. The physical spatial layout is as important as engineering and biology. Way finding and interpretation need to be integrated in the beginning.
   - Integrate with upstream and downstream projects into an integrated management.
   - Provide for 'natural' functions of the river, limit 'non-natural' development in the river.
   - Lots of "board walk" type feature need inaccessible areas where we really let it go 'wild' to see how this benefits wildlife.

Appendix D –Visioning Goals and Field Trip Comments

Tres Rios Constructed Wetlands Project

Visioning Goals and Field Trip Comments

The workshop team listed the following visions goals:

- Long term sustainability
- Naturally functioning river system
- Adaptive management through the life of project
- More than "construction" project, needs to be a long-term cooperation between agencies
- Safe region for people and animals
- Best water quality
- Least maintenance
- Compatible wildlife
- Meet habitat and water quality goals simultaneously
- Design adaptive projects
- River discharge "best" for river
- Recreation good but limited to not impact primary functions
- Education public, politicians, and legislators about the economic benefits of the project
- Water quality regulating wetlands for chlorine removal
- Water quality polishing
- Water supply aspect (wetlands are water transportation for downstream projects and Buckeye Irrigation)
- Responsibility and reliability for transport of effluent
- Flood control and habitat need to be carefully designed and balanced
- Vision of downstream on river to not miss other opportunities downstream – flexibility in piping and plumbing (maximum effluent from regulating wetlands is 920 mgd)
- Enhancing habitat (especially by interpretive centers)
- Non-public areas for secluded habitat including seasonal breeding
- Take the time to make it beautiful for the people
- Educate about rich cultural history of area
- Remember it is sensitive ecosystem
- Work the water hard
- Protect project security and access, to exclude ATV access

Field Trip

The afternoon began as the team ventured out for a field trip. The goal of the field trip was to see the current state of the demonstration wetlands and reflect upon the demonstration projects successes, challenges, and lessons learned. After the field trip the team was asked for to share their thoughts. Ideas expressed about the demonstration wetlands included the following:

- Aestetic improvement from early project
    - Pennywort
    - Clarity of water
    - Openness/ surroundings
- Cottonwoods too thick in entry to Hayfield
- "Sandbar" at Cobble how does it affect flows and vegetation
- Saltbush Can be used as barrier for people around outside of basins
- Why pennywort not in basin?
    - Thick bulrush on banks?
    - High water flow?
- Density of aquatic plants
    - Fish oxygen favorable
    - How do fish utilize habitat
    - Are aquatic plants in the middle of basins?
    - Need a study (pop nets or 2 ring nets)
- Sites very different
    - Vegetation and looks
    - Rodents evident at Hayfield
- Shoreline vegetation
    - What are true constraints on hydroseeder?
    - Other equipment that sprays from higher point?
    - Maybe system of sprinkler heads permanently set in wetlands
- Some open water better for species diversity than pennywort cover (monoculture)
- More song birds in south Cobble because of trees
    - Vertical structure important
- Better habitat diversity with islands, maybe shorter than in C2
- Average day ~1 ft variation in depth in regulating wetlands
- For salt: good to have slightly higher islands
- Native plantings early help keep invasive species out of islands
- Pennywort safety hazard can't see where the bank is
- Saltbush as access control may be bad because people do things to "get to" wildlife
- Platforms, bird blinds raised higher up so people can get a view over vegetation
- Trail on levee can provide higher viewing area
- Maintenance of ramadas, platform, viewing structures, etc. possible manufactured wood
- Paul's waterfall plunge pool idea
    - Want option to create quick mini-flood(~1000 cfs)
    - Add oxygen to improve water quality and fish habitat

    - ~15-20 ft drop
- Keep ability to convey full flow through overbank wetlands
- Multiple discharges from overbank wetlands to create stringers channels through area now bare
- Step pool, waterfalls with boulders, pool riffle system
- Mimic natural system rather than pipes to river
- Need landscape architects to create aestetically pleasing feature
- Have many of these outfall features, not just at 91st Avenue
- Could create a discharge area that has a lot of noise?
    - Attract people?
    - People may be a nuisance to control?

Appendix E – Wetland Visioning Graphics

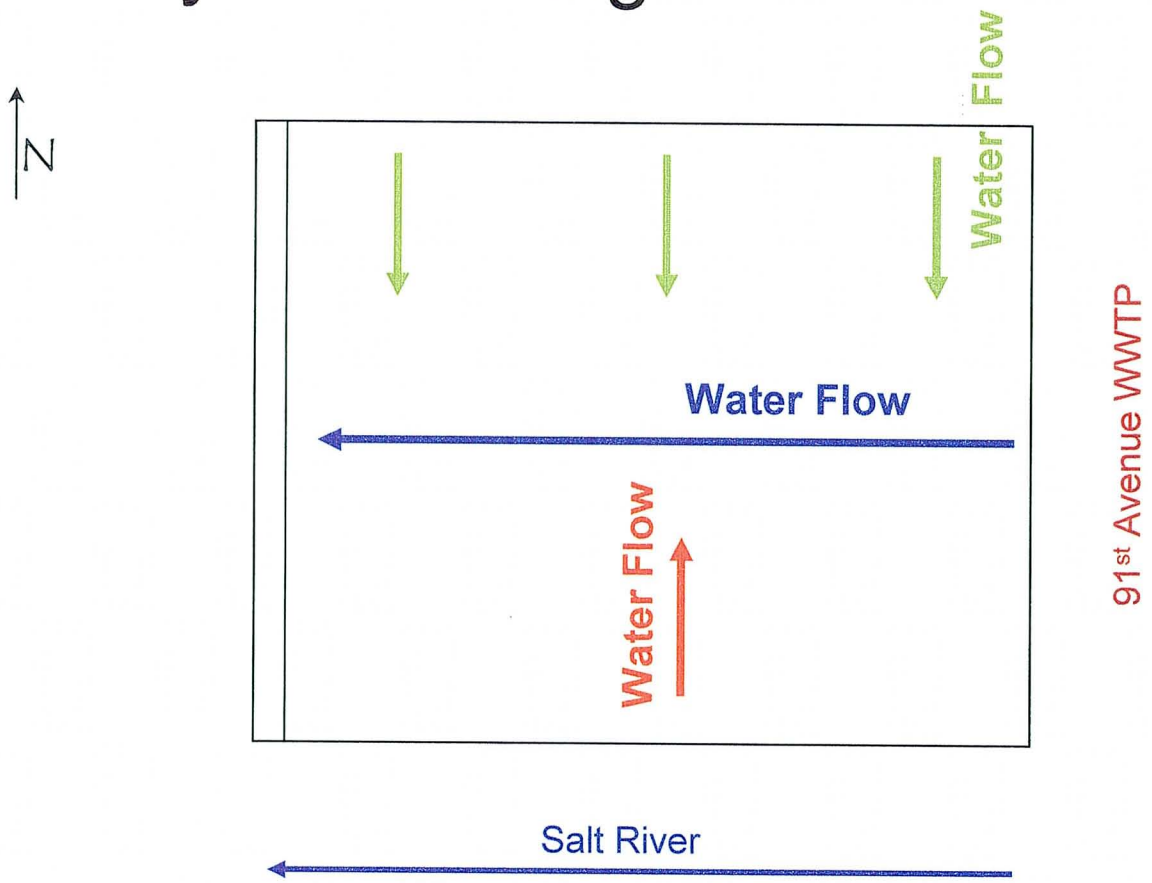
Tres Rios Constructed Wetlands Visioning Workshop

Conceptual Sketches

November 19-20, 2002

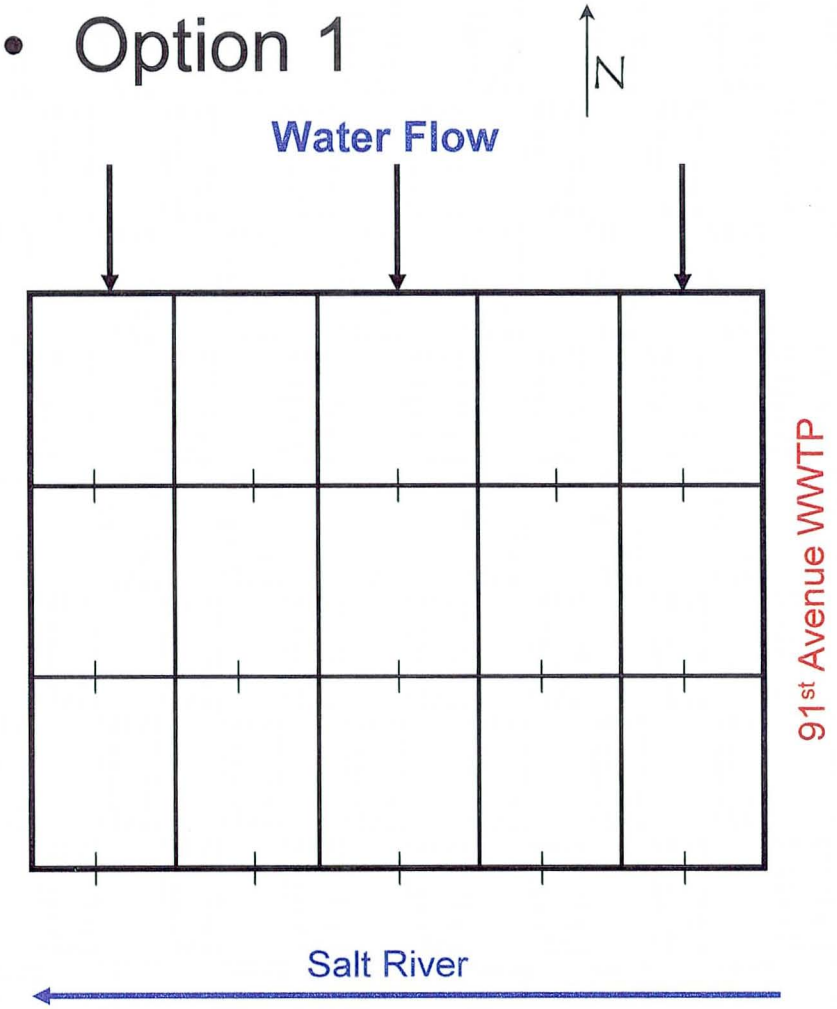
Regulating wetlands conceptual design options

- Naturally functioning

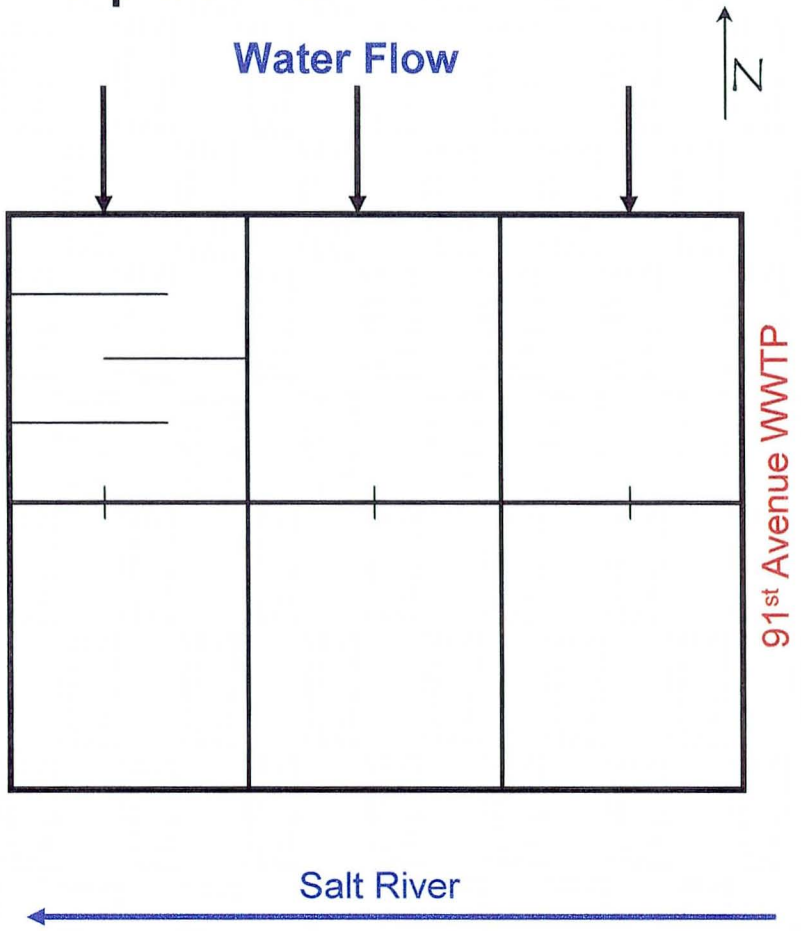


Design Concepts

- Option 1

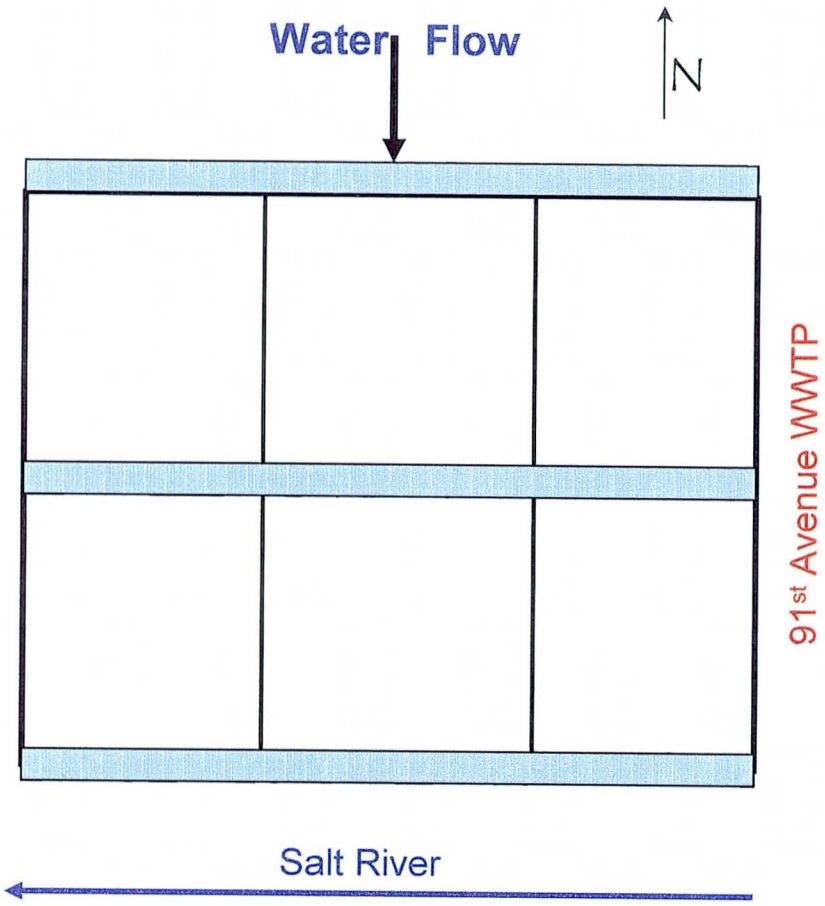


- Option 2

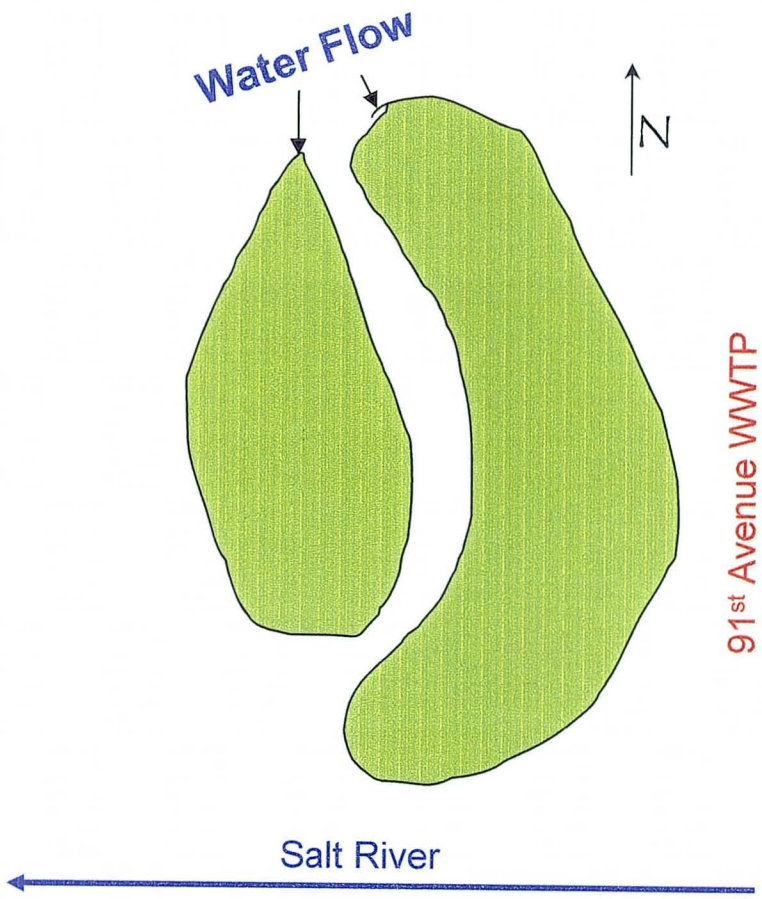


Design Concepts

- Option 3

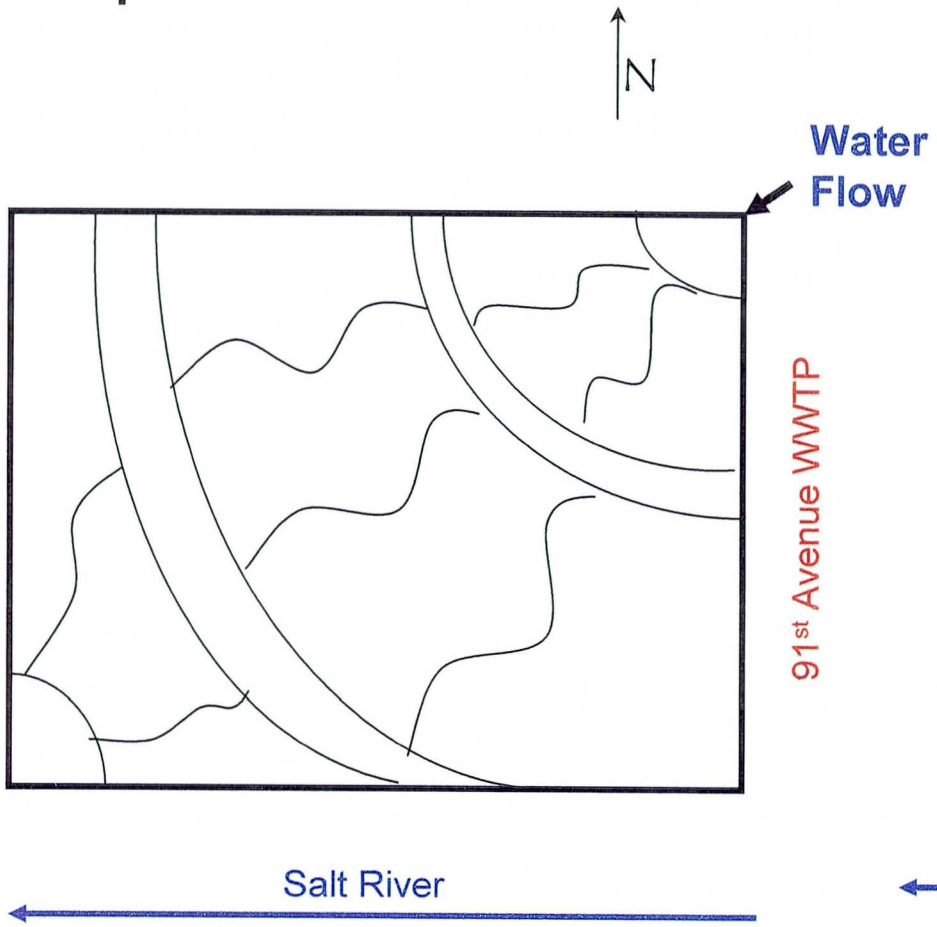


- Option 4

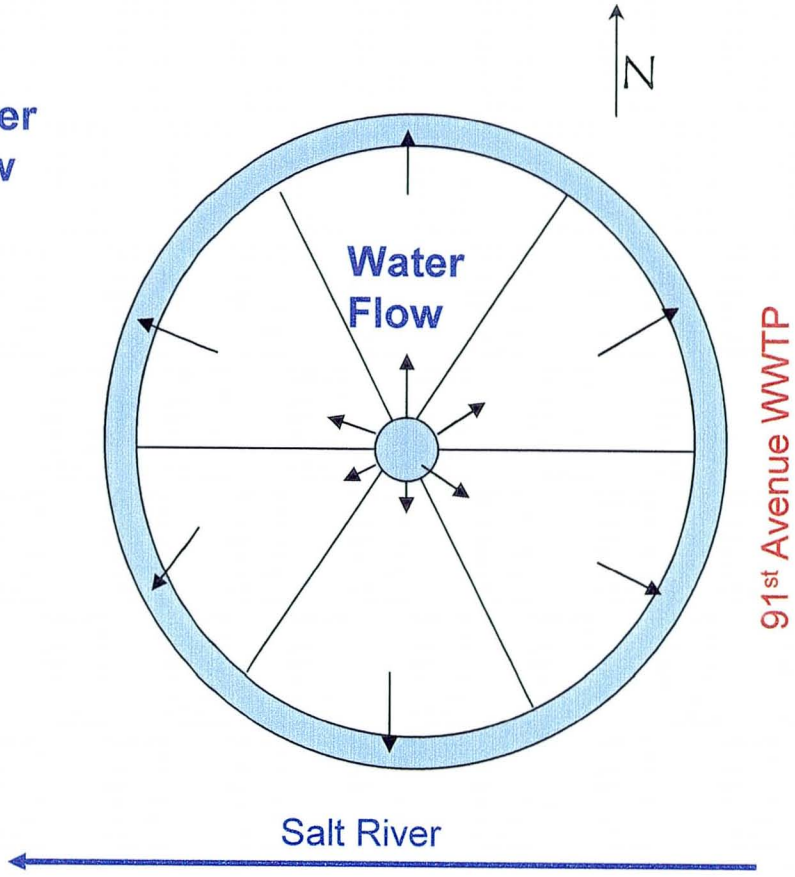


Design Concepts

- Option 4

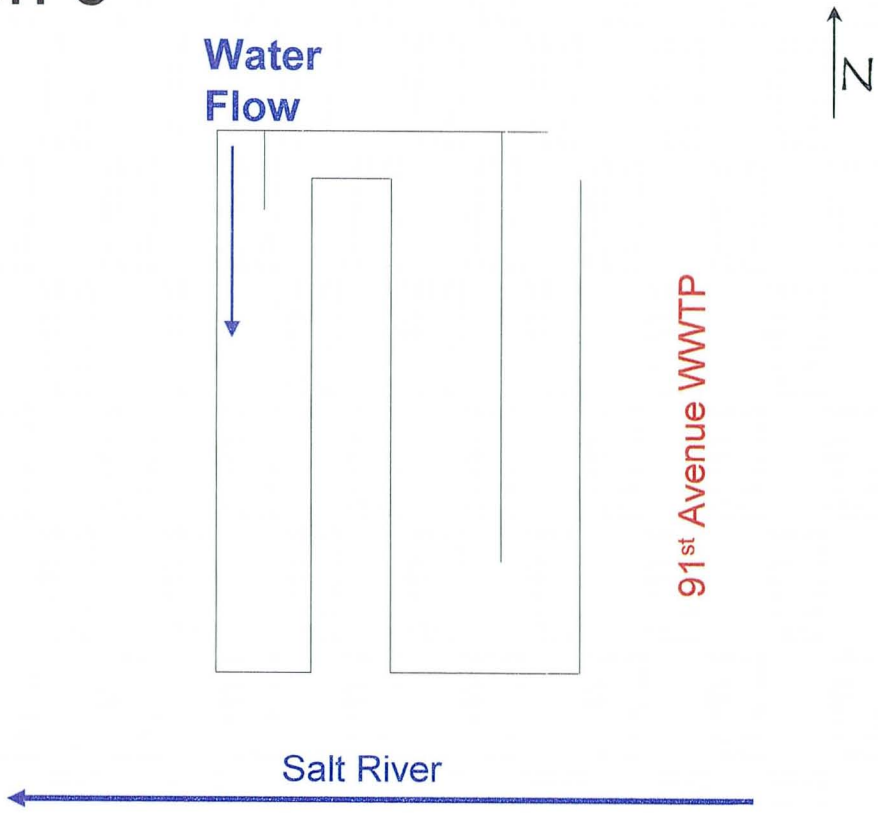


- Option 5



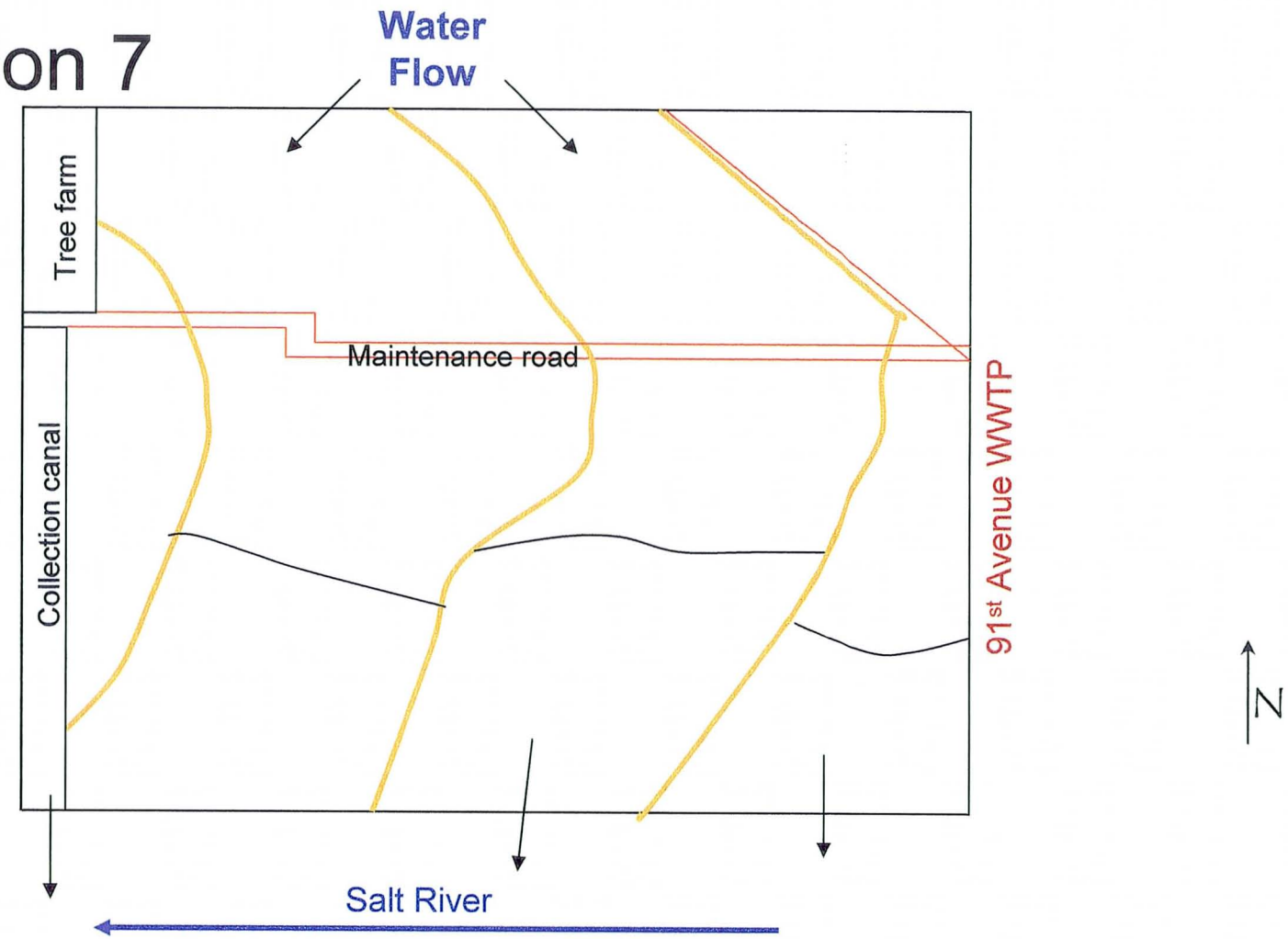
Design Concepts

- Option 6



Design Concepts

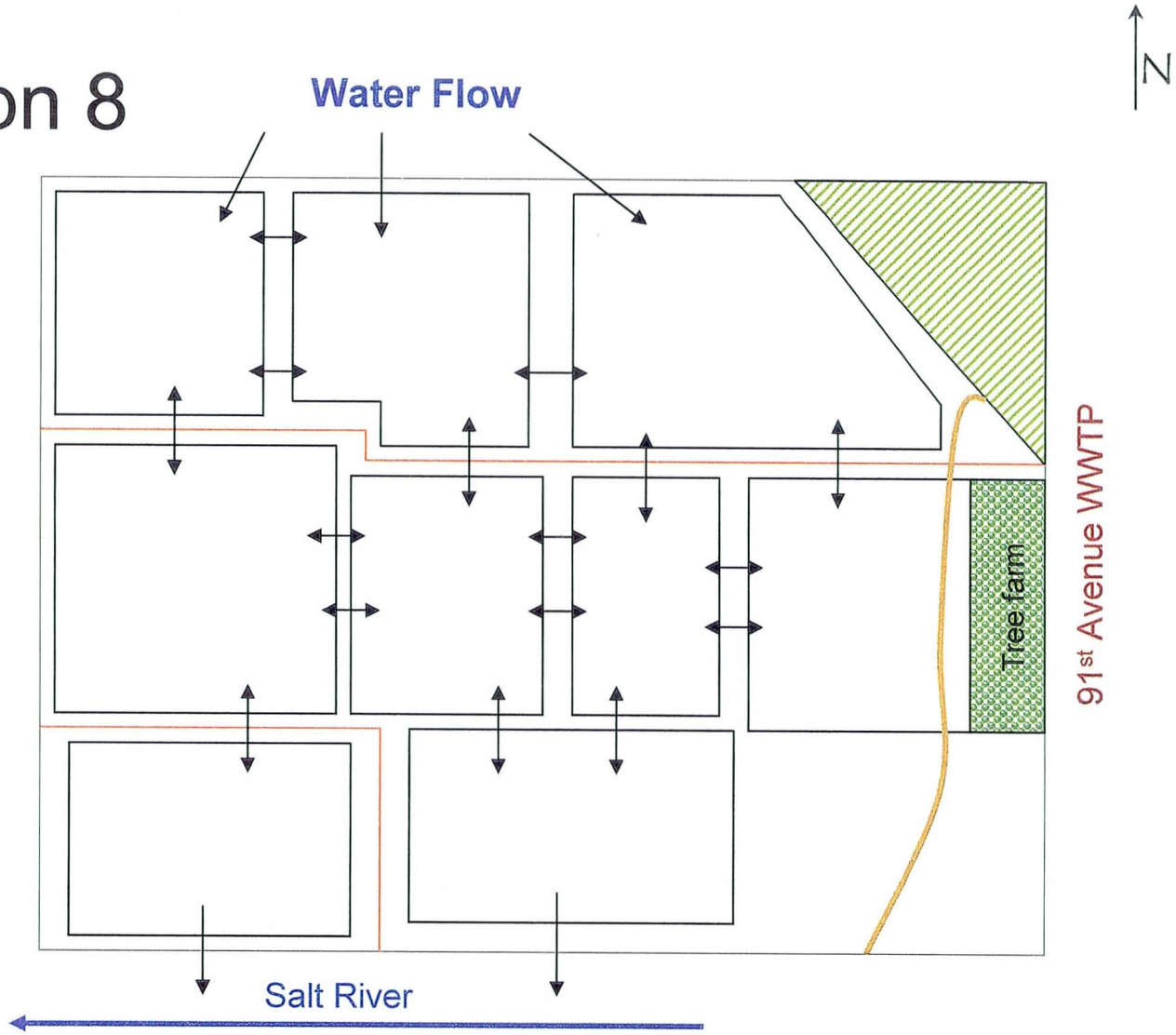
- Option 7



Design Concepts

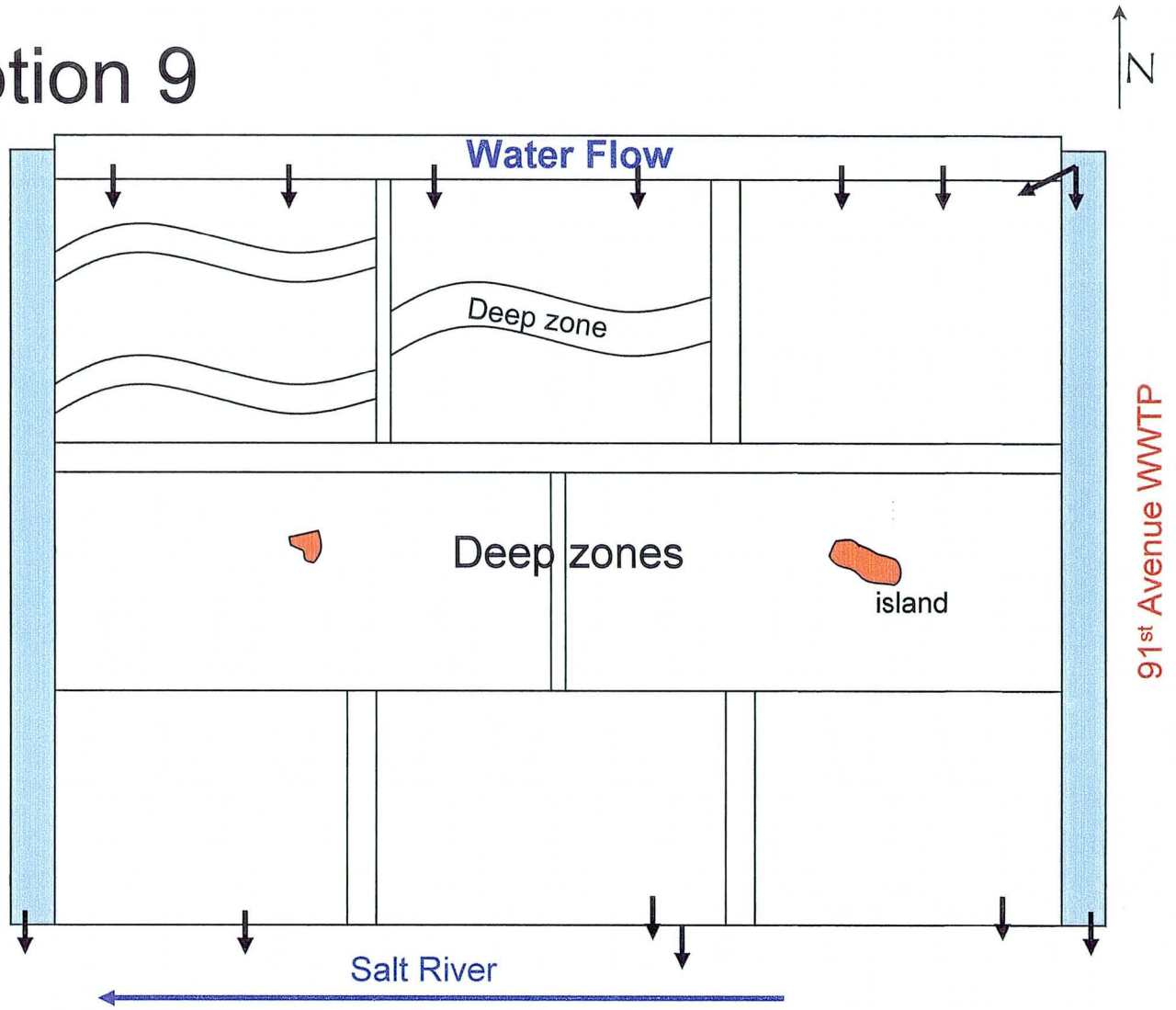
- Option 8

Multiple inlets/outlets allows flexibility in basin operations



Design Concept

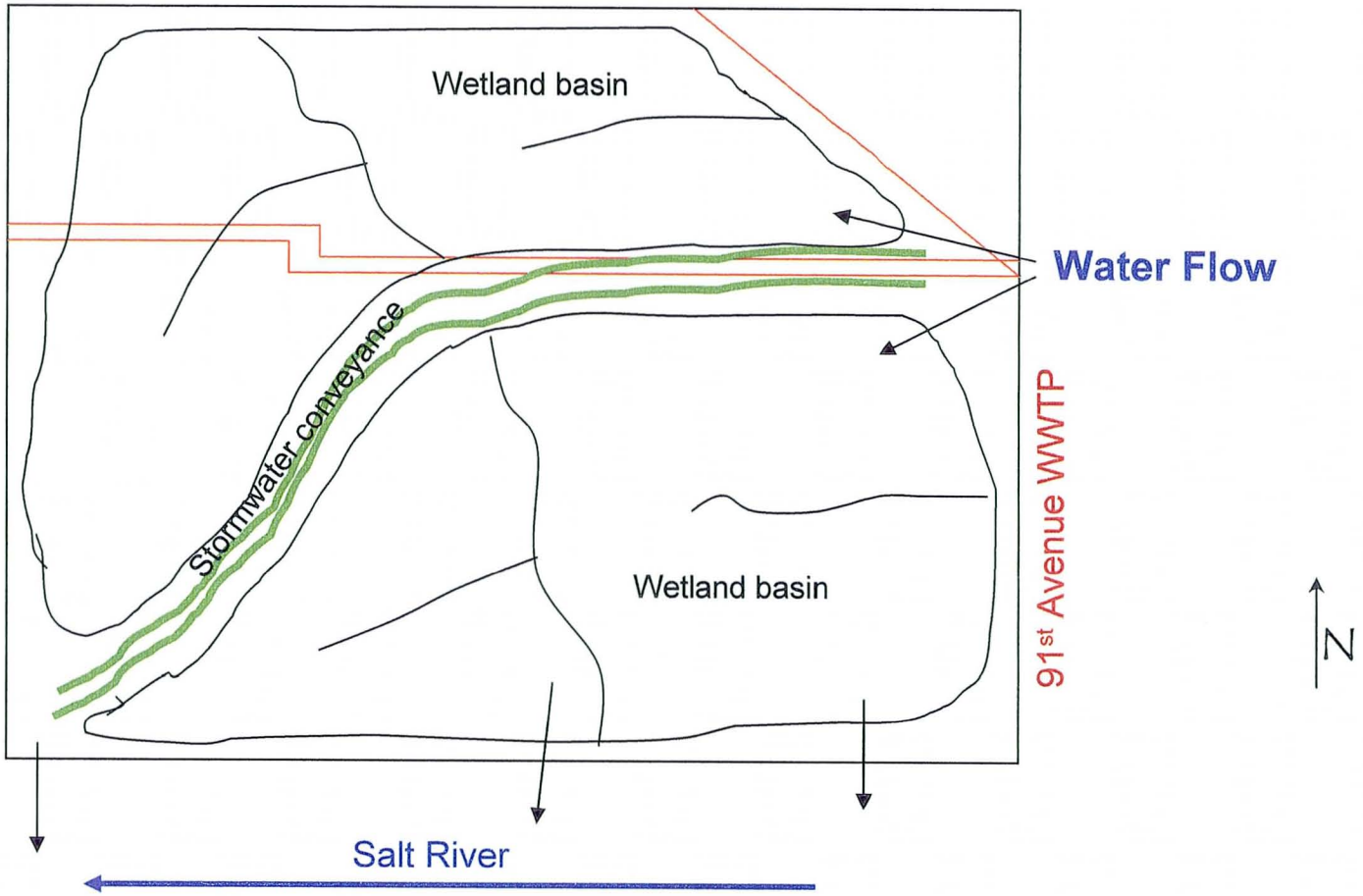
- Option 9



PK

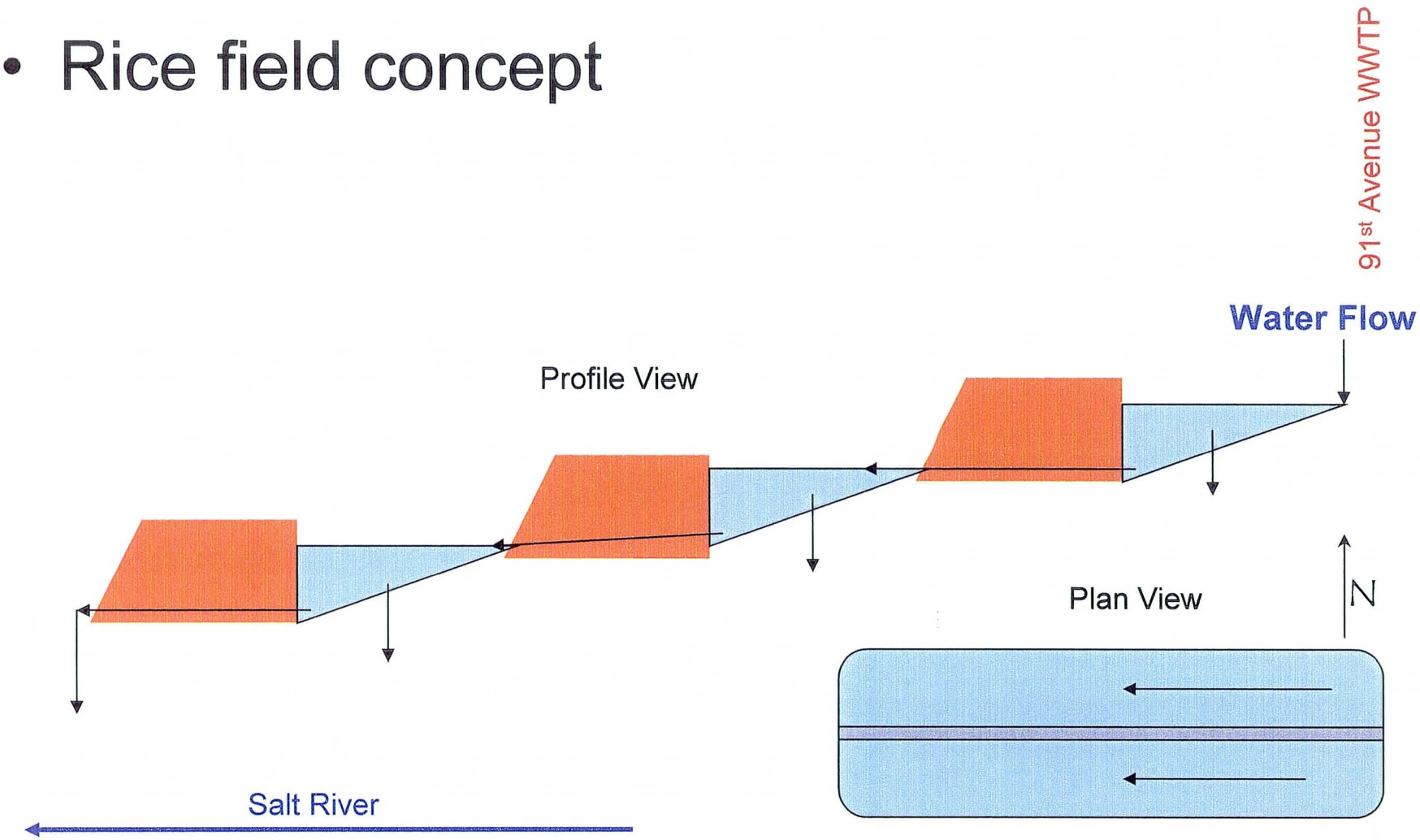
Design Concepts

- Option 10



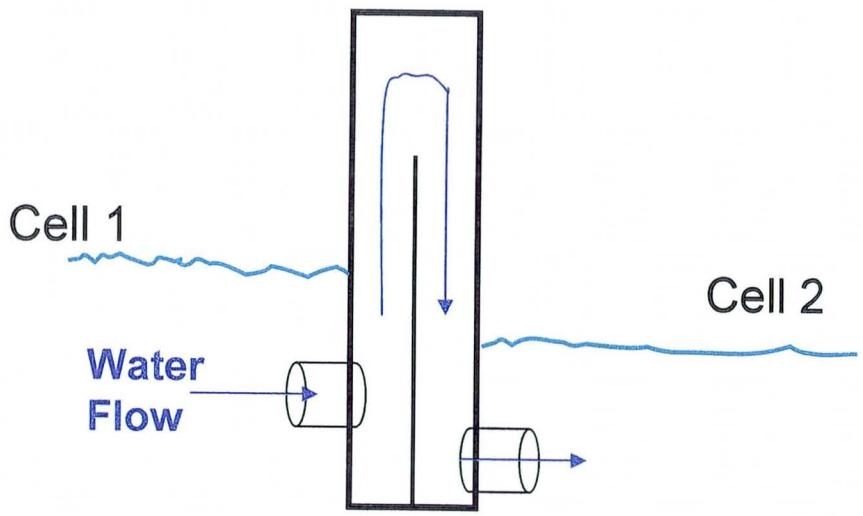
Overbank Wetlands

- Rice field concept



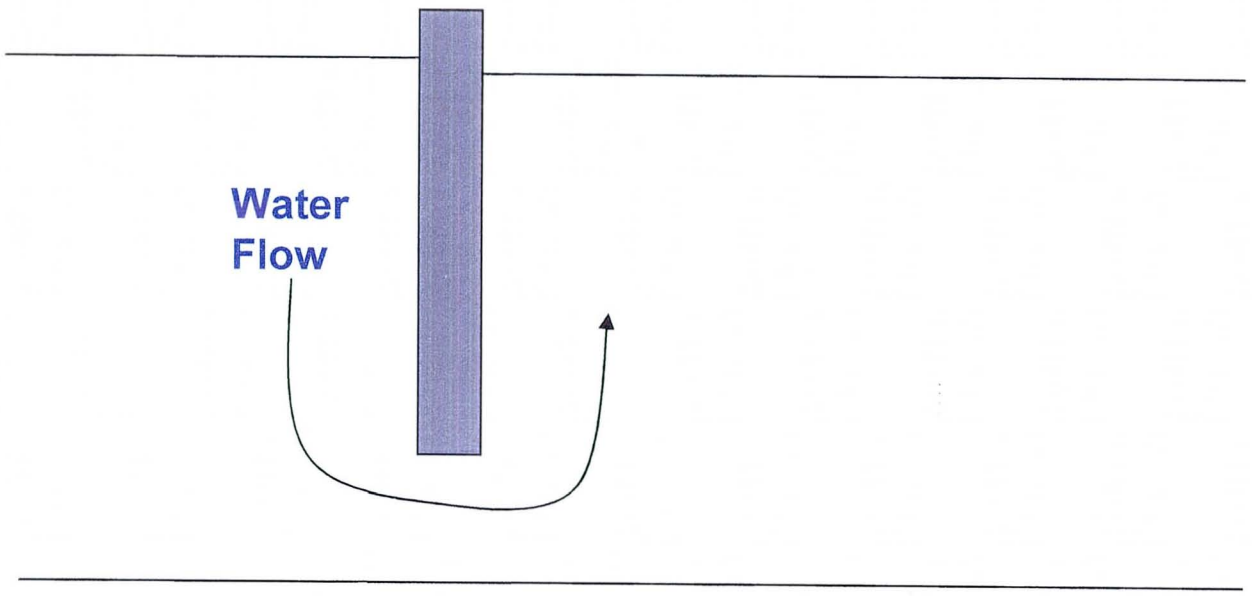
Control Structures

- Agri-drain



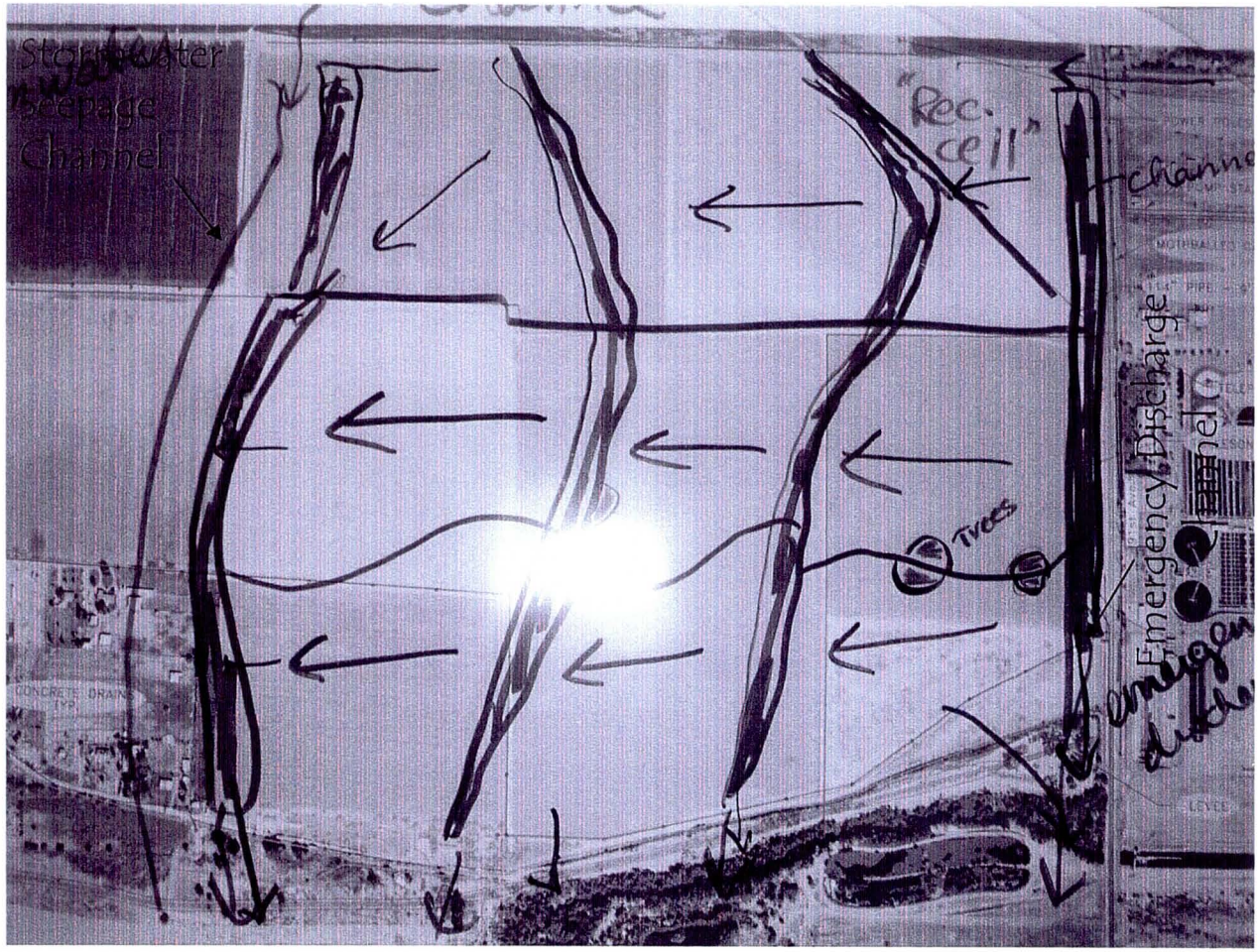
Control Structures

- Gate Culvert

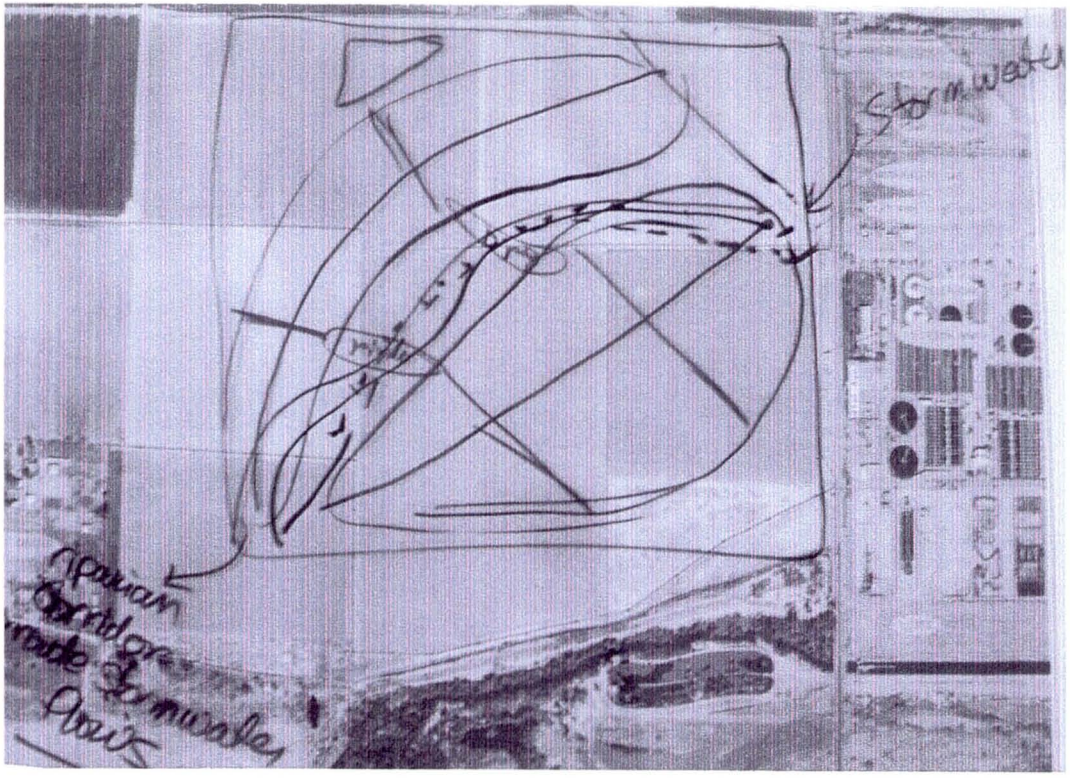


Regulating Wetlands

Regulating Wetlands

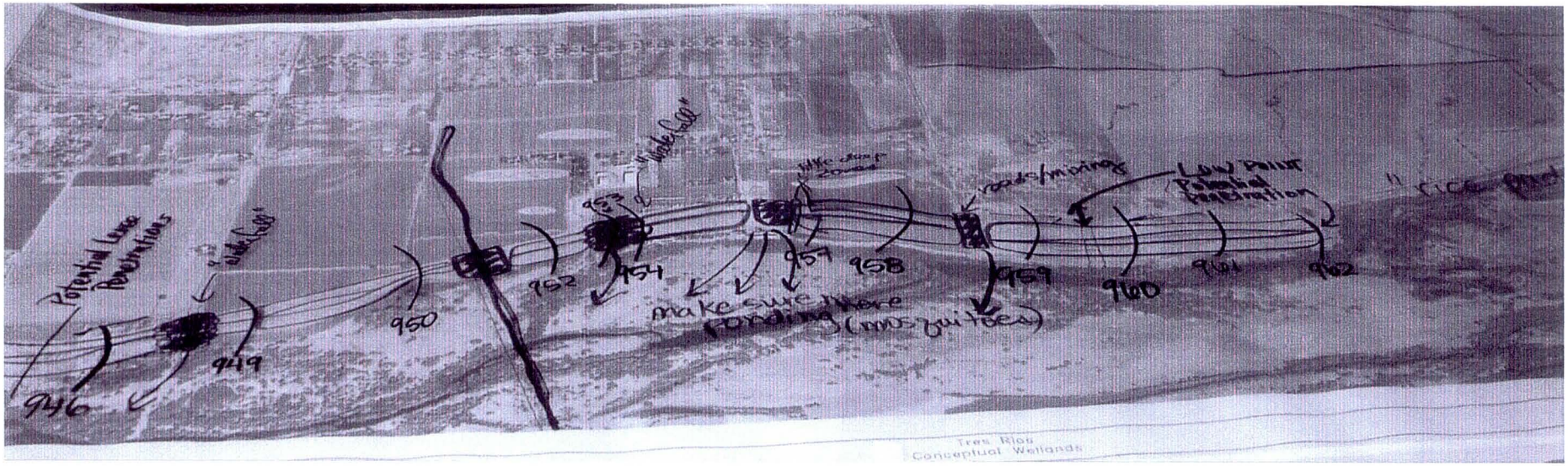


Regulating Wetlands



- Stormwater Collect at NE
- Passes through Center of Site
- Flows to Riparian Corridor

Overbank Wetlands



- "Rice Paddy" Concept
- Two "Braided" Channels
- Elevation Drop Mixing Zones