City of Tempe
P.O. Box 5002
140 East Fifth Street Ste. 301
Tempe, AZ 85280

602-350-8645 (FAX)

Tempe

City Attorney's Office

Writer's Direct Line 350-8227

96-002-013
SALT RIVER
004

ORIGINAL

RECEIVED 10-11-96

October 7, 1996

Arizona Stream Adjudication Commission
Attn: Ms. Christina Waddell
1700 W. Washington St., Suite 404
Phoenix, AZ 85007

Re: Request to consider previously submitted evidence

Dear Ms. Waddell:

Attached to this letter you will find a copy of the "Notice of Appearance and Intent to Participate" form of the Arizona Navigable Streambed Adjudication Commission that was completed, dated and filed on or about January 14, 1994 by the City of Tempe. Attached to that form Tempe set forth a concise statement as to navigability and public trust values as well as an Exhibit Index of the three sets of documents filed by the City of Tempe. A phone call to your office indicated that the three sets of Tempe documents could probably be located and that a letter from me requesting that they be considered on behalf of the City of Tempe in the current proceedings should be sufficient to have those documents considered by the Commission at this time. Should you have any difficulty locating the three document sets previously submitted by the City of Tempe, I would be more than happy to have them reproduced and submitted at this time. If you have any questions, comments or requests, please do not hesitate to call me.

Sincerely yours,

W. Kent Foree

W. Kent Foree
Assistant City Attorney

WKF/wg

Enclosure

Maricopa County, Lower Salt River
03-005-NAV
4/7/03
Evidence Item No. 013

RECEIVED 10-11-96

BEFORE THE
ARIZONA NAVIGABLE STREAMBED ADJUDICATION COMMISSION

IN THE MATTER OF THE NAVIGABILITY OF THE SALT RIVER [From Granite Reef Dam to the Gila River Confluence]	ADMIN. DOCKET NO. 94-1
	NOTICE OF APPEARANCE AND INTENT TO PARTICIPATE

A. NAME, ADDRESS AND TELEPHONE NUMBER OF RESPONDENT

Name: City of Tempe

Address: P. O. Box 5002
Tempe, AZ 85280

Telephone: 350-8227

****

(Please check Box B and provide the requested information if you intend to participate as a party in the above-captioned matter. See Commission Rule R12-17-108(A)-(C). Please check Box C and provide the requested information if you intend only to testify before the Commission or to file documents with the Commission, or both, but do not want to participate as a party. See Commission Rule R12-17-108(E). If more room is needed to respond, please attach a supplemental statement identified by paragraph number.)

[X] B. APPEARANCE AND INTENT TO PARTICIPATE AS A PARTY

1. The person named in Section A above intends to appear as a party in the above-captioned matter.

If represented:

Attorney Name: W. Kent Foree

Address: P. O. Box 5002
Tempe, AZ 85280

Telephone: 350-8227

2. Concise statement of position as to whether or not the Salt River was navigable as of February 14, 1912.

See attached page.

3. Concise statement as to the public trust values associated with the Salt River from the Granite Reef Dam to the Gila River confluence if found navigable.

~~See attached page.~~

4. List of witnesses, including address and telephone number, and for each witness a brief summary of the testimony that witness will give.

Name: Steve Nielsen
Address: P. O. Box 5002
Tempe, AZ 85280
Telephone: 350-8432

Brief summary of testimony:
All aspects of City of Tempe Rio Salado Development Plan including background and supporting studies and documents.

Name: Richard Bauer
Address: P. O. Box 5002
Tempe, AZ 85280
Telephone: 350-5100

Brief summary of testimony:
Evidentiary foundation if necessary for photos submitted by Tempe from the Tempe Museum.

Name: CH2M HILL
Address:

Telephone:

Brief summary of testimony:

5. Index of Exhibits to be offered at public hearing attached and made a part hereof. Two bound and indexed copies of documentary exhibits have been filed with the Commission this date.

See Tempe Exhibit Index.

****

☐ C. INTENT TO TESTIFY, FILE DOCUMENTS, OR BOTH, WITHOUT FORMAL APPEARANCE AS A PARTY

1. The person named in Section A above intends to testify before the Commission in the above-captioned matter about: ______________________________

____

____

____

____

____

Please notify me of the date and time the Commission will hear testimony from the public.

2. The person named in Section A above is submitting the attached documents for the Commission to consider. (Please briefly identify each document submitted.)

____

____

____

____

____

DATED this 14th day of Jan., 1994.

(Signature of Party, or Attorney, if represented, or of interested person)

CITY OF TEMPE

EXHIBIT INDEX

Document Set I

(A) Index and machine copies of 31 photos located in Tempe Historical Museum--Photographs and Archives--"Old Settlers" collection. Prepared by Richard Bauer.

(b) Historic American Engineering Record (HAER No. AZ-29) Ash Avenue Bridge (Tempe Bridge, Old Tempe Bridge and Salt River Bridge) spanning the Salt River at the foot of Ash Avenue. January 1991.

Document Set II

Bound copy of City of Tempe Rio Salado Development Plan booklet dated January 1993.

Document Set III

Rio Salado Engineering Report prepared for the City of Tempe by CH2M HILL dated June 1992.

2. Concise statement of position as to whether or not the Salt River was navigable as of February 14, 1912.

Tempe does not support a determination of "navigability" for land title purposes. The waters of the Salt and Verde Rivers in this reach were almost completely diverted or stored by or with the approval of the United States as of February 14, 1912. The evidence presented to the Commission clearly establishes that the Salt River--even prior to diversions and damming--was an impediment to the "highway" for trade, travel and commerce and was not susceptible for use in the "customary modes of trade or water."

3. Concise statement as to the public trust values associated with the Salt River from the Granite Reef Dam to the Gila River confluence if found navigable.

See City of Tempe Rio Salado Development Plan - 1993 update. The public interest in protecting and preserving areas for evacuation of storm/flood flows is important but can be accomplished without a determination of "navigability". In conjunction with this preservation other public and private uses may occur which is in the public interest.

The common law doctrine of riparian water rights was specifically abrogated from the laws of first the Territory of Arizona and then the State of Arizona. Arizona Constitution Art. XVII §1. There are important public interests in this reach of the Salt River, particularly for flood control/protection, which need to be asserted and protected. There is no need, however, to cast such a potentially broad and dark shadow based in riparian land title law where riparian water rights do not exist. See Lockwood dissent in State v. Bonelli Cattle Company, 107 Ariz. 465, 489 P.2d 699 (1971).

tempe

rio salado

Development Plan

City of Tempe
Community Development Department

RESOLUTION NO. 1751

A Resolution of the Council of the City of Tempe adopting the Tempe Rio Salado Plan including the map and text therein:

WHEREAS, the Tempe General Plan, 1978 directed the formulation of specific guidelines for development of the Salt River and environs in Tempe known as Rio Salado; and

WHEREAS, the City Council did direct the City Planning staff to prepare plans for the development of the Rio Salado; and

WHEREAS, the Mayor did appoint a body of citizens, the Tempe Rio Salado Advisory Commission, and charged them to evaluate the Rio Salado plan and advise the City Council on matters effecting the Rio Salado; and

WHEREAS, the Tempe Rio Salado Advisory Commission for over two and one-half years did diligently conduct an intensive study of present and future needs, goals and objectives of the community and their relationship to the Tempe Rio Salado Plan and its alternatives and did recommend to the City Council its adoption; and

WHEREAS, information on the Tempe Rio Salado Plan has been made available to the general public through the distribution of reports, newspaper publicity, two "River Walks," and discussions with various civic groups; and

WHEREAS, the Tempe Planning Commission has conducted a public hearing on April 14, 1982 to give opportunity for the interested citizens to make their viewpoints known regarding the Tempe Rio Salado Plan and has considered these comments in its recommendations; and

WHEREAS, the Tempe Planning Commission, on April 14, 1982, did approve the Tempe Rio Salado Plan, including the map and text incorporated therein, and did recommend that the City Council adopt said Plan as the official guide for future public and private development in the Rio Salado; and

WHEREAS, the Tempe City Council, on May 20, 1982, did hold a public hearing on the Tempe Rio Salado Plan and has considered the comments, opinions, and desires of the citizens of the community; and

WHEREAS, the Tempe Rio Salado Plan will encourage the optimum development of land along the Salt River within Tempe, promote the development of outdoor recreational facilities, and combine flood control with environmental design in a manner that will achieve the greatest social and economic benefits for the citizens of Tempe and will promote the systematic execution of the goals, objectives, and policies of the Tempe General Plan pertaining to the Rio Salado; and

WHEREAS, the Arizona State Legislature adopted Senate Bill 1346 creating the Rio Salado Development District and mandating the preparation of a master plan based upon the plans of jurisdictions within the District; and

WHEREAS, the Arizona Revised Statute 9-461.09 et seq. provide for the preparation and adoption of specific plans based on the General Plan as may be required for the systematic execution of the General Plan;

NOW, THEREFORE, BE IT RESOLVED by the City Council of the City of Tempe that the Tempe Rio Salado Plan, including the map and text, is hereby adopted as the official guide for future development of the Rio Salado;

BE IT FURTHER RESOLVED that the City Council hereby directs the Rio Salado Advisory Commission and the administrative staff to proceed with the preparation of measures to implement said plan, including but not limited to, a Zoning Overlay District, pilot projects, and detailed plans;

BE IT FURTHER RESOLVED that the Rio Salado Advisory Commission be informed of all matters affecting the physical development of the Rio Salado and be given the opportunity for comment and recommendation prior to any further City action on them;

BE IT FURTHER RESOLVED that in order that the Rio Salado Plan shall at all times be current with the needs of the City of Tempe and shall represent the best thinking of the Council, the Rio Salado Advisory Commission, the Planning Commission and the departments of the City in the light of changing conditions, the Rio Salado Advisory Commission shall annually review the Tempe Rio Salado Plan and recommend to the Council extensions, changes and additions to the Plan which the Commission considers necessary;

BE IT FURTHER RESOLVED that the administrative staff is hereby directed to publish the Plan in a form suitable for public distribution and ensure its wide dissemination.

PASSED AND ADOPTED by the Council of the City of Tempe, Arizona, this 20 day of May, 1982.

Harry E. Mitchell
Mayor

ATTEST:

[signature]
City Clerk

APPROVED AS TO FORM:

David Merkel
City Attorney

I, Karen Brittingham, the Deputy City Clerk of the City of Tempe, Maricopa County, Arizona do hereby certify the above to be a true and exact copy of Resolution No. 1751, passed and adopted at the Regular Council Meeting of May 20, 1982, by the Tempe City Council, Tempe, AZ.

DATED this 13th day of January, 1994.

Karen Brittingham
Karen Brittingham, CMC
Deputy City Clerk

96-002-013

RECEIVED 10-11-96

SALT RIVER

CITY OF TEMPE

ORIGINAL

DOCUMENT SET II

Bound copy of City of Tempe Rio Salado Development Plan booklet dated January 1993.

W. Kent Foree
Assistant City Attorney
City of Tempe
P. O. Box 5002
Tempe, AZ 85280
350-8227

City of Tempe

Mayor

Harry E. Mitchell

City Council

Neil Giuliano (Vice-Mayor)
Dennis Cahill
Don Cassano
Joseph Lewis
Frank B. Plencner
Carol Smith

City Manager

Terry L. Zerkle

Deputy City Managers

Gary Brown
Jim Piper

City Staff

Terry Day	Community Dev. Director
Pat Flynn	Management Serv. Director
David Merkel	City Attorney
Jim Jones	Public Works Director
Ron Pies	Community Services Director
David Scott	Building Safety Director
Cliff Jones	Fire Chief
Dave Brown	Police Chief

Rio Salado Advisory Commission

Dave Hanna (Chairman)
Jim Acker
Nick Appleton
Jim Becker
Tom Burbey
Scott Burge
Mike Burke
Udell Busch
Eric Edwards
Joan Grace
Mary Hegarty
Philip Heinrich
Sally Heinrich
Shirlee King
Pamela Livingston
Frank Long
Glenda Miwa
Rev. Frank Williams

Photo and Graphics Credits

Mark Vinson
Tempe Historical Museum
A.I.A. Rio Salado/Arizona
ASU - College of Arch. & Env. Design
H.N.T.B.
Habitat
Salt River Project
Parsons Brinckerhoff
CH2M Hill

Rio Salado Task Force

Steve Nielsen (Project Manager)
Tom Ankeny
Bill Coughlin
Duane Dawson
Terry Day
George Elley
David Fackler
George Fletcher
Harvey Friedson
Howard Hargis
Denzil Jones
Jim Jones
Jon Kimoto
Atis Krigers
Gary Meyer
Dave Newkirk
Lee Quaas
Ed Vanderginst

Production Assistance

Gary Meyer	Project Planner
Shelley Hearn	Graphic Designer
Roisan Rubio	Consultant

January 1993

Table of Contents

1

Introduction

Introduction

Purpose

The purpose of Tempe's Rio Salado Project is to encourage the optimum development of outdoor recreational facilities, and combine flood control with environmental design in a manner that will achieve the greatest social and economic benefits for the citizens of Tempe. One of the goals is to enhance the quality of life for all citizens by improving currently under-developed land into a desirable, multi-purpose, water-based recreation area.

The Tempe Rio Salado Plan is a specific plan intended to achieve the systematic realization of the goals, objectives, and policies of the Tempe General Plan pertaining to the Salt River area. As such, it is the principal guide for the City Council and its Boards and Commissions in making decisions concerning development within the Rio Salado planning area.

Scope

This Plan updates the 1982 Rio Salado Plan and includes significant new material. This update is necessary because many factors have changed since the 1982 plan, as outlined in the following text.

The Tempe Rio Salado Plan includes:

1) A statement of the goals, objectives, and policies for the improvement, development and use of lands;

2) A general description of the scope and concept of development in and around the Salt River;

3) General descriptions of methods and programs for the implementation of this plan.

Context

The Tempe Rio Salado Planning Area extends along the course of the Salt River from 48th Street on the west to Price Road on the east (approximately 5 miles) and from University Drive on the south to Curry Road on the north (approximately 1 mile). The segment of the river within Tempe's jurisdiction is situated roughly halfway between the confluence of the Salt and Verde Rivers to the east and the confluence of the Gila, Agua Fria and Salt Rivers to the west.

Project History

The Rio Salado Project is an idea that has been explored at several levels of government for the past 25 years. It had its formal beginnings in the College of Architecture at Arizona State University in 1966 as a student design project. The concept was a linear park and green belt along a flowing Salt River to revitalize the neglected riverbed. In addition, Phoenix, Tempe and Mesa would be connected to the Gulf of California by a system of locks, similar to the Panama Canal, in order to receive international commerce. The portion of the concept dealing with a linear greenbelt received a considerable amount of recognition by local public and private organizations. In 1969, the Valley Forward Association and the Maricopa Association of Governments (M.A.G.) gave their official backing to the concept of a linear park and greenbelt.

The Tempe Community Development Department prepared a Rio Salado Design Study in 1977 for its 5-mile section of the river. This study generated three concepts: a desert-oriented development with limited water features; a water-intensive development; and a moderate water-use plan. An August, 1977 grant from the Department of Health, Education and Welfare made possible further in-depth study of the 5-mile portion of the Salt River located within Tempe's city limits.

With interest growing, Mayor Harry Mitchell appointed an ad hoc citizens group, the Tempe Rio Salado Advisory Commission, in August of 1979. The purpose of the Commission was to garner broad citizen input and advise the City Council, as well as to continuously explore opportunities for improving the area. The Commission proved to be so effective that it was made permanent by the Council. Also, a Rio Salado Overlay Zoning District was created in 1982 to help accomplish the specific objectives of the Tempe Rio Salado Plan.

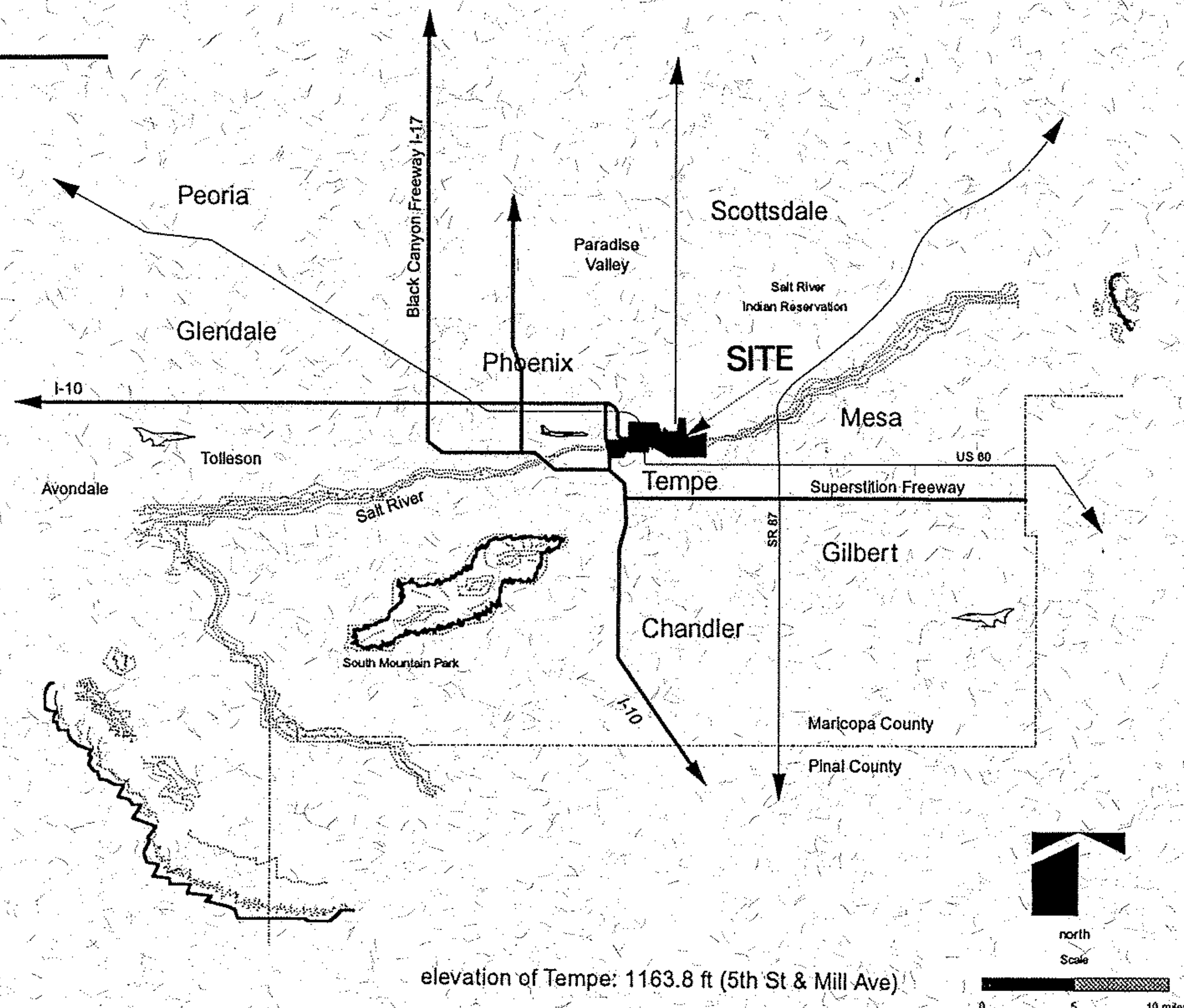
As both governmental and private agencies began to embrace the concept of the Rio Salado Project, the Arizona House and Senate created the valley-wide Rio Salado Development District in April 1980. The consulting firm of Carr-Lynch was retained by the District to prepare a Master Plan which stretched across the entire length of the river channel, within the metropolitan area.

At the same time, Tempe's Community Development Department completed several further studies, culminating in the 1982 Rio Salado Plan. This plan was based on the moderate-use water concept presented in the 1977 plan. The main aspect of this concept was to develop water features above an 800-foot wide main channel and use existing water sources to fill 180 acres of lakes.

In 1986, the State Legislature approved a referendum placing the issue of financing a Valley-wide Rio Salado Project before the voters. On November 3, 1987, the proposed tax levy on real property and the authority to issue bonds that would have helped finance the Project over a 25-year period was defeated. Although funding for the District failed, a majority of Tempe voters favored the project. Therefore, the Tempe City Council resolved to develop the Rio Salado in Tempe. This decision was made with support from the Rio Salado Advisory Commission and the recognition of an opportunity to pursue the concept further.

The City of Tempe has been a leader in planning and promoting the development of the Rio Salado area since the concept's inception. With that kind of background and support, City staff is working toward realizing the goals and objectives summarized in following chapters.

Tempe Rio Salado in its Metropolitan Context

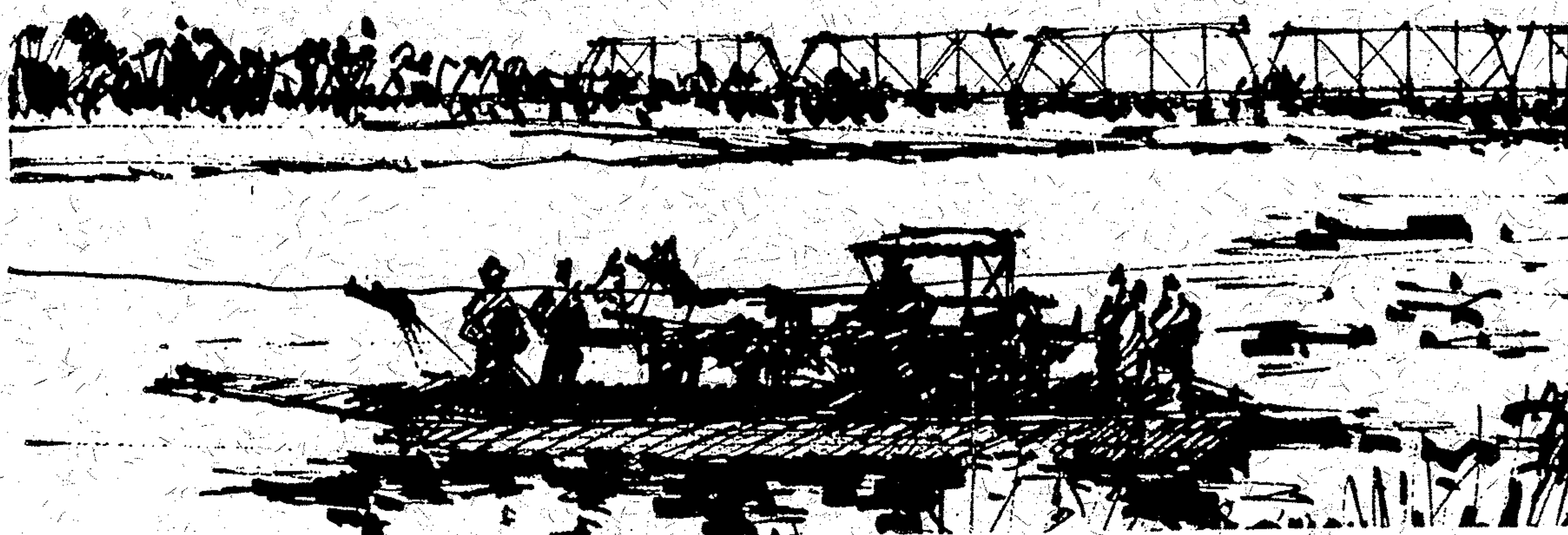


elevation of Tempe: 1163.8 ft (5th St & Mill Ave)

Background

In the 1800's, the flowing Salt River created a natural break in transportation on the man-made trade route connecting Tucson and Prescott. Travelers preparing to cross the Salt provided a ready market for an enterprising entrepreneur, Charles Trumbull Hayden. In 1871, he established a store and ferry service at the crossing on the south bank of the river. The ferry service was located at the "narrows" where the river was narrowest and the bottom was firm. This early development eventually grew to become Tempe.

In 1911, Roosevelt Dam was built upstream, greatly reducing the flow of water into the lower reaches of the Salt while intensifying destruction due to periodic releases. By the late 1930's, all the water had been diverted for agricultural, industrial and domestic uses. The river did not flow again in its natural channel until 1965, when a major flood occurred. During this 30-year period, gravel mining operations, dumping and varied development appeared in this "available" land. The risk of building in the flood plain seemed to be tempered by the fact that no threatening water had appeared in the river during this period. Instead of declaring the flood plain to be a natural preserve, cities zoned the river and adjacent land for development. People built homes and businesses in the flood plain, taking incredible risks. Those ventures proved ill-advised, as flood waters reclaimed the river channel causing bridge failure, extensive property damage, costly traffic congestion and even some loss of life. Following these catastrophes, new efforts were initiated to counter the risk of flooding.



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2

The Rio Salado Plan

Introduction

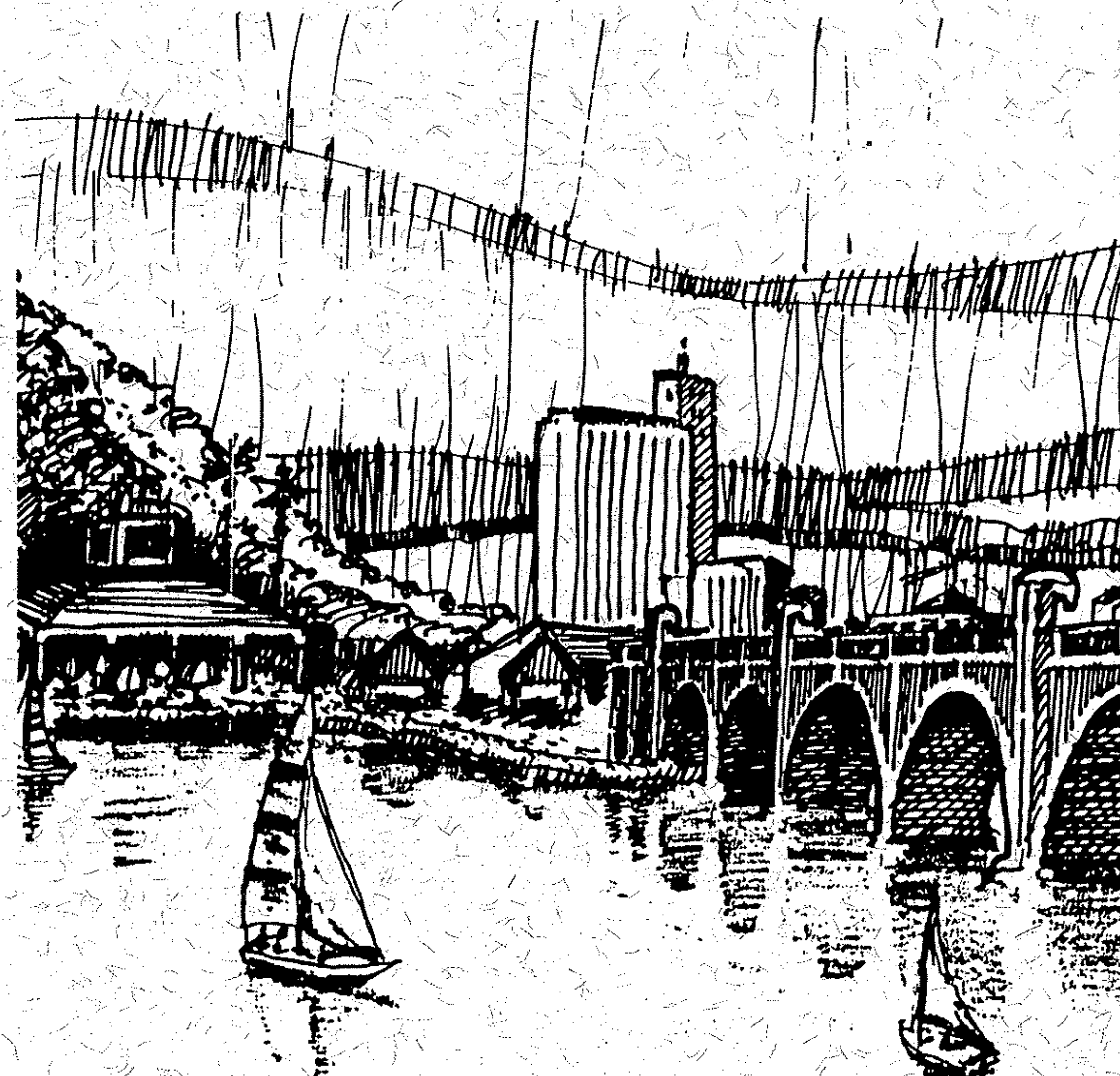
Flood control is a primary criterion in the Rio Salado Plan. Channelization of the river has made possible the development of properties on reclaimed land. Over 800 acres of land which were located in the flood plain have become available for development due to construction of the channel. This has presented the opportunity for construction of resorts, restaurants, retail shops, marinas and recreation features, which are compatible with the park and water features. Channel banks will be landscaped and terraced park lands made usable for the citizens. Thus, we are able to improve this previously under-developed land.

The 1977 Tempe Rio Salado Plan called for a "low-flow channel" within a larger channel to accommodate typical water releases from the upstream Roosevelt Dam. A typical release by the Salt River Project is 5000 cubic feet per second (c.f.s.). By containing this typical flow within a low-flow channel, additional land is made available for recreation. The low-flow channel ranges from 300 to 400 feet in width.

Tempe is, however, preparing for a "worst case" scenario and building-in precautions. A 100-year frequency flood event of 215,000 c.f.s. is accommodated by the larger 1000 foot wide channel, even though improvements to Roosevelt Dam should lower that flow to 160,000 c.f.s. Development within the 1000 foot wide channel will include bridges, roadways, hiking/biking trails, landscaping and marinas. All of the above should be able to withstand the 100 year flood situation. Also, these uses would not be disrupted by typical flow releases which would be contained by the low-flow channel.

Water Supply

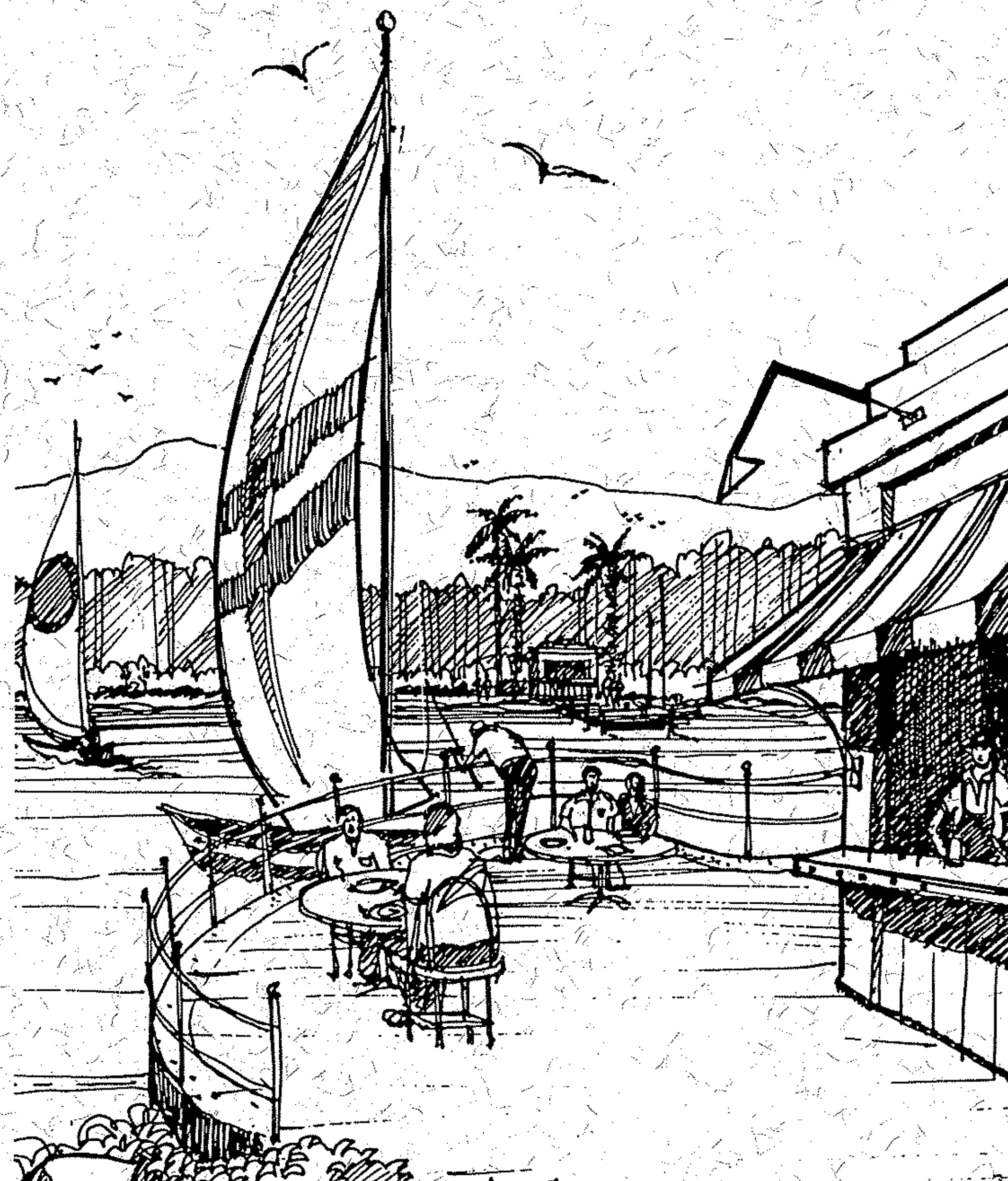
Tempe's Rio Salado Plan includes streams within the channel and a 200-acre lake up to the level of a 10-year "terrace." There are currently several options for the water supply including the following two primary options. One alternative is the use of water from the Central Arizona Project (C.A.P.) which would be delivered through the S.R.P. canal system. Another option is the indirect use of reclaimed water through a storage and recovery process. In this scenario, reclaimed water is recharged into the ground, accruing credits and allowing water to be pumped from the ground as needed. The water will be used for boating and fishing as well as landscape irrigation. Overall, the concept is one of water conservation.



Water Bodies

Water features, in the form of lakes and streams within the channel, total about 300 surface acres. The primary lake is concentrated between Hardy Drive and the Indian Bend Wash, an area dominated by active recreation. This lake totals about 165 surface acres and features boating and fishing.

Areas west of Hardy Drive will have meandering streams in the low-flow channel, with limited lakes. When water releases of 5000 c.f.s. come downstream, the low-flow channel will fill completely, still allowing for recreation in the remainder of the 1000 foot wide channel. Areas east of the Indian Bend Wash, where existing riparian areas are located and where water currently accumulates, will be targeted for more passive recreational uses such as hiking, bicycling and activities not based on active water use.



Recreation

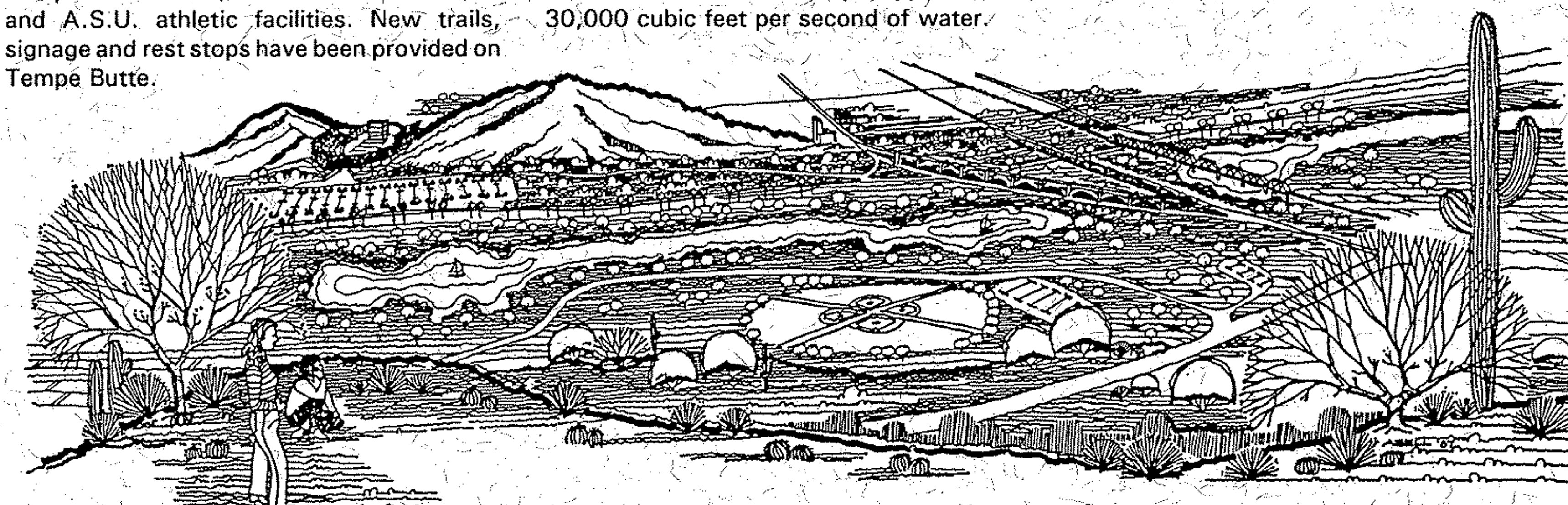
There are currently many recreational land uses within the project area. The area north of the river is dominated by the City of Tempe's Papago Park. The park has 480 acres of open space and has been planned for new development with improved trails, signage and public facilities. The existing trails for horse-back riding tie in well with the circulation plans for Rio Salado, which call for a strong link between Papago Park and the new channel. The East Papago Freeway being placed on an earthen berm, allows for wide openings underneath, thereby providing access between the river and the park.

South of the river are several areas oriented toward recreation, such as Tempe Butte, Tempe Beach Park, Rio Salado Golf Course and A.S.U. athletic facilities. New trails, signage and rest stops have been provided on Tempe Butte. Tempe Beach Park, just west of Mill Avenue on the south bank, constitutes a unique interface between the downtown commercial district and the river. Its use as a gathering place will be further expanded with the development of arts facilities in the park. These would include cultural, performing and visual arts, as determined through an analysis of needs in the community.

The Rio Salado Golf Course is a 9-hole course located in the Indian Bend Wash just south of McKellips Road. It is a joint project, located on public land, built and operated with private funds, creating revenue and providing recreation for the city. The plan retains a low-flow channel for water feature improvements. The total channel conveys approximately 30,000 cubic feet per second of water.

Arizona State University has several recreation facilities existing in the area, with further development planned. Current facilities, rated amongst the finest in the nation, include a football stadium, tennis courts, baseball stadium, track facility and a golf course.

Other forms of recreation, both active and passive, are planned for the channel itself. Examples include active water-based recreation such as sailboating, paddle boats, cable-powered skiing, and swimming. Passive recreation near the water includes hiking, bicycling, jogging, horse-back riding, fishing, and picnicking.



Open Space

Large open space areas are preserved in and around the river. As Tempe's largest unbroken open space, the river itself is a significant resource. It provides the opportunity for varied recreational and educational activities. With appropriate landscaping, the open space can serve as an urban retreat, a welcome escape from civilization in the very heart of the urbanized area. A comprehensive system of hiking/biking trails connect the various open space features.

These open spaces also provide natural habitats for wildlife. By means of extensive revegetation, displaced native animals and birds will be encouraged to return to the area.

Circulation/Transportation

One of the challenges in creating a true urban retreat is to work out creative solutions to the three freeway designs as they relate to the river. Currently under construction, the East Papago Freeway follows the north bank of the river through Tempe, making it a dominant feature in the Rio Salado. This freeway is elevated on an earthen berm with landscaped embankments. The Price-Pima Freeway is a partially completed north/south link along the eastern boundary of this project and the expansion of the Hohokam Expressway on the western boundary of Tempe has already provided improved access to the Rio Salado area.

Upon arrival at the Rio Salado, vehicles will circulate on the meandering, scenic Rio Salado Parkway. The Parkway provides an east-west circulation route on the south bank of the river, allowing convenient access to various park features. The Parkway is designed as a wide, landscaped boulevard.

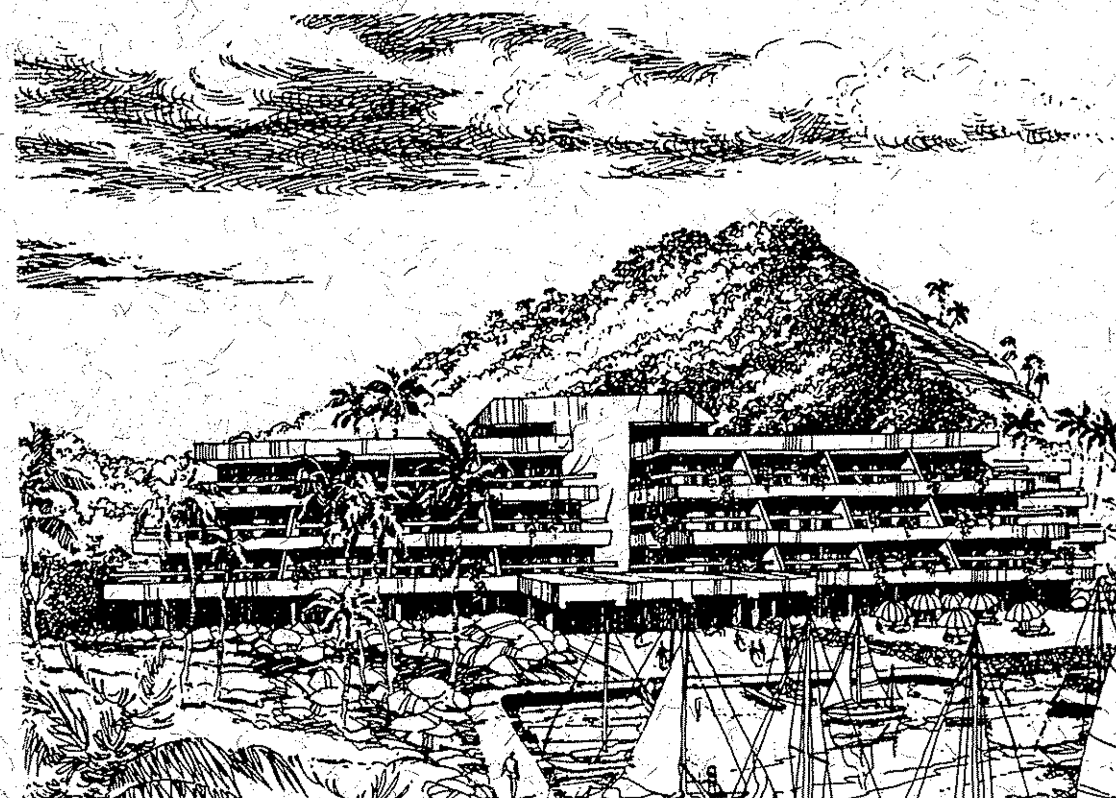
Improved all-weather crossings will exist with the new Priest Drive Bridge and an additional bridge currently under construction at Mill Avenue.

In addition to vehicular access, a light-rail transit system has been planned by the Regional Public Transit Authority (R.P.T.A.) This segment is part of a Valley-wide system connecting the Rio Salado with other important regional destinations. Also, other public transit such as the downtown circulator, expanded fixed routes and dial-a-ride is planned to serve the Rio Salado area.

Within the park itself, emphasis will be placed on pedestrian circulation, bicycling and horse-back riding. This emphasis on alternate forms of transportation ties in with the concept of creating an overall trail system throughout the city. By improving canal banks and railroad rights-of-way, bicyclists, runners and pedestrians throughout the community will have alternative transportation routes to reach the Rio Salado. This city-wide trail system will be enhanced by this link to the Rio Salado.

Residential Development

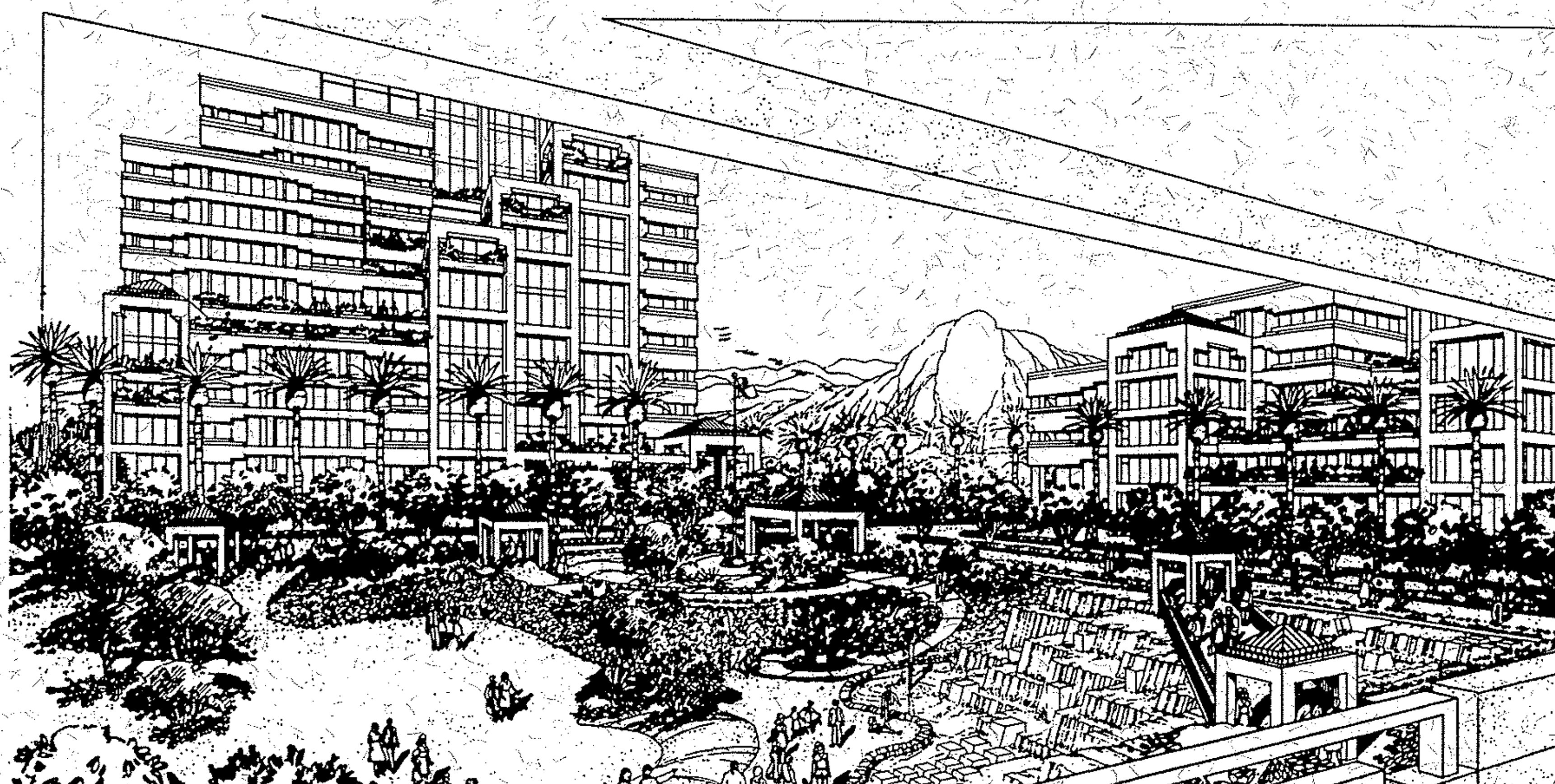
New residential development within the Rio Salado is planned primarily as an extension of the downtown area. Integrated into multiple-use developments, new residential structures are also encouraged south of the river between Priest Drive and Farmer Avenue, as well as along the Indian Bend Wash. High property values in peripheral areas and current zoning indicates that future residential developments will tend towards relatively high density multi-family.



Commercial Development

Under the current plan, commercial development will be concentrated near Rural Road and near Mill Avenue. Retail shops and restaurants here will benefit from nearby water-oriented recreation and provide needed services to users of the Rio Salado.

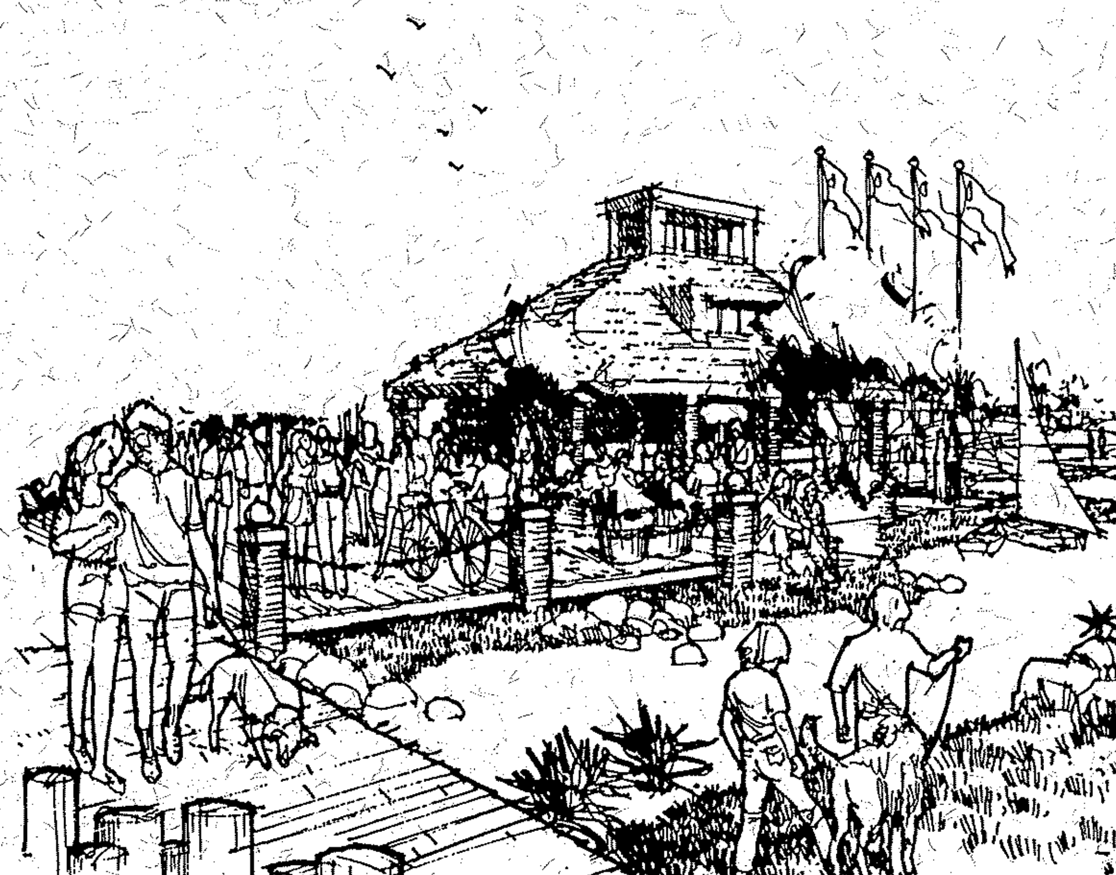
Rio Salado will provide a beautiful setting for adjacent shopping and dining, creating an atmosphere unmatched elsewhere in the metropolitan area. These new developments will enhance the existing commercial activity at the Big Surf recreation complex, the existing retail shops, and along Rural Road as well as downtown Tempe. Commercial development concepts will be discussed in more detail later in the Development Plan.



Resort Development

Potential resorts along the river are anxiously awaited by the tourism and convention businesses in Tempe. A river-side setting could provide a beautiful site for such facilities. The City of Tempe has already been contacted by potential developers of such facilities. Resorts would encourage "round-the-clock" activity and vitality in the area. Additionally, tourism in Tempe would create more commercial activity and tax revenues. Some benefits to the city will include installation of landscaping and recreational amenities with private funds.

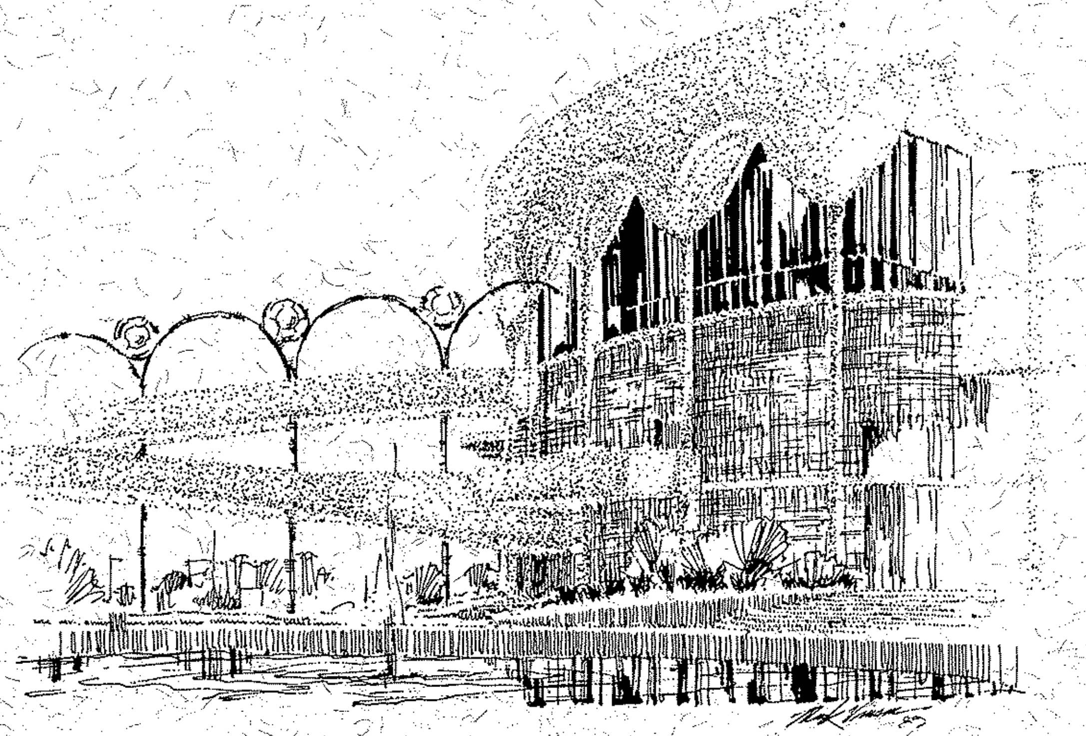
This type of development will occur primarily near the active recreation areas between Mill Avenue and the Indian Bend Wash.



Arizona State University

Arizona State University is a key player in the development of the Rio Salado. A.S.U. is a primary land owner and developer along the south bank of the river. The University, in cooperation with the Sun Angel Foundation, has constructed the 18-hole Karsten Golf Course within the Rio Salado, east of Rural Road. Also, A.S.U. is working on a joint project with the City of Tempe to develop the south bank between Mill Avenue and Rural Road. North of Sun Devil Stadium, a multi-use development is planned, tying Sun Devil Stadium and recreation areas to the Rio Salado lake.

The intensity of activities around the stadium makes the immediate area especially attractive for development. Proposed uses include shops, restaurants, office towers, a conference center, a resort hotel, marina and amphitheater.



Project Statistics

Overlay District Area:	**5.7 square miles** (3636 acres)
Land Uses:	
Recreation:	1089 acres
Single Family:	43 acres
Multi-Family:	138 acres
Commercial:	45 acres
Commercial/Recreation:	378 acres
Mixed Use:	90 acres
Industrial:	1339 acres
Industrial/Commercial	117 acres
Municipal:	86 acres
Recreation/Educational:	311 acres
Total:	**3636 acres**
Water Features:	
Primary lake:	165 acres
Secondary water features:	80 acres
Total: (approximate)	**245 acres**
Floodway:	**706 acres**
Area Reclaimed After Channelization:	**838 acres**

3

Goals, Objectives & Policies

Goals, Objectives & Policies

Goals, objectives and policies are necessary guides to the development of the Rio Salado Plan. Goals define the broader concerns of the Rio Salado Plan. Objectives are more specific and demonstrate an understanding of the goals, leading to the formulation of specific policies.

The availability of open space provides Tempe with a unique opportunity. The sensitive development of the Salt River will give Tempe a central focus upon a vast open space, rare in urbanized areas today.

The following goals are designed to guide the development of these lands in a manner that will preserve open space, enhance recreation, and provide planned economic development while revitalizing and protecting the unique character of the Salt River.

The General Plan

Goals and Objectives

The General Plan for the City of Tempe defines the goals, objectives and policies for future land use, circulation, identification and beautification throughout the City. The Tempe Rio Salado Plan is an integral part of the General Plan, focusing on the Rio Salado area. As such, the plans must be consistent and complementary.

The following goals, objectives and policies are taken from the Tempe 2000 General Plan and are also part of the Rio Salado Plan:

Goal I.

Strive to Make Tempe a Beautiful and Unique City.

Objective:
Enhance the "tangible" elements of a quality of life through urban beautification, maintaining and upgrading standards of quality in all levels of public and private development, including redevelopment and infill.

Objective:
Enhance the "tangible" elements of a quality of life by expanding social, recreational, educational, environmental and cultural programs.

Objective:
Maximize the use of all publicly-owned open space, as well as acquire additional open space, to optimally provide for the recreational, social, cultural, economic and ecological diversity of the City.

Objective:
Improve the City's environment by making a strong commitment to programs that improve air and water quality, conserve natural resources, reduce noise and visual pollution, and reduce the use of, and dependency on, non-renewable energy sources and related materials.

Objective:
Maintain the integrity of residential neighborhoods by encouraging new, redevelopment or infill that is in concert with existing land use and zoning patterns.

Goal II.

Develop a Multi-Modal Circulation System.

Objective:
Support new development, redevelopment or infill that reduces traffic congestion and travel time.

Objective:
Promote alternative forms of transportation and integrate those systems into the current and projected land uses of the City.

Objective:
Support a freeway system that accommodates alternative forms of transportation on an equal basis.

Objective:
Encourage development that contributes to bikeways and transit and that can be accommodated on the existing transportation system.

Goal III.

Diversify and Stabilize the City's Economic Base.

Objective:
Encourage types of development, redevelopment and infill as well as land uses that assure tax stability and diversify the City's economic base.

Objective:
Encourage types of land uses and development that economically and environmentally reinforce the City's commitment to the amenities that reflect an exceptional quality of life.

Objective:
Encourage land use and economic development shown to meet local needs and be ecologically sustainable.

Goal IV.

Promote Infill Development That Creates Long-Term Compatibility and Stability.

Objective:
Develop and use guidelines that help assess proposed infill.

Objective:
Provide for meaningful input from surrounding property owners and users.

Objective:
Monitor the short and long term effects on infill development, whether it be new or part of redevelopment, on adjacent properties and/or neighborhoods.

General Plan Policies

Land Use Policies:

Policy:
Encourage and promote land uses that are economically and environmentally beneficial to the city.

Policy:
Formulate and implement comprehensive guidelines for the development of the Rio Salado Project.

Policy:
Encourage and implement programs that further enhance the revitalization of the downtown.

Policy:
Work with Arizona State University to encourage its continued growth and contributions to the community, specially at its research park and facilities along the Rio Salado. Ensure that these facilities are complimentary to the City's Rio Salado project as well as its main campus. Also, ensure that campus growth be compatible with the downtown and adjacent residential neighborhoods.

Circulation Policies:

Policy:
Work with the appropriate agencies to pursue development of canal banks, railroad rights-of-way and other easements to expand and accommodate alternative modes of transportation.

Policy:
Encourage and implement a greenbelt / linear park network that links residential and non-residential areas as well as educational and recreational facilities throughout the City.

Policy:
Encourage and implement grade separations to ease circulation for all forms of transportation throughout the City.

Policy:
Encourage development that contributes to bikeways and transit and that can be accommodated on the existing transportation system.

Environmental Policies:

Policy:
Encourage, improve and implement programs, in both public and private development, that ensure the continued availability of water.

Policy:
Encourage and implement technology and programs that result in the undergrounding of all transmission lines.

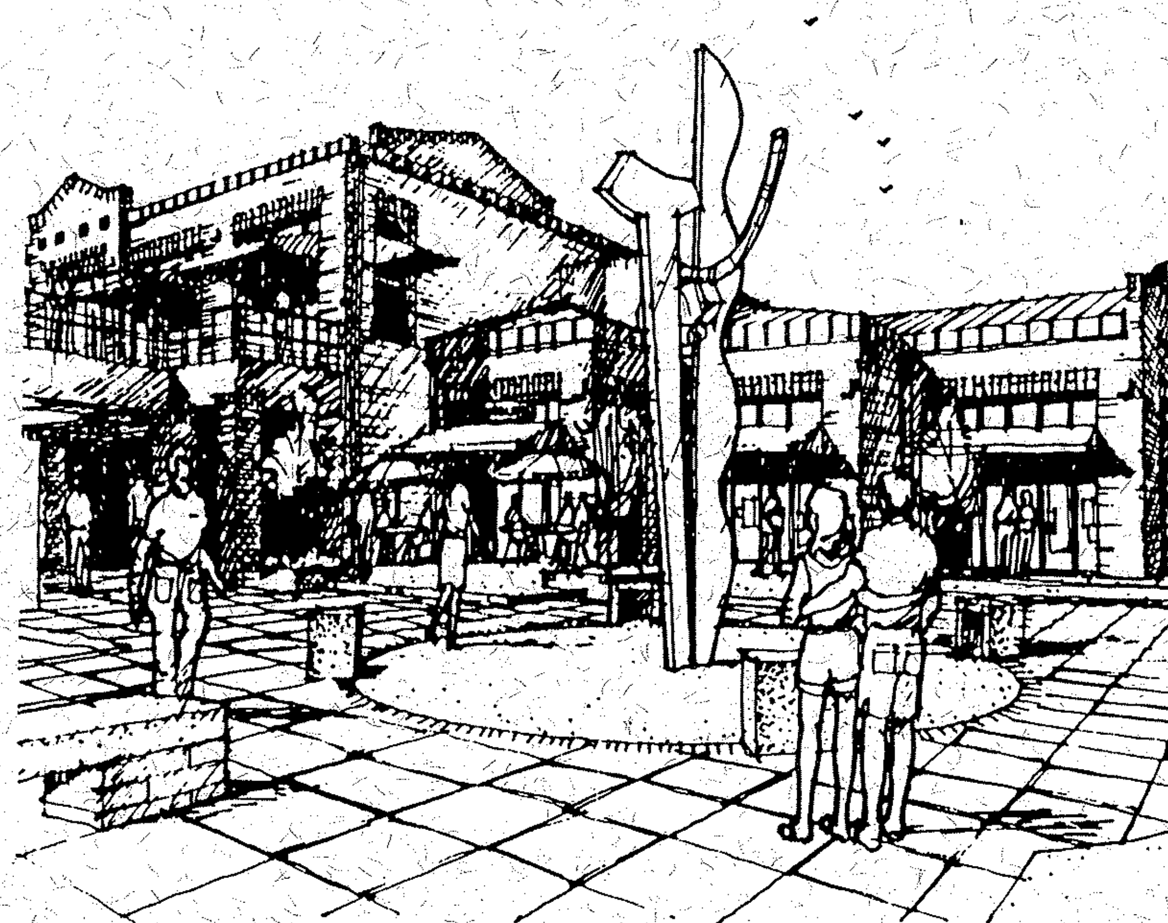
Policy:
Encourage and implement programs that conserve non-renewable resources as well as reduce energy consumption.

Policy:
Encourage developments that are environmentally sensitive.

Urban Beautification Policies:

Policy:
Encourage and implement a systematic program that combines a variety of physical design elements and landscaping that enhances the visual character of the City.

Policy:
Maintain the commitment to a strong, comprehensive municipal arts program.



Goals, Objectives and Policies of the Tempe Rio Salado Plan

Goal I

Encourage the Optimum Development of Land Along the Salt River.

Objective:
Encourage commercial and industrial development in order to generate revenues to offset the cost of improvements to the area.

Objective:
Develop the potential for residential development adjacent to the Salt River compatible with the environmental constraints of the Sky Harbor Airport flight pattern.

Objective:
Revitalize and preserve the unique open space along the Salt River and develop linkages between it and adjacent recreational facilities.

Objective:
Establish a harmonious and complementary relationship between the Rio Salado Project and existing and future development on adjacent lands while upgrading the quality and integrity of existing land uses.

Objective:
Integrate the East Papago Freeway design into the Master Plan such that the freeway complements the Tempe Rio Salado Project.

Objective:
Incorporate circulation systems into all developments and support a wide range of transportation alternatives.

Objective:
Enhance the public facilities and services in the Rio Salado area through the City's Capital Improvement Program.

Goal II

Promote the Development of Outdoor Recreational Facilities.

Objective:
Provide a wide variety of recreational opportunities for all citizens.

Objective:
Encourage the private development of recreational facilities on public and private lands for the public good.

Objective:
Enhance the desirability of Tempe as a place to live, work or visit by developing an attractive urban retreat with outdoor recreation as its primary focus.

Goal III.

Combine Flood Control With Environmental Design in a Manner That Will Achieve the Greatest Social and Economic Benefits for the Citizens of Tempe.

Objective:
Continue working with appropriate government agencies to achieve a satisfactory resolution of the flood control component in the most environmentally and aesthetically desirable way.

Objective:
Encourage the moderate use of water to form lakes, ponds, and streams as an integral part of the design and development of Rio Salado. Make use of reclaimed water such that potable domestic water is not used.

Goal IV.

Continue the Coordination of an Administrative Framework to Promote the Development of the Tempe Rio Salado Project.

Objective:
Continue the use of the Rio Salado Overlay District to provide a smooth transition from the Rio Salado Project to adjacent project uses. Enforce high standards of development within the district.

Objective:
Acquire lands as necessary to attain the goals of the Tempe Rio Salado Project.

Objective:
Continue the planning and development of pilot projects, both public and private, to demonstrate a commitment to the Rio Salado Project and to aid in implementing the plan.

Objective:
Pilot projects should be funded through a wide range of funding sources.

Objective:
Continue the Tempe Rio Salado Advisory Commission as a permanent citizen's advisory body to the City Council and other boards and commissions.

Objective:
Continue to build an inventory of financing and implementation recommendations that will lead to the successful completion of the Tempe Rio Salado Project.

Goal V.

Improve the Quality of Life in the Region.

Objective:
Guide the development of projects in the Rio Salado area which enhance the lifestyle of Valley residents.

Goal VI.

Provide Educational Opportunities for the Community in and Around the Salt River Area.

Objective:
Provide environmental education in the form of wildlife retreats and habitats, as well as interactive exhibits and field study.

Objective:
Construct a Water Conservation Garden to demonstrate the efficient use of natural resources and serve as a learning tool.

Objective:
Preserve the Hohokam archeological sites in the area.

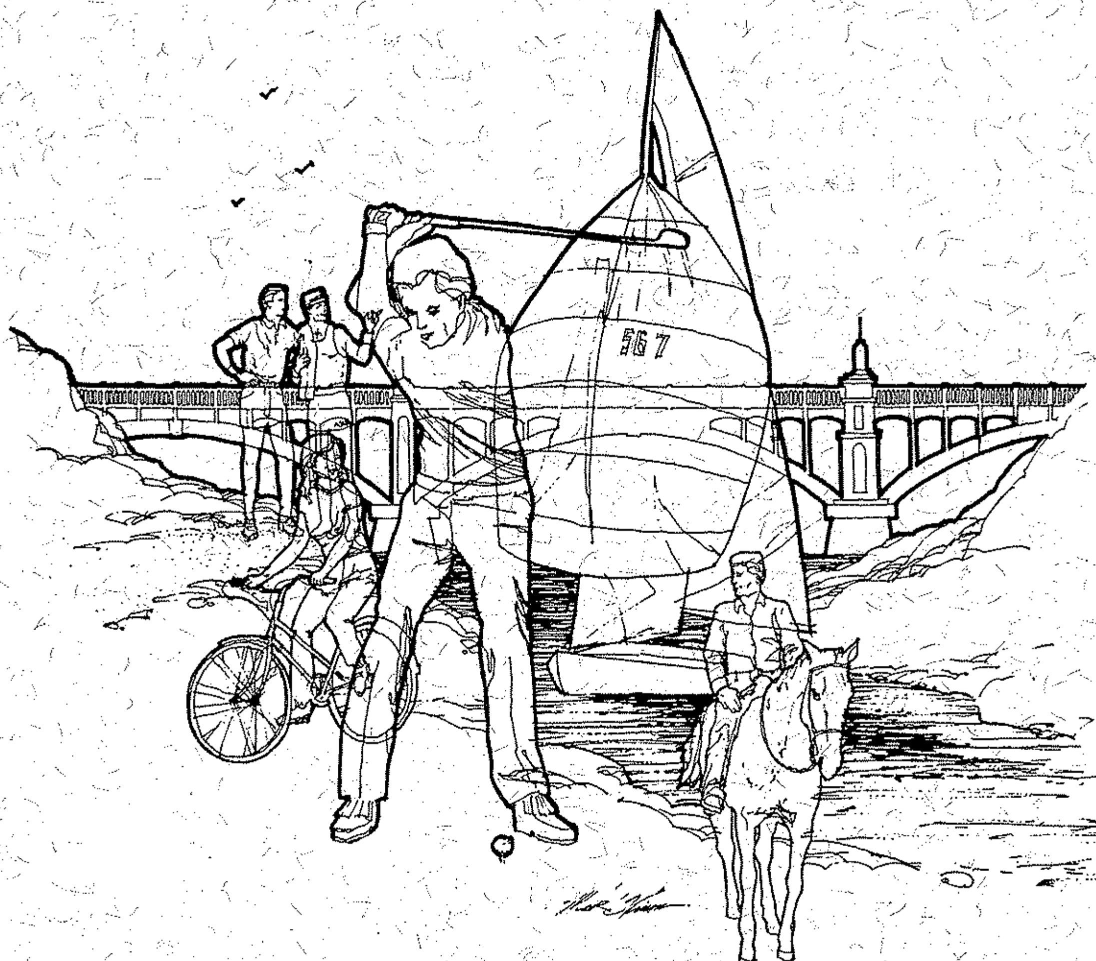
Goal VII.

Protect the Environmental Quality of the Lands in the Salt River Area.

Objective:
Continue to pursue solutions for reducing noise pollution. Study methods of noise abatement in relation to freeway design and other transportation routes through the area.

Objective:
Promote the efficient utilization of water through reclamation, reuse, recycling and other water-saving measures.

Objective:
Improve the air quality by a) developing multi-modal transportation systems consistent with air quality plans, b) promoting efficient land use which in turn promotes efficient vehicular circulation, and c) planting ample vegetation to replenish the oxygen supply.



Policies of the Tempe Rio Salado Project:

Policy:
The City of Tempe is committed to the realization of the Tempe Rio Salado Project.

Policy:
The Tempe Rio Salado Project reaffirms the goals, objectives and policies contained in the General Plan and promotes the development of land uses which are in accordance with the overall goals of the Plan.

Policy:
The City of Tempe actively promotes the development of the Tempe Rio Salado Project by fostering cooperative public and private efforts and encouraging private developers and landowners to capitalize on the commercial and recreational opportunities of the Tempe Rio Salado Project.

Other City Policies

1. The Rio Salado Overlay District

The Rio Salado Overlay District was established by the Tempe City Council to provide a smooth transition from the Rio Salado Project to the various uses located on lands adjacent to the project area. Its goal is to help realize the Tempe Rio Salado Plan. It has been incorporated into City Ordinance 808, the "Zoning Ordinance" of Tempe, in the form of an Overlay District. It establishes higher standards of development for properties located within its bounds and is currently being implemented through the City's plan review process.

2. The Downtown Tempe Plan

The downtown plan projects what the downtown may look like in the year 2000. Downtown continues to be one of Tempe's greatest success stories and receives recognition at the state and national levels. Its truest measure of accomplishment, however, has been its acceptance and support by the citizens of Tempe. Downtown is adjacent to the Rio Salado Project and is vital in encouraging participation in the area of the river.

The philosophy of the City is that downtown should continue to emphasize an historical theme. This reinforces the fact that Tempe had its origins in the downtown and respects the many historical structures remaining there.

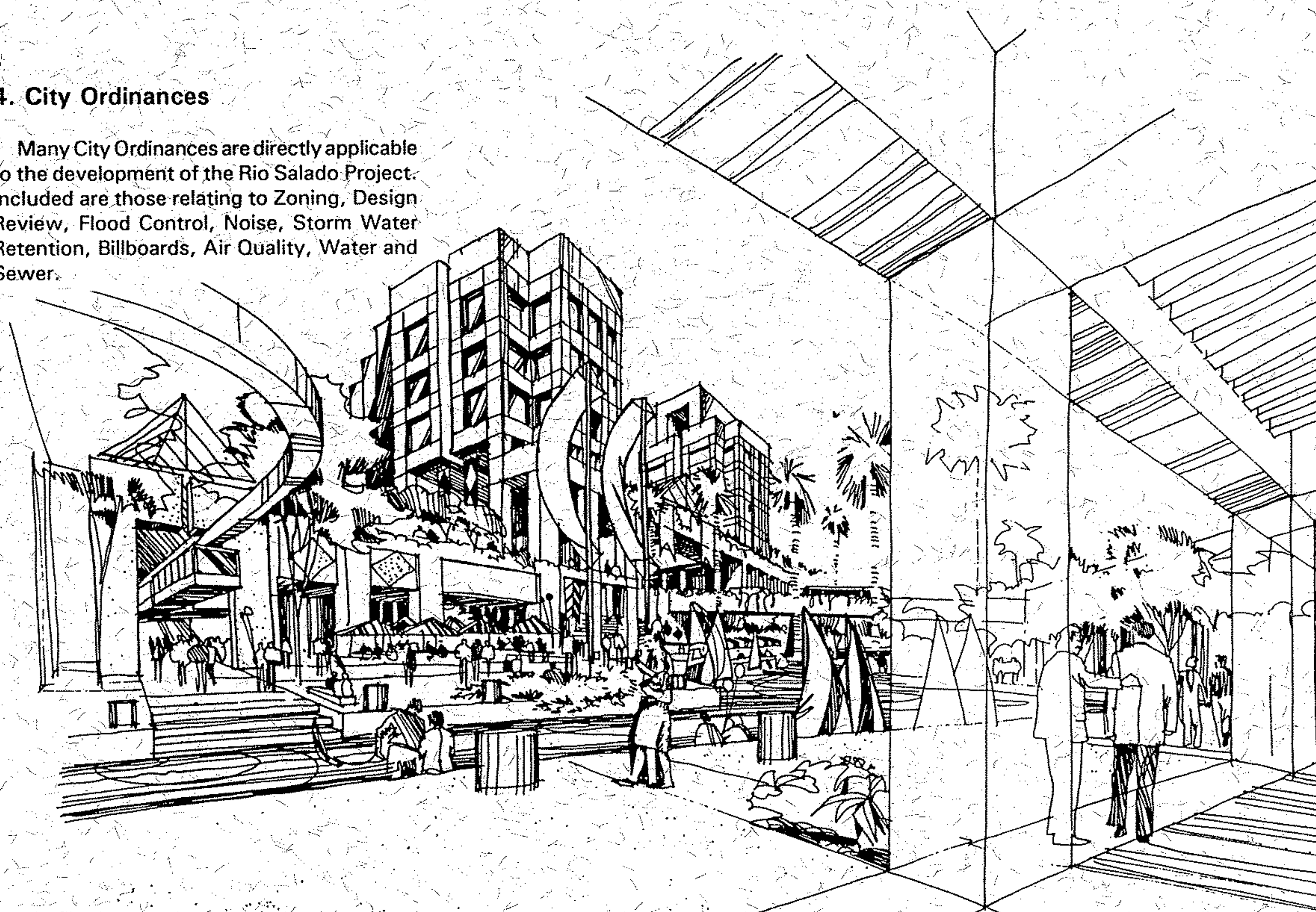
3. The Tempe Bikeway Plan

Bikeway planning has been an integral part of the General Plan since the mid-70's. An updated bikeway system for Tempe is summarized in the Tempe 2000 General Plan and includes proposed commuter-oriented and recreational routes. A full-time transportation planner is currently on staff with the city and provides regular updates to the Bikeway Plan.

The bikeway system is an important concept in tying the Rio Salado to the surrounding community through an improved "secondary transportation" network which would include trails along canal banks and railroad rights-of-way throughout the city. In addition, this system of paths would be an important aspect of circulation within the Rio Salado itself.

4. City Ordinances

Many City Ordinances are directly applicable to the development of the Rio Salado Project. Included are those relating to Zoning, Design Review, Flood Control, Noise, Storm Water Retention, Billboards, Air Quality, Water and Sewer.



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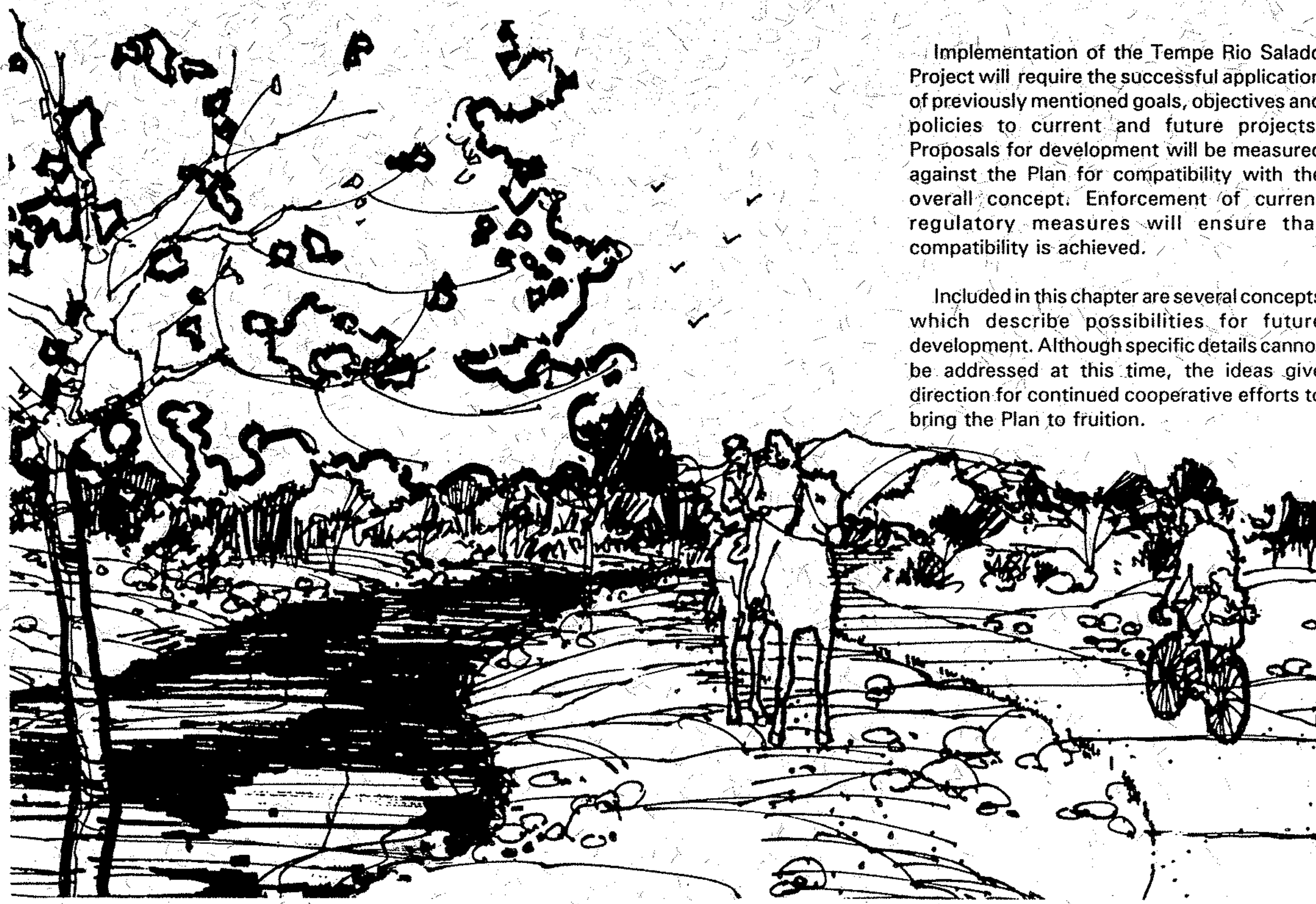
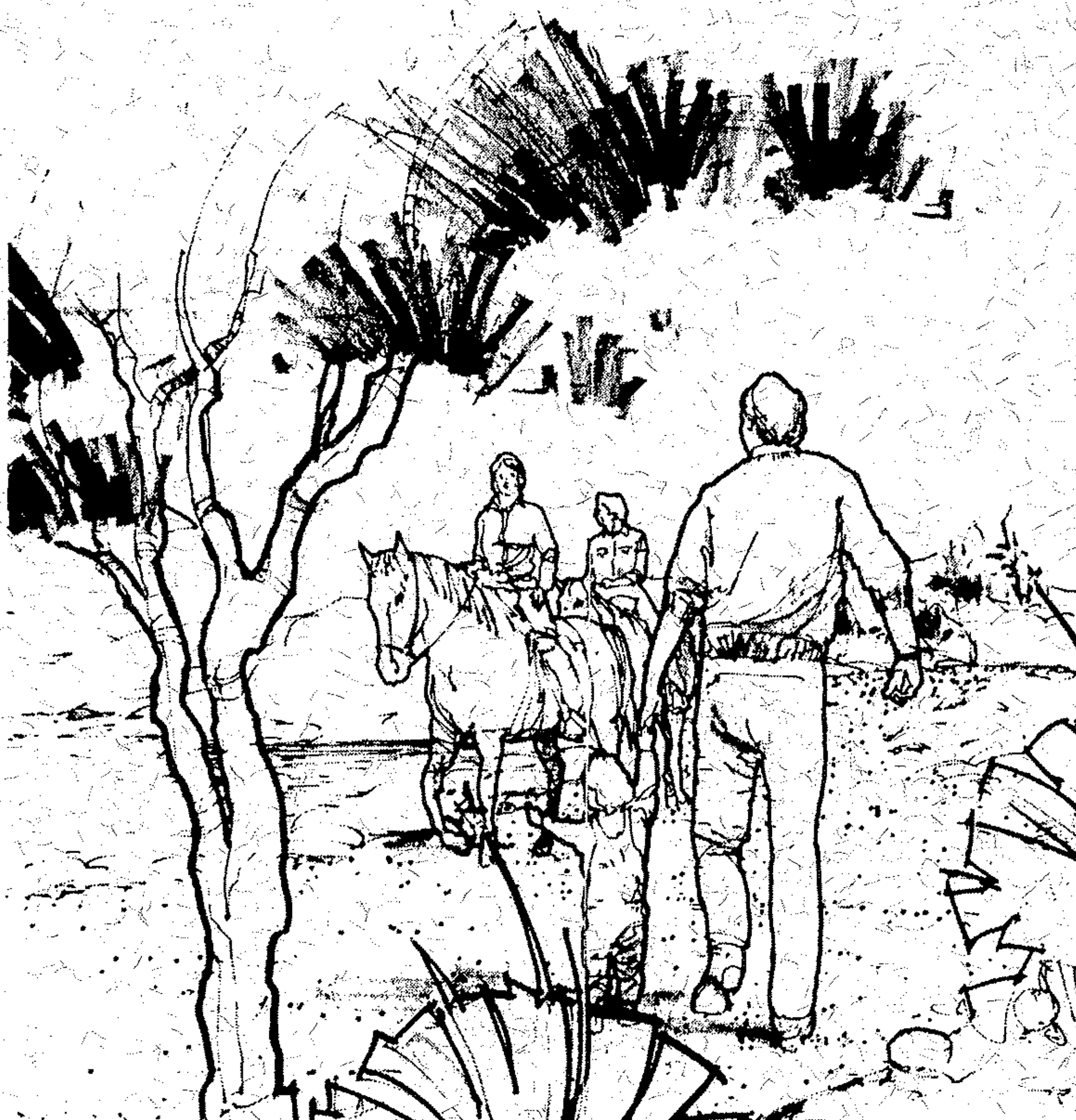
Implementing The Plan

Implementing The Plan



Implementation of the Tempe Rio Salado Project will require the successful application of previously mentioned goals, objectives and policies to current and future projects. Proposals for development will be measured against the Plan for compatibility with the overall concept. Enforcement of current regulatory measures will ensure that compatibility is achieved.

Included in this chapter are several concepts which describe possibilities for future development. Although specific details cannot be addressed at this time, the ideas give direction for continued cooperative efforts to bring the Plan to fruition.



Regulatory Measures

Implementation can be accomplished through judicious use of the City's regulatory power and assisted by setting a good example to the community. City ordinances provide guidance necessary to ensure that future development is compatible with Tempe's General Plan and Rio Salado Project.

The City actively enforces its ordinances pertaining to zoning, billboards, flood control, storm water retention, noise, water quality, refuse and dumping. This ensures the development of a safe, desirable, functional and pleasing environment within the Rio Salado Project area and its environs.

Funding

Creative methods of securing funding are necessary to turn the Rio Salado concept into a reality. Cooperative efforts between public and private agencies are needed, as well as funding from programs sponsored by federal and state agencies. Also, land donations, development rights and easements will be solicited from governmental agencies.

In some cases, commercial development may include aspects that qualify for public funding as recreation uses. For instance, funds from the State Urban Lakes program may be used if public access is provided around the entire perimeter of a lake body. Also, the State Urban Fishing program can be tapped as a resource. In similar ways, other existing programs can be utilized to assist in the implementation of Tempe's Rio Salado Project.

The City could also assemble large parcels of land for various uses and sell or lease that land to private developers. Similar programs have worked well in redeveloping Tempe's downtown. This concept has proven to be one that benefits both the citizens and the developers.

To help finance the Tempe Rio Salado Project, the City:

1. Encourages the significant investment of private capital to achieve the goals of the Rio Salado Project;

2. Assists in land assembly & acquisition for projects;

3. Assists in the development of land through Requests for Proposals (R.F.P.'s) from private developers for projects on public lands;

4. Commits to the Rio Salado by including projects in the Capital Improvement Program Budget.

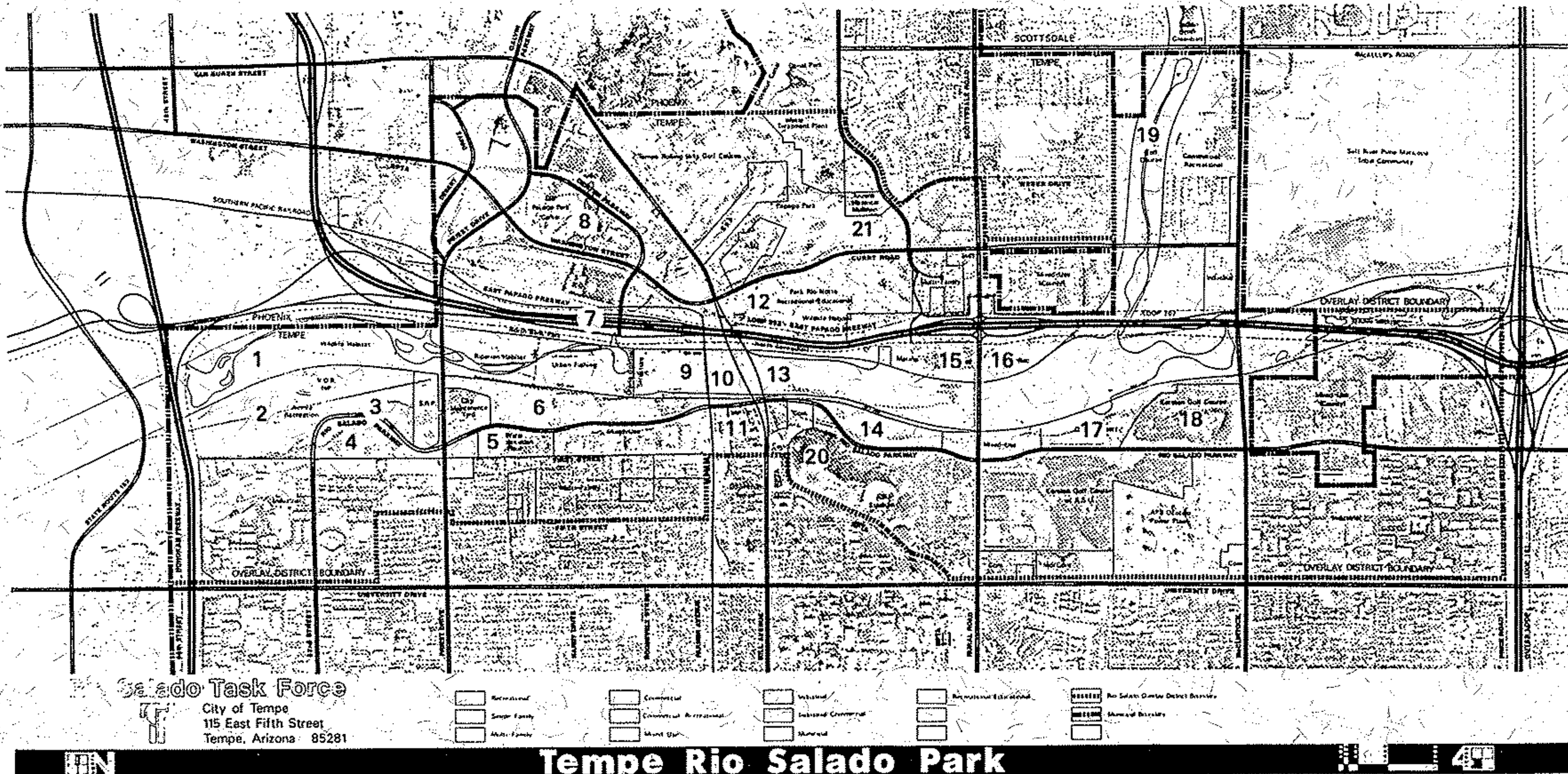
5. Provides public facilities and services where required;

6. Encourages the use of industrial development bonds for suitable projects within the Tempe Rio Salado Project area;

7. Promotes the input and donation of materials and labor from civic, professional, service and trade organizations;

8. Requires developers to commit funds toward infrastructure improvements.

Points of Interest



1. Salt River Channelization - Hohokam Expressway to Southern Pacific Railroad
2. Recreation Site West Of Priest Dr.
3. Rio Salado Parkway
4. Ice Arena Site
5. Water Reclamation Facility
6. Rio Beach
7. East Papago Freeway
8. Papago Park Center
9. Proposed Inflatable Dam
10. Salt River Channelization - S.P.R.R. to McClintock Drive
11. Tempe Beach Park
12. S.C.E.N.E.
13. New Mill Avenue Bridge
14. Hayden's Ferry
15. The Boardwalk
16. Commercial Development Site
17. Private Development
18. Karsten Golf Course at A.S.U.
19. Rio Salado Golf Course
20. Tempe Butte
21. Papago Park

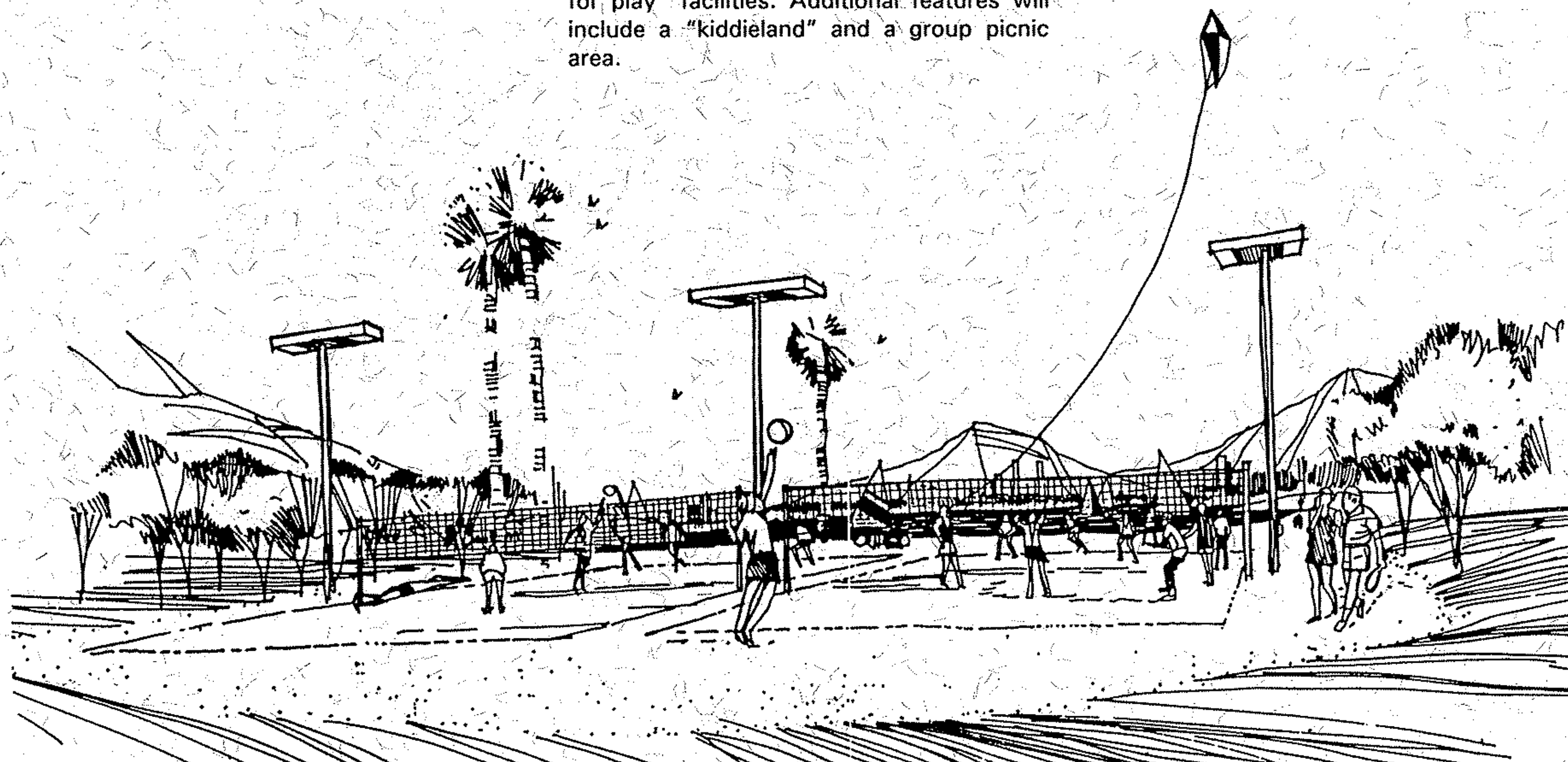
Development Activities & Possibilities

1. Salt River Channelization - Hohokam Expressway to Southern Pacific Railroad (S.P.R.R.)

This project was completed in 1991 by the Arizona Department of Transportation.

2. Recreation Site West of Priest Dr.

Lease negotiations have been completed for a 123-acre recreational development. Privately funded ballfields, volleyball, batting cages and mini-golf will be available as "pay for play" facilities. Additional features will include a "kiddieland" and a group picnic area.



3. Rio Salado Parkway

This meandering scenic roadway will link together destinations along the south bank of the river. The existing parkway will be extended west of Priest Drive, tying into 52nd Street.

4. Ice Arena Site

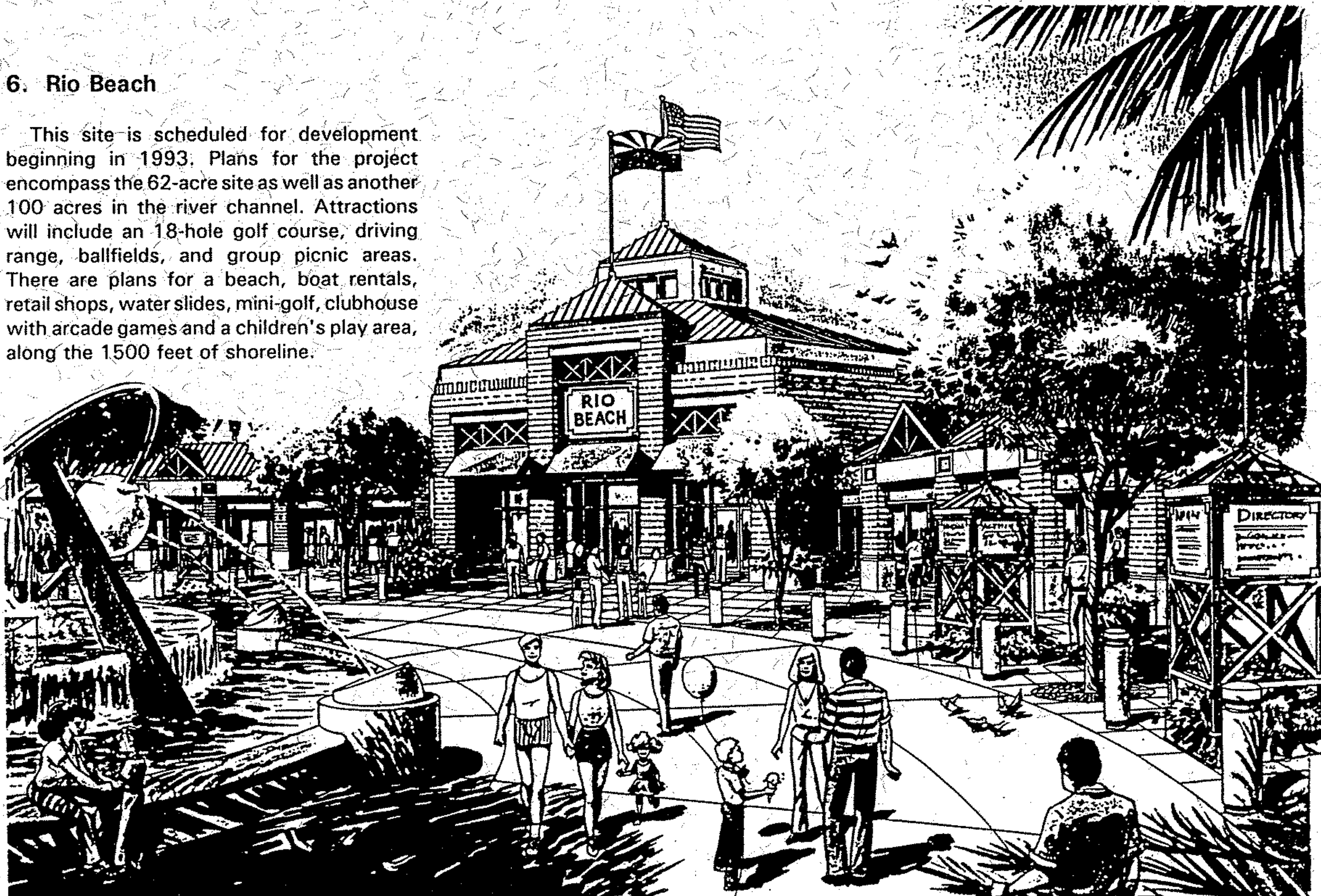
This 25-acre parcel is planned for development as an ice rink with two separate sheets of ice. One of the rinks is proposed to have seating for professional ice hockey events. Also included are plans for skate rental shops, a restaurant and bar.

5. Water Reclamation Facility

Plans have been completed for a Phase One capacity of 6 million gallons per day (m.g.d.) of treated water. This facility, if constructed, could be expandable up to 15 m.g.d. and will allow Tempe to re-use waste water which is now being sent to the 91st Avenue Facility in Phoenix.

6. Rio Beach

This site is scheduled for development beginning in 1993. Plans for the project encompass the 62-acre site as well as another 100 acres in the river channel. Attractions will include an 18-hole golf course, driving range, ballfields, and group picnic areas. There are plans for a beach, boat rentals, retail shops, water slides, mini-golf, clubhouse with arcade games and a children's play area, along the 1500 feet of shoreline.

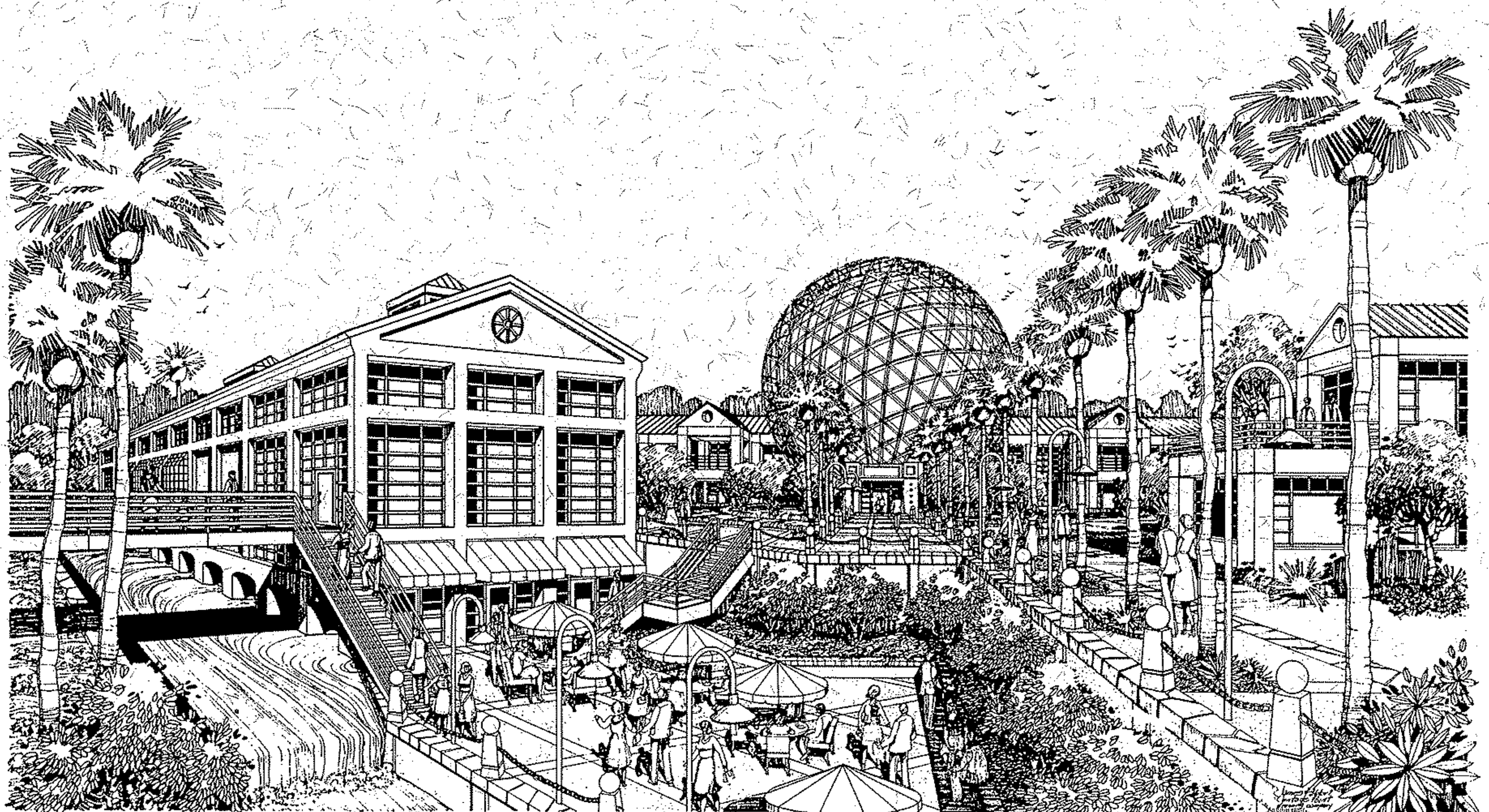


7. East Papago Freeway

Currently under construction, this 10-lane freeway will provide Valley-wide access to the project. Completion through Tempe is scheduled for December '94. In late 1992, the freeway should be open as far east as Priest Drive. Views of the Rio Salado Project will unfold to travelers in both the east and west directions, especially at elevated ramps and interchanges. A landscape buffer will help to transition between the freeway and park development.

8. Papago Park Center

Along the north bank of the river, west of Mill Avenue are the headquarters for the Salt River Project. A major expansion has begun with the construction of a new office tower for S.R.P. near Washington and 56th Streets. This is the first phase of the Papago Park Center, a mixed-use complex which is to include 7 million square feet of hotel, retail, office and light industrial (research and development) uses on 428 acres. Benefits to the Rio Salado include the conversion of the Grand Canal into a "River Walk" through the S.R.P. property and the donation by S.R.P. of a 15-acre park south of the East Papago freeway from Priest Drive to the railroad bridge near Mill Avenue.



PAPAGO PARK EXPOSITION CENTER
VIEW TO RENOVATED HYDRO PLANT
& EXHIBITION BUILDINGS

9. Proposed Inflatable Dam

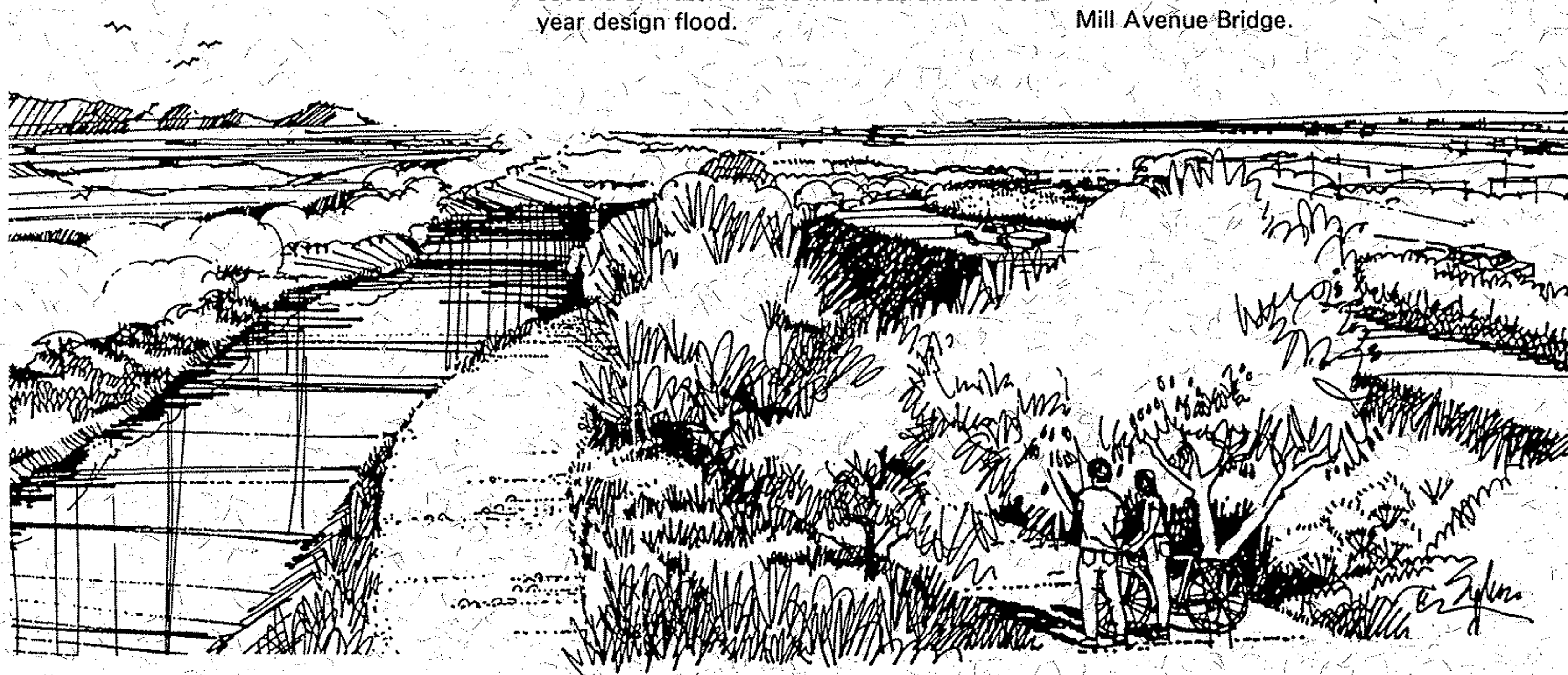
Anticipated to be constructed sometime after 1995, the dam will be built in four spans of 200 feet each. Constructed of a rubber material similar to a tire tread, the inflatable dam can be deflated quickly to allow the safe passage of flood waters. This technology has been used successfully around the world with proven results in similar climates.

10. Salt River Channelization - S.P.R.R. to McClintock Drive

This flood control project was designed to meet Tempe's plans for recreational and commercial uses along the river. Funded primarily by the Flood Control District of Maricopa County along with the Arizona Department of Transportation, this floodway provides a capacity of 250,000 cubic feet per second of water. This is in excess of the 100 year design flood.

11. Tempe Beach Park

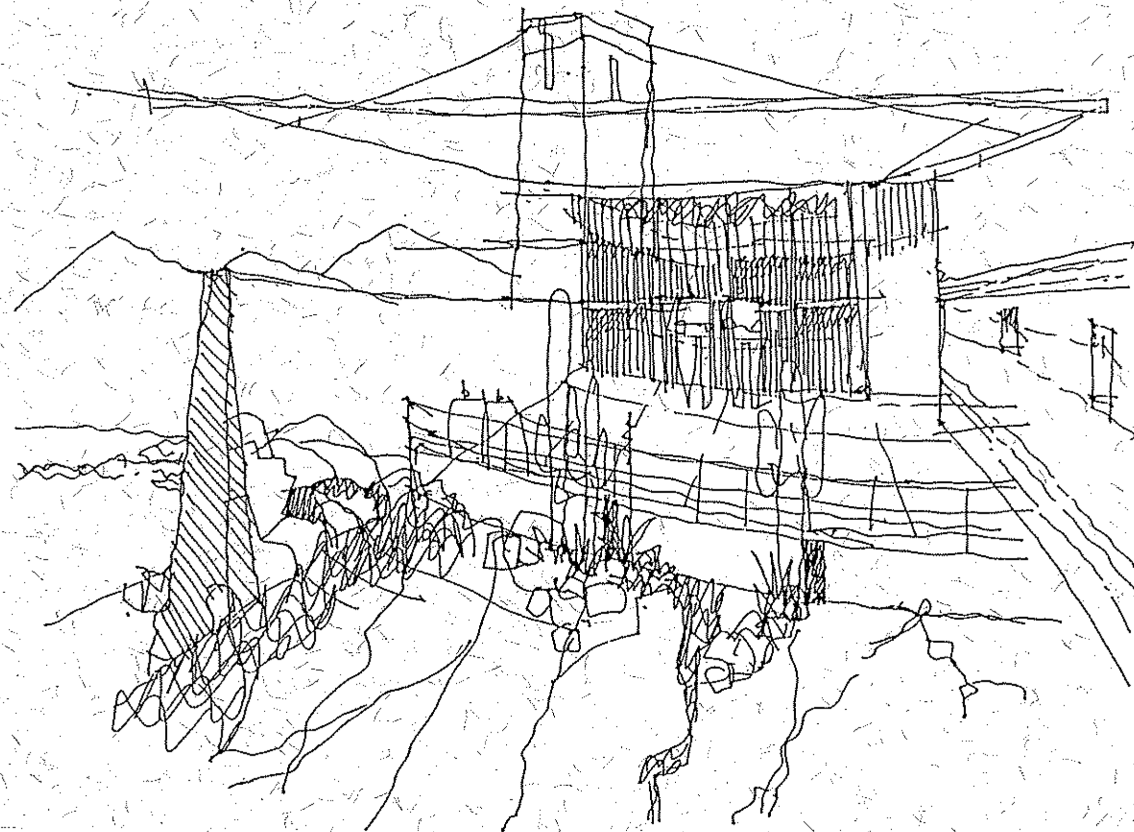
Just west of the Mill Avenue Bridge is the Tempe Beach Park, currently home of the Tempe Arts Center. Plans call for an improved arts facility with good access to the river and improved park amenities. This location is an ideal pedestrian terminus to the thriving downtown and provides a compliment to the water-oriented recreation nearby. It also creates a link to the development east of the Mill Avenue Bridge.



12. S.C.E.N.E.

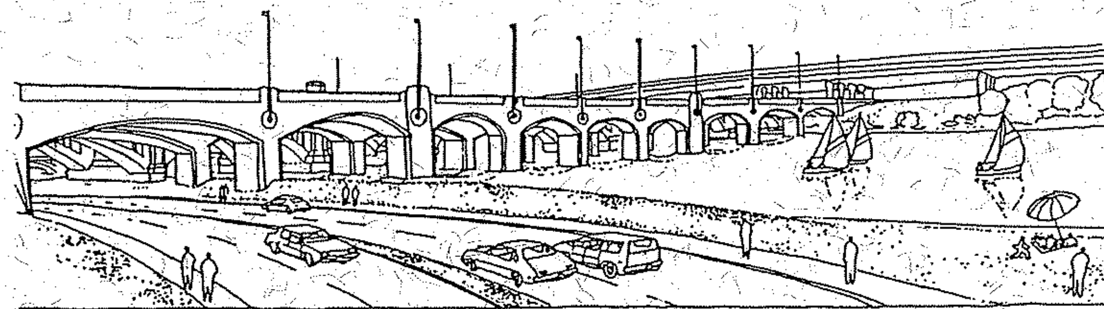
The Southwest Center for Education and the Natural Environment (S.C.E.N.E.) is a concept which has materialized from a set of planning workshops. The concept includes facilities for learning about the environment in a natural desert setting.

The facility would serve several purposes, providing display and exhibit space for environmental education, establishing a resource center/data bank for information about the environment, and providing a natural setting in which to learn more about our environment firsthand.



13. New Mill Avenue Bridge

The new structure will carry northbound traffic across the Salt River, replacing the "at-grade" crossing through the river bottom. Similar in proportion, size and height to the existing bridge, the new bridge will feature a more streamlined appearance yet retain some of the "art deco" details. Pedestrian stairways will connect both banks of the river via a walkway along the east side of the new bridge. Bike lanes will be incorporated into the design. Also, the new bridge will be set apart a sufficient distance from the old Mill Avenue Bridge to allow good visibility of the historic structure. Plans call for completion of the new bridge in the Fall of 1993.



Second Mill Avenue Bridge Location Study & Design Concepts

14. Hayden's Ferry

Near the Mill Avenue bridge, on the south bank, a commercial development with retail shops, a resort hotel and restaurants would tie-in with the redeveloped downtown and draw activity from this urban hub to the water's edge. The water and accompanying recreation would be a natural attraction which shop owners could capitalize on. A current proposal calls for the re-creation of a ferry for the conveyance of people across the river, much as the original Hayden's Ferry did. The plan also calls for the reconstruction of the original flour mill, complete with water wheel, as an operating museum/mill. This would serve as the focal point of a retail plaza and promenade leading to the lake.

The City of Tempe is working jointly with Arizona State University in offering this land for private development. The project area is along the south bank of the river, both east and west of Rural Road. The area north of Sun Devil Stadium is planned for a multi-use development including a park-like setting for tailgate parties near the river. An amphitheater could provide seating for pep rallies before the games and walkways under the Rio Salado Parkway will allow easy access to the stadium without having to cross any streets. The area adjacent to Rural Road is planned for commercial development which will serve the community year-round. Retail shops and restaurants in that development will benefit and profit from the sports activities nearby.

15. The Boardwalk

Along the north bank of the river, commercial developments are planned east and west of Scottsdale Road. To the west, a project called "The Boardwalk" is planned to include a marina and retail shops near the large water bodies in this area. This would provide a prospective terminus for the Hayden's Ferry. Ample parking at the Boardwalk will also serve the adjacent recreation features.

East of Scottsdale Road, additional residential development will complement proposed commercial uses. The confluence of the Salt River and Indian Bend Wash provides a scenic focal point for activity of all types. With many forms of water-based recreation nearby, commercial activity should thrive in this location and provide needed services to users of the park.

16. Commercial Development Site

Similar to the Boardwalk in concept, this site is publicly owned. Commercial shops are anticipated to line the water's edge in a manner reminiscent of the San Antonio Riverwalk. Located at the upper end of the lake, this site will feature panoramic views and serve as the connection to other recreational development in the Indian Bend Wash.

17. Private Development Site

Resort hotel and office uses are planned for this privately held parcel which features lake frontage. It is also bordered by the Karsten Golf Course at A.S.U. Other potential features of the site include a health club and international tennis facility.

18. Rio Salado Golf Course

This project is a good example of the type of commercial based recreation encouraged in the Tempe Rio Salado Project. Located in the Indian Bend Wash, south of McKellips Drive, the site is a natural extension of the Indian Bend Wash development in Scottsdale. The City of Tempe initiated the concept and requested proposals from private developers for the implementation of a golf course. The winning proposal was a 9-hole, lighted course which keeps the low-flow channel open for water features by the City and also includes a small lake on the upper banks. The course opened for play in December 1990.

19. Karsten Golf Course at A.S.U.

Arizona State University, in conjunction with the Sun Angel Foundation and Karsten Manufacturing, constructed an 18-hole championship golf course between McClintock Drive and Rural Road along the Rio Salado Parkway. The design includes water features and a grade-separated crossing for golfers under the Parkway. The City of Tempe is cooperating in optimizing channelization to protect the golf course. Karsten, an open-to-the public facility, is the home course for Arizona State's N.C.A.A. champion men's and women's golf teams.

20. Papago Park

Papago Park will have new barriers installed to keep vehicles off of pedestrian trails. Also, new parking areas will provide access to the trailheads for pedestrians and emergency vehicles. Horseback riding will be encouraged along the new trails which will also feature shade structures, benches, picnic areas, and information markers. Also, an archeological exhibit area is planned near the prehistoric Loma del Rio ruins.

The new Arizona Historical Society Museum has been constructed along the east edge of the park, creating a new cultural attraction. Also, an environmental learning center is planned near the Salt River in Papago Park.

Access from Papago Park to the river is an important factor in the design of the Tempe Rio Salado Plan. Currently, the East Papago Freeway is being constructed on an earthen berm, punctuated by large openings allowing free access between the park lands.

21. Tempe Butte

Enhanced recreational amenities are being planned for these public lands which are prominent geographic features of the region. As an example, new hiking trails up and around Tempe Butte have recently been completed, offering grand views of the valley. These paths also provide a prominent recreation feature in the center of town.

Vehicular trails that have scarred the natural terrain of the park are being revegetated and have been replaced by more defined pedestrian trails with gentle slopes and informative markers.

Continuing Projects

Many of the concepts vital to the success of the project can be tested by implementing projects of moderate scale. The following factors will be addressed in these projects:

1. Water holding structures, erosion barriers, and recirculating equipment will be tested for their effectiveness.

2. The water holding capacity of soils will be determined. If necessary, lake bed sealing techniques will be tested for their effectiveness.

3. Treated effluent from one of the new water reclamation plants will be utilized in the water features. Also, underground water storage and recovery programs could be implemented.

4. Water circulation concepts will be tested to establish water movements that will be most appropriate to maintain acceptable water quality.

5. Landscape concepts will be developed and implemented in a phased plan. Plant material that is low in water consumption and high in oxygen production will be encouraged in many places.

6. Water runoff and drainage from existing natural washes and man-made water features currently falls into the river bottom and percolates into the underground water table. These sources have been analyzed and are being incorporated into designs for ongoing projects in the area.

7. Tempe identification markers and entry themes are being implemented to welcome visitors to Tempe. Distinctive signage and other aesthetically pleasing elements will identify this as a project unique to Tempe.

8. Funding through available grant monies will be pursued through various institutions. Also, utilizing available state and federal funds will facilitate the implementation of this plan.

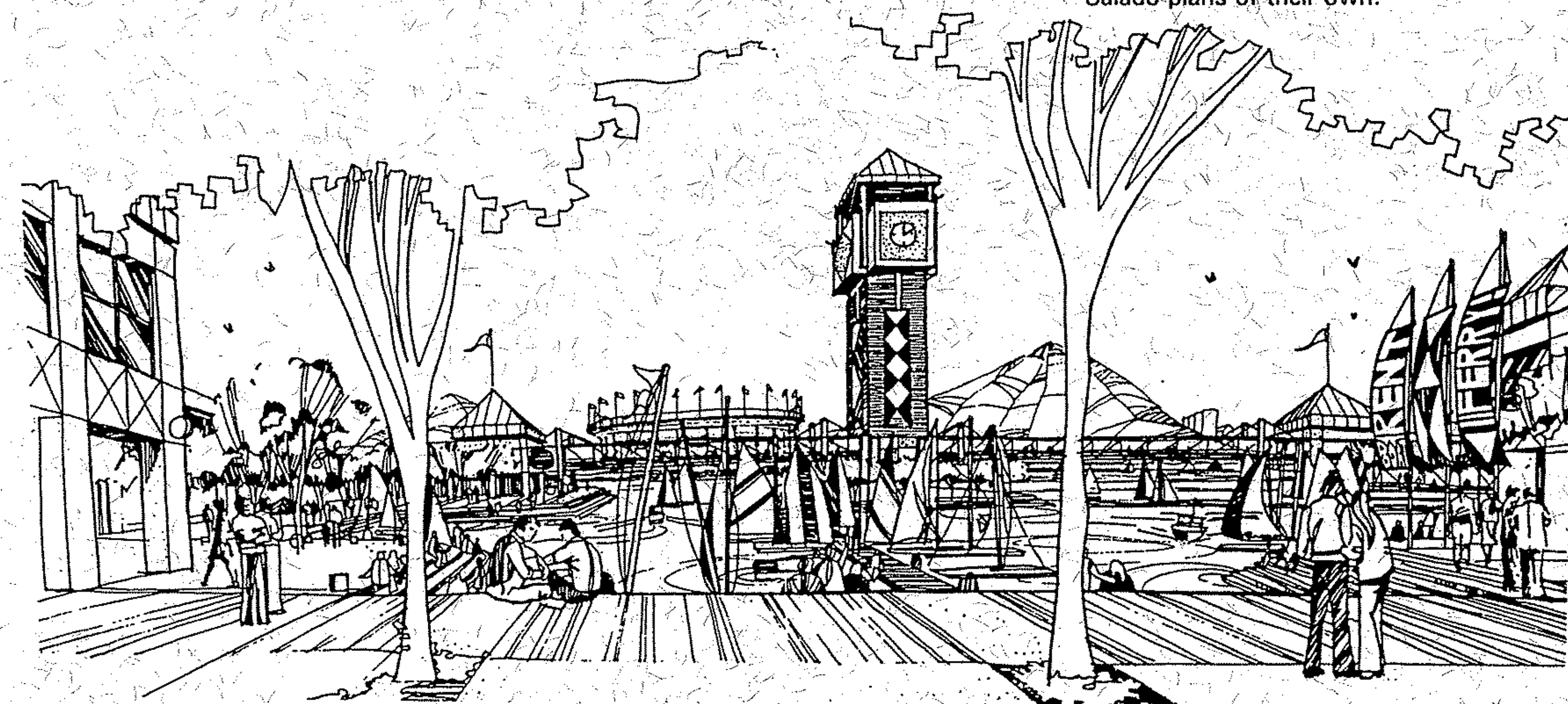
9. Private development for recreation and other public purposes continues to be encouraged on public lands through creative partnerships.

Continued Role Of Citizens In The Rio Salado Project

The Tempe Rio Salado Advisory Commission will continue to advise the City Council and its Boards and Commissions on all matters pertaining to the development of property within the Rio Salado Project. Other groups such as local service organizations, clubs and neighborhood associations will be encouraged to join in the effort to promote the Tempe Rio Salado Project. To this end, the general public will be kept informed on the progress and potential of the project.

An interdepartmental staff group at the City of Tempe, known as the Rio Salado Task Force, continues to meet regularly to coordinate the review of current proposals and projects within the Rio Salado Overlay District. The Task Force will make recommendations to the Rio Salado Commission and City Council for proposed projects and ensure that these projects are of appropriate character and quality for the area.

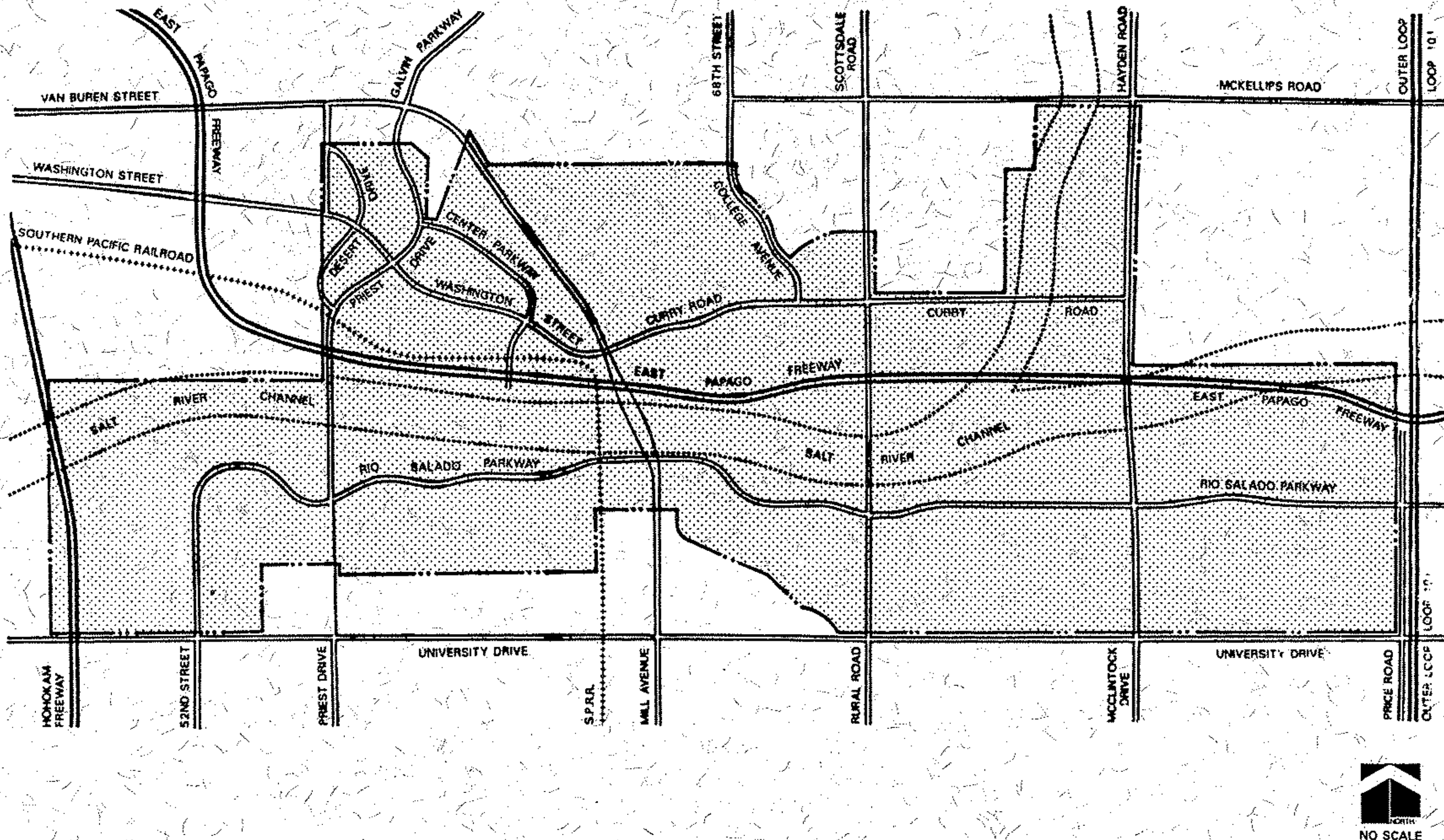
It is envisioned that the Tempe Rio Salado Project will be an example and inspiration to surrounding communities. The development of a complementary Rio Salado Project in the neighboring communities of Phoenix and Mesa would fulfill the dream of a continuous urban oasis throughout the valley and provide a regional park that would be a showpiece for the State. To facilitate this, the City of Tempe will actively support and assist neighboring communities in their efforts to implement Rio Salado plans of their own.



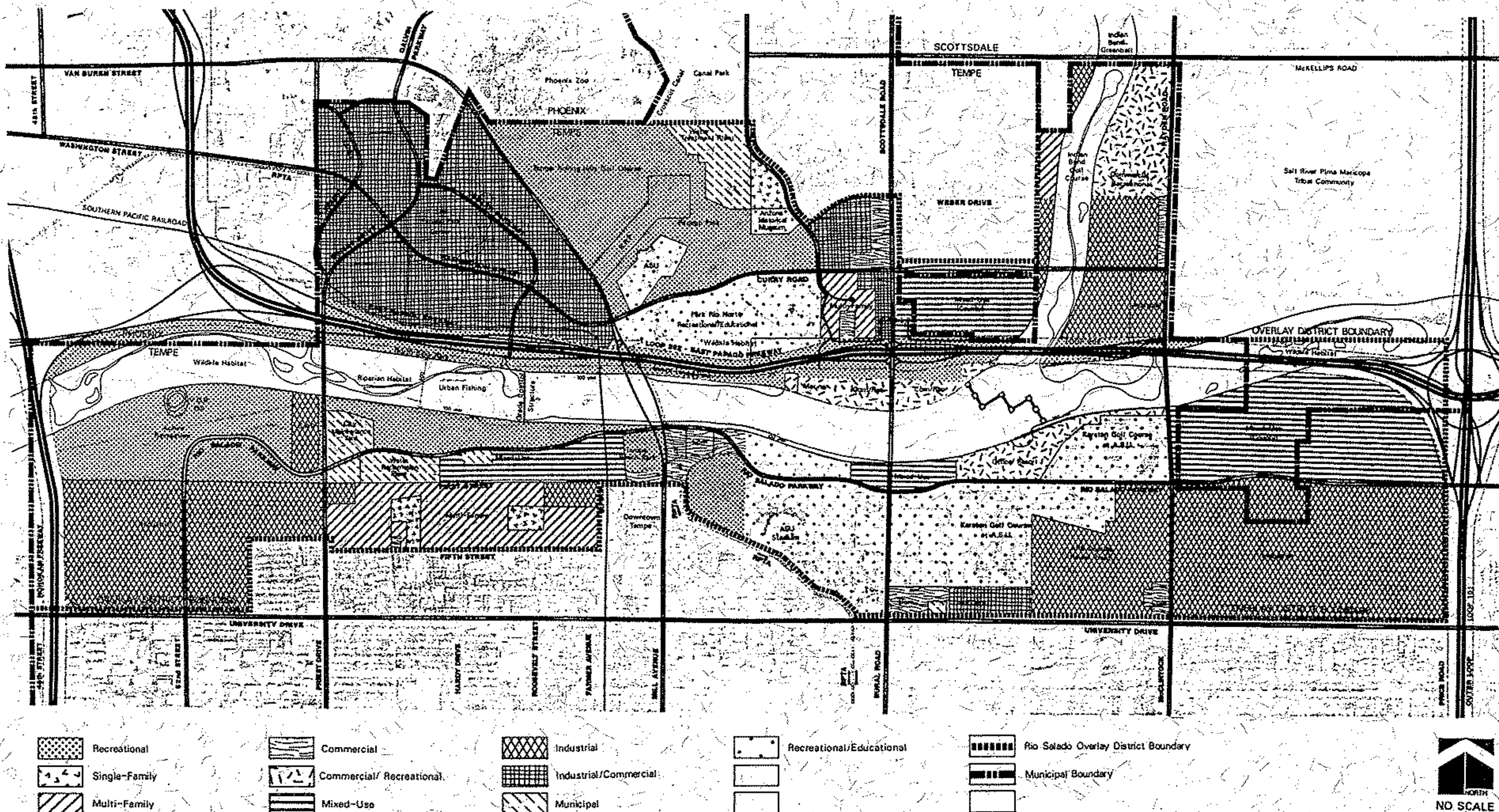
5

Appendix

Rio Salado Overlay District Map

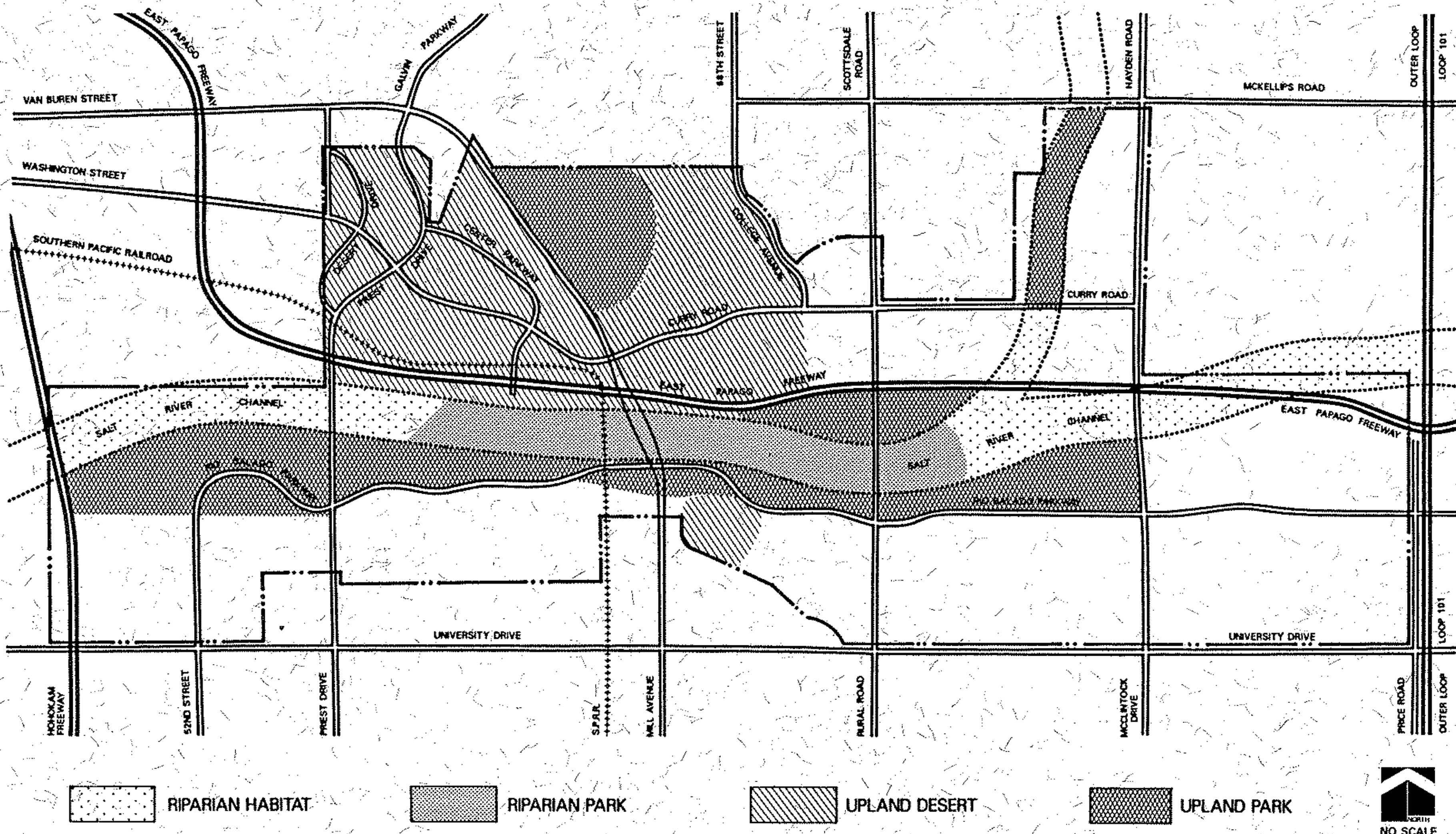


Land Use



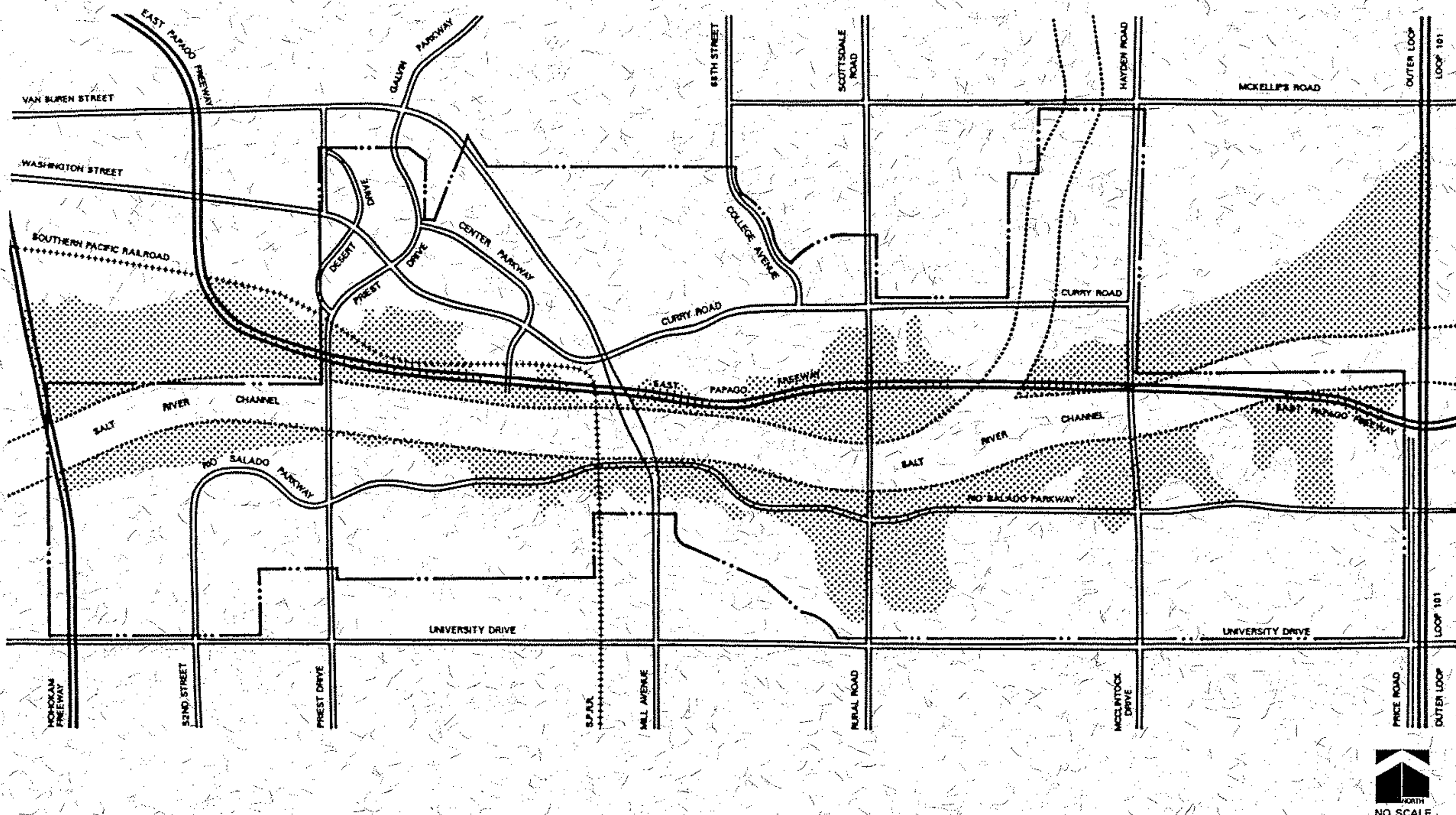
VAN BUREN STREET
WASHINGTON STREET
SOUTHERN PACIFIC RAILROAD
48th STREET
PHOENIX
TEMPE
SCOTTSDALE
Phoenix Zoo
Canal Park
Crosscut Canal
Curry Road
Park Rio Norte Recreational/Educational
Wildlife Habitat
Riparian Habitat
Urban Fishing
Grade Control Structure
LOOP 202 - EAST PAPAGO FREEWAY
OVERLAY DISTRICT BOUNDARY
Weber Drive
McKELLIPS ROAD
Salt River Pima Maricopa Tribal Community
Indian Bend Greenbelt
Indian Bend Golf Course
Rio Salado Parkway
ASU Stadium
Karsten Golf Course at A.S.U.
Downtown Tempe
Fifth Street
University Drive
Price Road
Loop 101
Scottsdale Road
Rural Road
Mill Avenue
Farmer Avenue
Roosevelt Street
Hardy Drive
Priest Drive
52nd Street
Hohokam Freeway
RPTA
McClintock
Recreational
Single-Family
Multi-Family
Commercial
Commercial/ Recreational
Mixed-Use
Industrial
Industrial/Commercial
Municipal
Recreational/Educational
Rio Salado Overlay District Boundary
Municipal Boundary
NORTH
NO SCALE

Landscape Zones

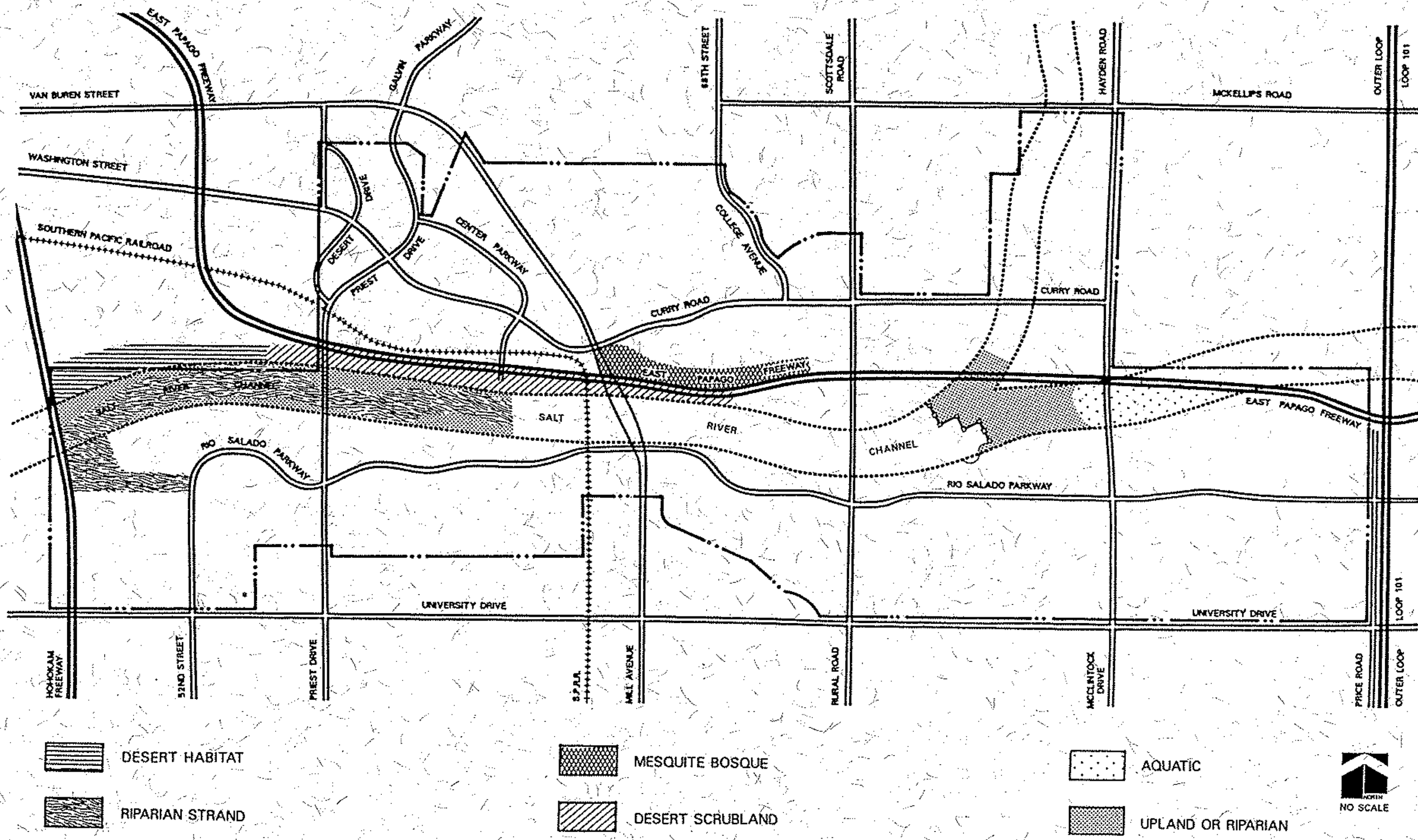


Land Reclaimed from the Salt River 100-Year Flood Plain

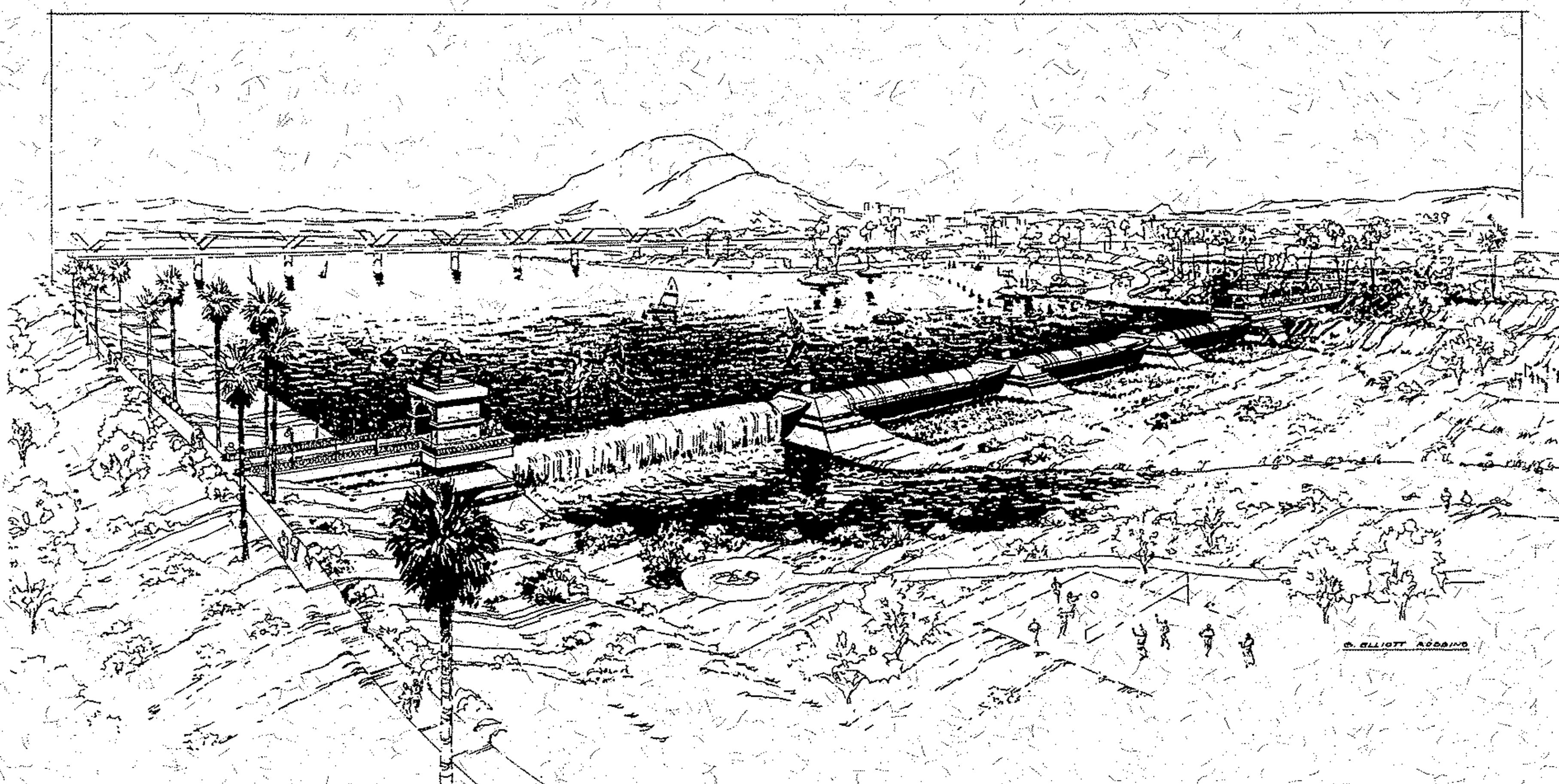
Area Reclaimed After Channelization: 838 acres



Wildlife Habitat Master Plan

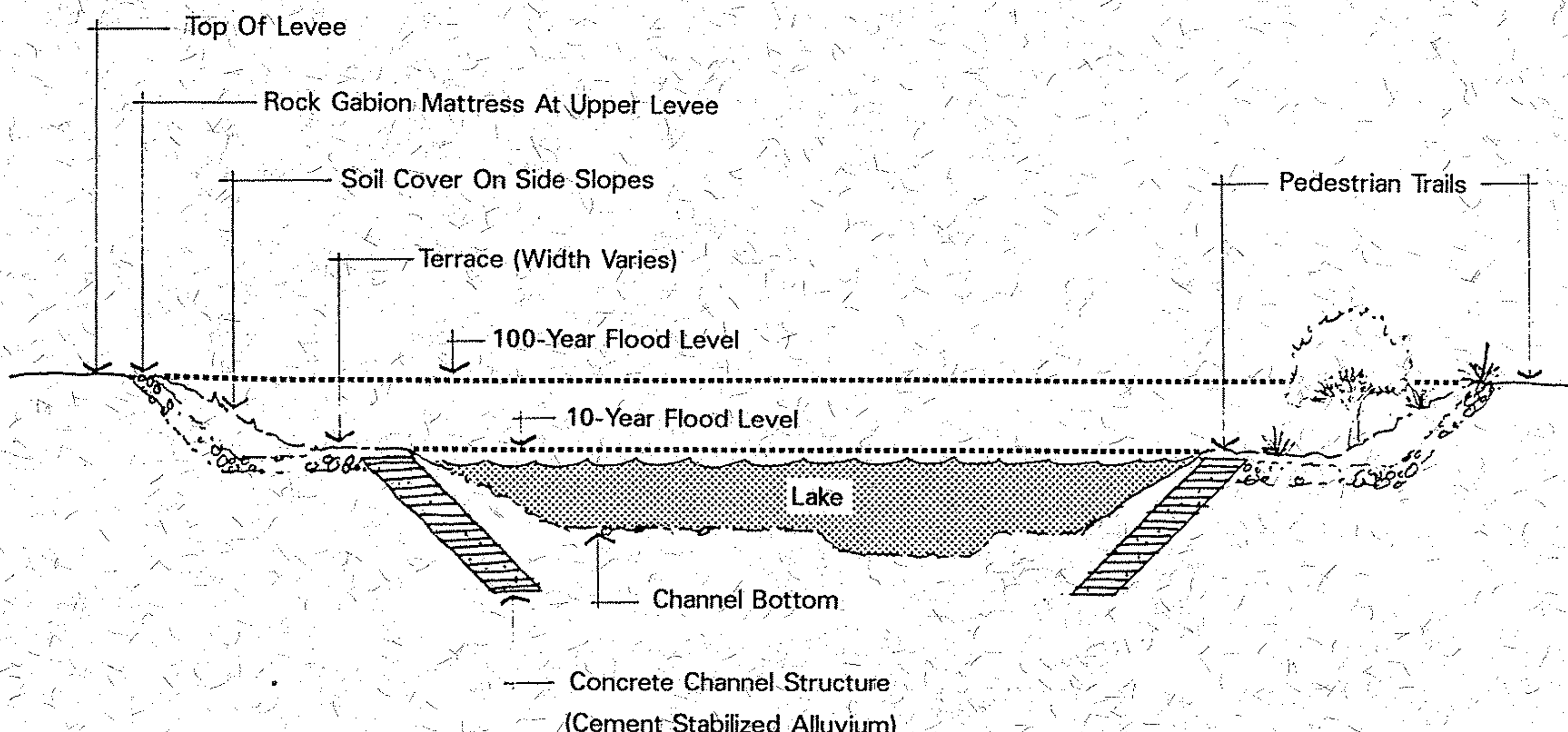


Artist Concept of Inflatable Dam



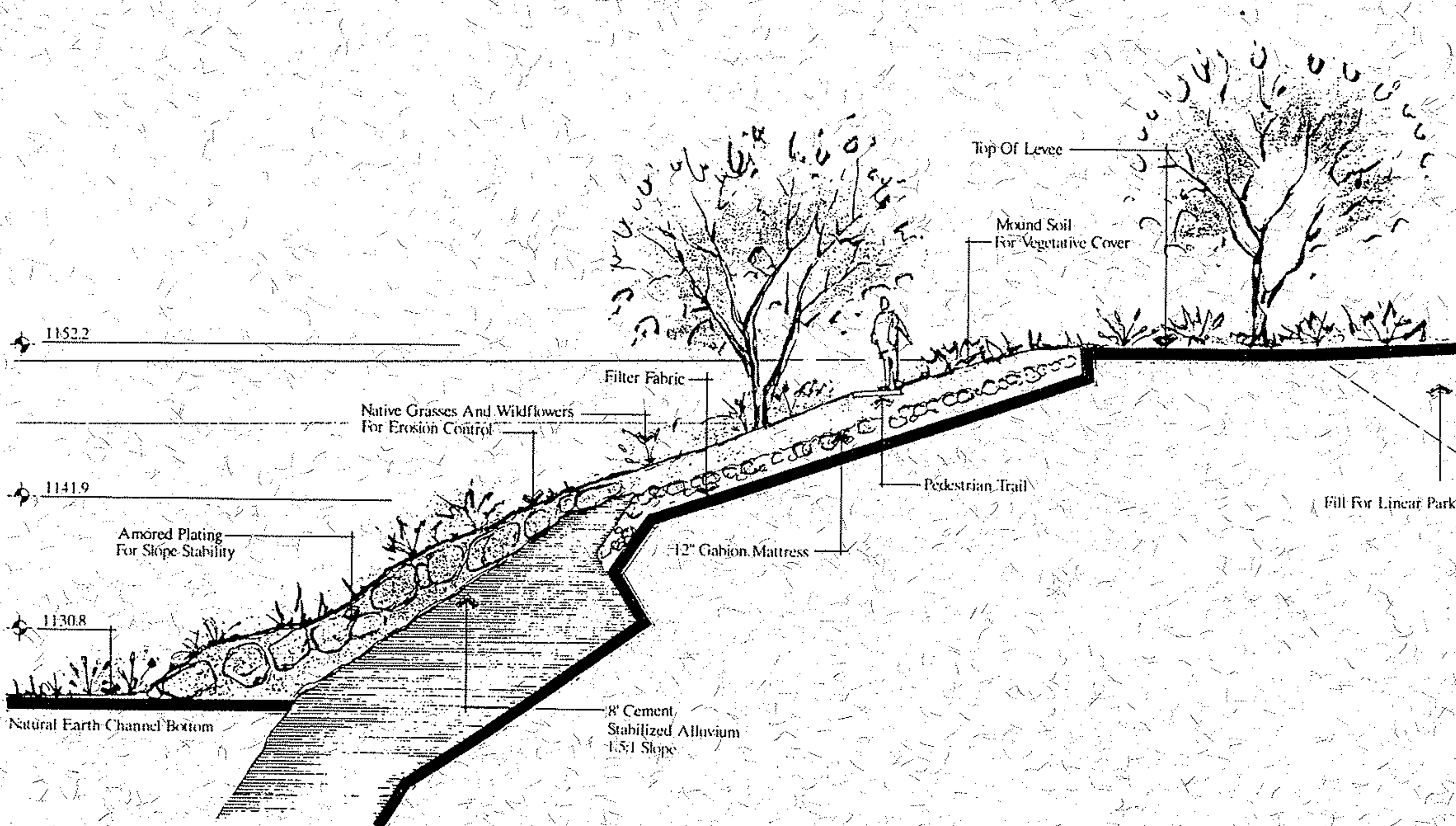
Typical Channel Section At Lake

No Scale

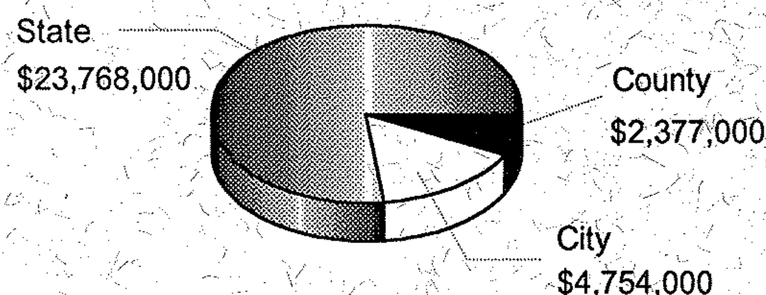


Improved Canal Embankment

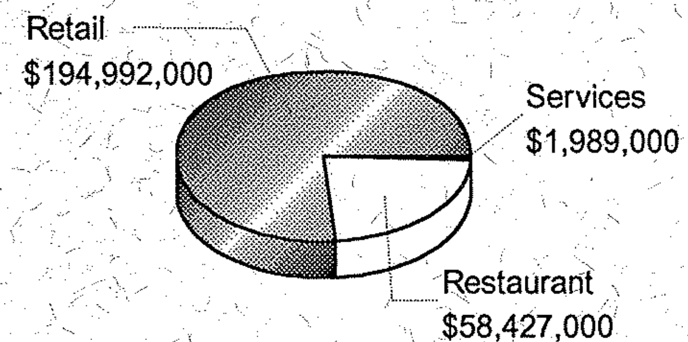
No Scale



Projected Annual Rio Salado Gross Sale Revenues

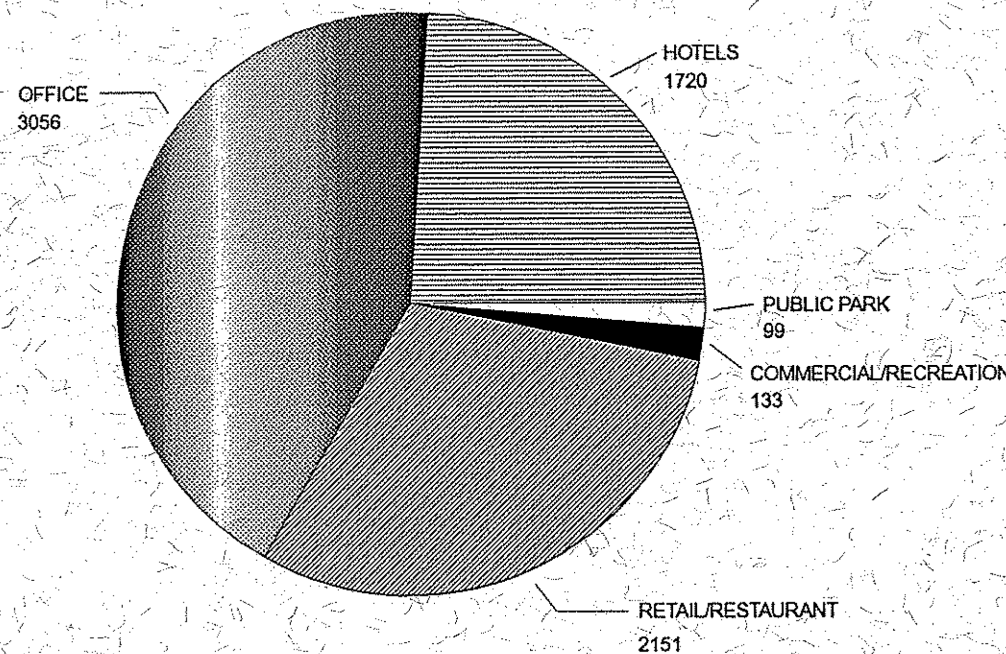


Annual Sales Tax Revenue
Total: $30,899,000



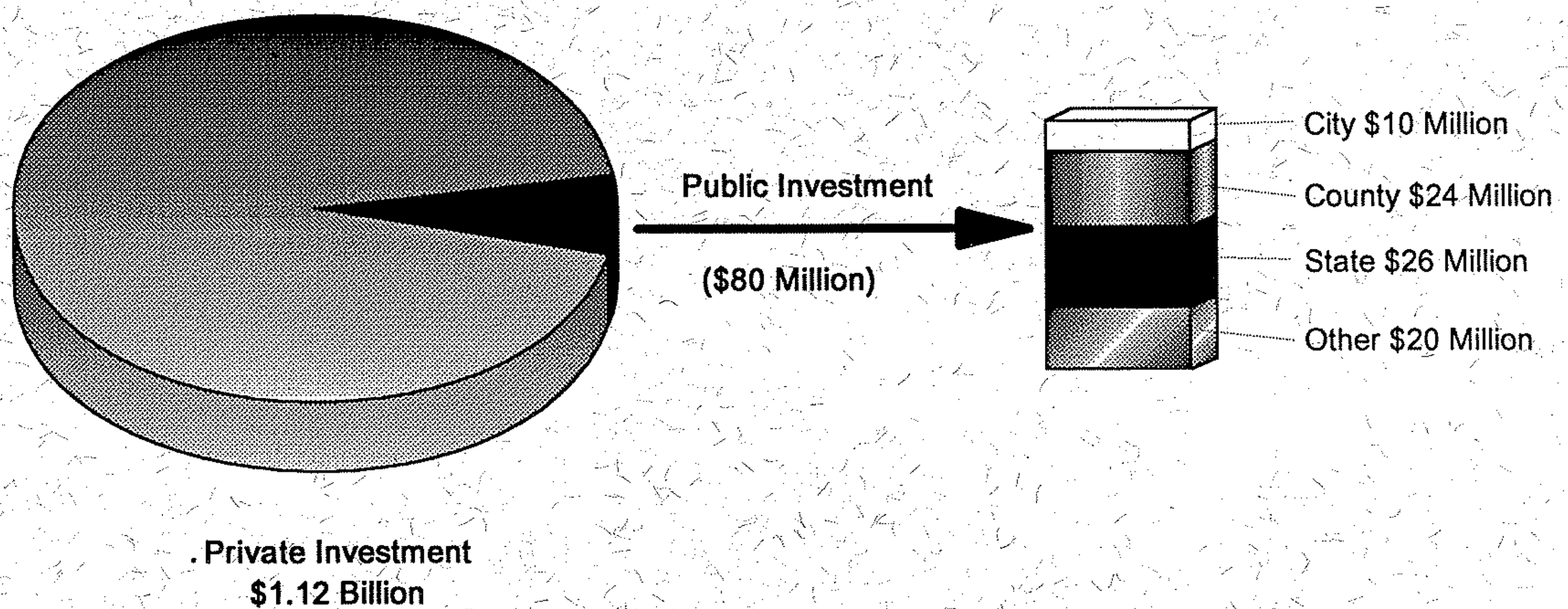
Sales Revenues
Total: $255,408,000

Rio Salado
Employment Projections



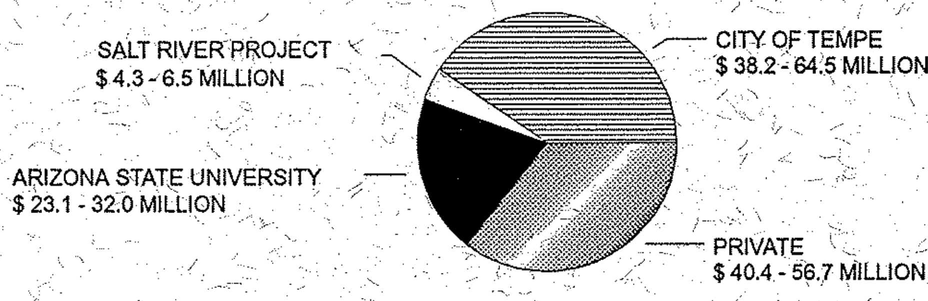
Permanent New Employment
Total: 7,159

Public/Private Investment

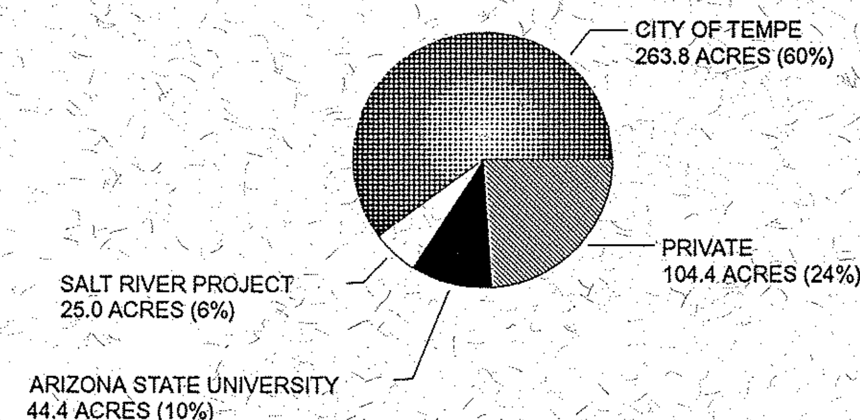


Total Development Cost: $1.2 Billion

Estimated Rio Salado Land Value After Channelization



LAND VALUE RANGE
TOTAL LAND VALUE: $106.0 - 160.6 MILLION



TOTAL ACREAGE REMOVED FROM FLOODWAY CHANNEL: 437.6 ACRES

Historic Floods on the Salt River

(shown in cubic feet per second)

February 1891	300,000
April 1905	115,000
November 1905	200,000
January 19-20, 1916	120,000
February 1920	130,000
March 1938	95,000
December 1965 - January 1966	67,000
February 21 - May 29, 1973	22,000
March 2, 1978	122,000
December 19, 1978	140,000
January 19, 1979	88,000
March 29, 1979	67,800
February 1980	180,000

Data for early floods obtained from the *Interim Report on Survey for Flood Control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam Site, Arizona,* U.S. Army Corps of Engineers, Los Angeles District, 1957.

Data for recent floods obtained from the U.S. Geological Survey, measured at 48th Street and the Salt River.

96-002-013

SALT RIVER

CITY OF TEMPE

DOCUMENT SET III

Rio Salado Engineering Report prepared for the City of Tempe by CH2M HILL dated June 1992.

W. Kent Foree
Assistant City Attorney
City of Tempe
P. O. Box 5002
Tempe, AZ 85280
350-8227

Rio Salado Engineering Report

Tempe

CH2M HILL

June 1992

CH2M HILL
Engineers
Planners
Economists
Scientists

June 10, 1992

PHX31608.EC.R1

Mr. Howard Hargis
Project Manager
City of Tempe
P.O. Box 5002
Tempe, Arizona 85280

Dear Howard:

Subject: Rio Salado Town Lake Engineering Report

CH2M HILL is pleased to submit for your review the Draft Engineering Report for the Rio Salado Water Resources Master Plan. This report is submitted in draft form to solicit comments and input from appropriate City staff. Please note that concurrent with your review this document is undergoing our in-house quality control review and therefore some minor errors and inconsistencies may not yet have been corrected by our staff. Any significant changes resulting from our review will be brought to your attention through the submittal of errata.

We request that this document be thoroughly reviewed by the Rio Salado Technical Committee. Your comments and suggestions are welcome. We anticipate receiving your input at our upcoming meeting on July 1, 1992.

We are grateful for the efforts of the staffs of the Engineering, Planning, and Water and Wastewater Departments, and of the Rio Salado Technical Committee during this project. We look forward to meeting with you in three weeks.

Sincerely,

CH2M HILL

James L. Butt, P.E.
Vice President and Regional Manger

PHXR31.018.51

Contents

Contents (continued)

Figures

Tables

Contents

Executive Summary

This Engineering Report represents the findings of a one-year study of the engineering feasibility of creating a Town Lake as part of the Rio Salado project. The report is intended to provide City decisionmakers with information regarding the Town Lake and alternatives for lake water supply in a format that complements information being generated by the City regarding overall water resource management plans. As such, this report makes no recommendations regarding water supply. This report includes the following information:

- Alternative methods of lake construction. These methods are primarily alternative approaches to controlling seepage losses to minimize impacts on the existing hydrogeology of the project area.
- Alternative approaches to protecting the lake from low quality stormwater runoff.
- Alternative approaches for supplying the lake with water.
- Recommendations for managing the lake's water quality.

Eight technical memorandums were prepared in earlier phases of this investigation of engineering feasibility that included the following topics:

- Alternative types of dam structures.
- Alternative lake locations and lake sizes.
- Other technical information regarding Salt River hydraulics, lake water quality, and permitting.

During this investigation, the Rio Salado Technical Committee, City staff, and City Council have provided direction to the project team. Key direction thus far has included:

- Beneficial uses. The Town Lake will be used primarily as a boating lake of sufficient water quality to be permitted for partial body contact. Consideration may be given to fishing on the basis of catch-and-release or for food consumption, but overall fishing is not currently a high priority beneficial use. Swimming in Town Lake will not be allowed due to safety considerations and the high cost of consistently maintaining a highly transparent water quality.

- Lake location. The lake will be created by two dams. The "downstream" dam located approximately 1,500 feet west of Mill Avenue, and an "upstream" dam located at the confluence of Indian Bend Wash and the Salt River. Selection of the dam locations establishes the lake surface area, volume, depth, and hydrogeological setting that can be used to determine lake construction features and engineering requirements.

- Dam types. The dams will be air-inflatable rubber fabric types, keyed to a concrete foundation.

Several major engineering decisions have yet to be made:

- What is the source of water supply to sustain Town Lake?

- What level of stormwater protection is appropriate to minimize negative water quality effects?

- What is the most cost-effective and environmentally "safe" method of controlling seepage losses from the lake? Seepage control must recognize known landfills and groundwater contamination that could be adversely impacted by raising the groundwater elevations in the vicinity of the lake.

Water Supply Options

There are five separate water supply options. Each of these options has variations for a subset of nine supply options. Among these nine options, some have further sub-alternatives to consider. The primary sources are reclaimed water from either the existing Kyrene WRF or the proposed North Plant WRF, or Salt River Project.

The options cover a range in capital cost from under $500,000 to over $20,000,000. Operations and maintenance costs for these options range from nothing to over $2,000,000 per year. The supply costs do not include the basic costs of wastewater treatment (sunk costs of Kyrene or future costs of the proposed North Plant).

The options range from direct reuse of existing reclaimed water produced at the Kyrene WRF (or the proposed North Plant) to extensive additional treatment schemes combined with aquifer storage and recovery systems. The additional levels of treatment provided for the reclaimed water (or SRP water) is directly related to the water quality of the lake. This report emphasizes lake water quality in terms of transparency. Transparency, or clarity, can be measured scientifically with a Secchi disk. A Secchi disk is a white and red round disk that can be placed at varying depths in the lake. If the disk is visible at a 2-foot depth, the interpretation is that the transparency is 2 feet. Each of the alternative water supplies has been characterized with the resultant probable average lake transparency. Transparency will be very low for a lake supplied with reclaimed water directly. Transparency will be high (clear) for a lake supplied with recovered (ASR) water. The higher the desired transparency, the higher the costs associated with supply.

Stormwater Management

The nutrients and other constituent pollutants usually found in urban runoff pose a significant threat to the quality of Town Lake. A range of alternative stormwater management schemes was evaluated. The recommended alternative intercepts and diverts a portion of the runoff that would otherwise enter the lake. Additional system components include constructing an upstream dam to retain nuisance runoff and detain large flows, and a plan to continually dewater the Price Road Tunnel to reduce the impacts of a major runoff event from its watershed. If the selected supply option entails an urban SRP reservoir, a more conservative design incorporating a higher capacity bypass may be needed. The approximate cost for the recommended plan is $3,309,000.

Seepage Losses

One of the major costs associated with creating the Town Lake could be related to the means and methods for controlling water loss from the sides and bottom of the lake.

Alternative technologies that are presented in this report include the conventional approach of lining the lake. Also included is an innovative approach using the underlying rock surface as the lake "bottom" in conjunction with slurry walls to form the sides of the lake. Even more innovative is an approach whereby the water is allowed to seep out the sides (and bottom where the hardrock is deep) only to be recovered with wells and pumped back into the lake.

The liner and slurry wall techniques have a much higher construction cost (over $14,000,000) but low maintenance cost. (Assuming the liner can be placed below the scour depth for a reasonable cost, there would be no replacement cost, i.e., O&M). The pumped seepage recovery system has a relatively low capital cost ($2,600,000), but a high annual cost ($200,000) associated with energy costs for pumping, maintenance of equipment, and more intensive groundwater monitoring than would be required.

Lake Quality Management

Maintaining the quality of the lake water over time will require a well-planned proactive program. Management options include aeration and circulation of the lake; withdrawal of water from the deeper, more stagnant areas of the lake; physical and chemical treatment; and the use of fish to control weeds. The costs for management are extremely variable and will depend on the final source water and transparency required. The annual maintenance cost would range from $200,000 to over $500,000 per year.

July 1, 1992 Presentation

The alternatives covered in this draft report will be presented in detail at the July 1, 1992, meeting. Following the meeting and based on direction received, this Executive Summary will be rewritten in summarized format to reflect the City's needs.

Section 1
Introduction

Background

Prior to the 1940s, the Salt River was a perennial stream providing water to the Valley of the Sun for irrigation and recreation. Following the developments of the Salt River Project, the river became a dry riverbed for most of the year, flowing only in response to large rainfall events. Over the years, sand and gravel extraction from the riverbed and floodplains, and the creation of several landfills dramatically altered the environment and habitat of the Salt River, creating an eyesore where a riparian oasis once existed.

In 1966, students in the ASU College of Architecture conceived an ambitious plan to restore the Salt River through creation of a series of lakes and streams. The project covered over 38 miles from Granite Reef Dam to the Gila River. The City of Tempe eventually assumed a leadership role in promoting the "Rio Salado" project, focusing the scope to cover the portion of the river within the City boundaries.

Today the vision of Rio Salado encompasses an area from McClintock Road to I-10, and includes a variety of commercial, recreational, and residential developments. The focal point of the project is a 200-acre recreational lake which will extend from about 1,500 feet west of Mill Avenue, east to the Indian Bend Wash. "Town Lake" will provide a gathering place for the Valley just as Hayden's Ferry once did near what is now Old Town Tempe.

In undertaking this bold renaissance of the Salt River, the City of Tempe faces the challenges of ensuring a reliable supply of water; creating a major water feature in the riverbed without compromising its flood control capabilities; and avoiding any adverse impacts on area Superfund sites and landfills. Further, the project requires that a high quality, aesthetically pleasing lake be developed and maintained using source water of possibly limited quality, in an extremely adverse environment for such water bodies.

Objectives

The Rio Salado Engineering Feasibility project is one step in the continuing Rio Salado journey. The objectives of the project are to evaluate the engineering feasibility of the major physical facilities needed for the lake and to investigate the available options for supplying Town Lake with water. The project must satisfy a confusing gamut of regulatory requirements and permitting issues.

This Engineering Report summarizes the findings and conclusions of the engineering work completed thus far. This report defines the water demands of the lake (Section 3) and recommends the design of the project's physical facilities (Section 4). It also details the opportunities and constraints for the selection of a source water supply for Town Lake (Sections 5 and 6), and the needs for long-term management of the lake water quality (Section 7).

Implementation of the project requires further predesign and final design investigations as well as agency coordination. As part of this study, preliminary discussions were conducted with the regulatory agencies and a general strategy for negotiating the regulatory maze was developed. Section 8 describes an implementation strategy for the next stages of the Rio Salado design and permitting activities.

Project Documentation

The engineering work performed to meet the project objectives began in February 1991. A series of Technical Memorandums (TMs) was produced documenting the findings of the various work elements. The TMs delivered to the City of Tempe were:

- TM 1 Data Inventory
- TM 2 Permitting Constraints
- TM 3 Water Balances
- TM 4 Salt River Hydraulics
- TM 5 Stormwater Management
- TM 6 Aquifer Storage And Recovery
- TM 7 Surface Water Development
- TM 8 Town Lake Feasibility Study

TMs 1 through 7 were produced only in draft form and were intended to provide preliminary findings to the Rio Salado Technical Committee. A compendium of TMs 1 through 7 was prepared under separate cover. As new and additional information was developed during the course of the work, these TMs were not updated, and therefore may not represent the latest or most accurate information. TM 8 was produced in final form for general use by the City. This TM summarized the findings of the previous TMs and presented new information concerning topics not included in the original project scope but added during the course of the project.

In addition to the TMs, two workshops were held with Tempe staff. At the workshops, the consultant staff presented findings to, and received direction from, the Rio Salado Technical Committee. The results of these workshops and regular project coordination meetings guided the work efforts as the project progressed.

Acknowledgments

This study was prepared by CH2M HILL with guidance and assistance from the City of Tempe Mayor and Council, and the City's Engineering Department staff. In addition, the City's Planning and Redevelopment and Water and Wastewater Department staff provided invaluable assistance. The Rio Salado Technical Committee also provided input and direction throughout the project. Assistance was also provided by the Salt

River Project, Arizona Department of Transportation, Arizona State University, the Bridgestone Engineered Products Company, and Aquatic Dynamics, Inc.

Limitations

The findings and recommendations presented herein are based on information either provided to, or developed by the Consultant for the purposes stated above. The information represents the best available information at the time of the work effort. Ongoing work by the City of Tempe, changes in institutional and regulatory policy, changes in cost or availability of materials, and other factors may impact the accuracy of the information provided. Some of the conclusions of this study are based on limited information and assumptions coordinated with Tempe staff. These assumptions have been identified as such where possible.

Currently the City is pursuing ongoing investigations into the feasibility of surface recharge near the Kyrene WRF, and is developing a comprehensive City-wide water/wastewater master plan. These studies were not complete as of this writing. The results are, therefore, not reflected in this report.

Section 2
Project Design Objectives

The design of Town Lake must consider a wide range of objectives and design criteria. In many cases these objectives are conflicting or competing. For instance, water quality is enhanced with a deeper lake; however, costs are reduced with a lower dam height. The evaluations performed for this study included consideration of many of these criteria and objectives, however the scope of the evaluations was limited to the engineering considerations. Land use, economic impacts, financing, and other related issues have been generally excluded from this study. These issues have, in some instances been incorporated into the evaluation process through input and direction by City of Tempe staff. This section describes some of the more significant objectives used in evaluating project alternatives.

Beneficial Uses

Perhaps the most obvious lake design objective is to maximize the beneficial uses that the lake will support. The most desirable lake design supports the widest range of uses. The potential uses are (listed from most difficult to attain to least):

- Swimming (full body contact)
- Sailboarding (partial body contact)
- Fishing for human consumption
- Boating (incidental contact)
- Catch and release fishing
- Passive recreation (no contact)

The level of use that can be attained depends on several factors. Federal, state, and county agencies such as the Arizona Department of Environmental Quality (ADEQ), and the Maricopa County Health Department (MCHD) each have requirements that impact lake uses. Aesthetic characteristics of the lake will also determine the range of uses. The ability to create and maintain a lake of sufficient water quality to support these uses depends on the quality of the source water and the degree to which the lake water quality is managed. Specific design recommendations will depend on the selected level of use.

Flood Control

The Salt River is the primary conveyance facility for flood water from the Salt River and Verde River watersheds through the Phoenix valley. The design flood for the river in the project area is the 500-year event, about 250,000 cfs. Recently completed and ongoing channelization projects in the area are intended to ensure that the design flood

is safely conveyed through the valley. The Arizona Department of Water Resources (ADWR) and the Flood Control District of Maricopa County (FCDMC) will require that the Rio Salado project not jeopardize the capacity of the river to contain flood water, even in the event of a dam failure.

The Salt River is a complex and dynamic system. Physical changes to one reach of the system invariably affect the rest of the system. The ability of the river to transport sediment is one of the characteristics that must be carefully considered when modifications to the river are proposed. The final project must minimize sediment transport-related impacts to the Salt River system. Specific design criteria for flood control include:

- The capacity of the channel and bridge structures to pass the design event must not be compromised.
- The water surface elevation during a 100-year flood event must not be increased by more than 1 foot.
- The flood wave that would result from a spontaneous failure of the dam must be contained in the channel.
- The single-event general scour downstream of the lake must not significantly increase.
- The equilibrium slopes of the channel must be maintained.

Environmental Impacts

The development of Rio Salado must consider impacts on the local groundwater aquifers. Specifically, the potential impacts to the North and South Indian Bend Wash Superfund sites, and several area landfills must be considered. ADWR and U.S. EPA concerns and regulatory constraints must be incorporated into the design of the project components. Environmental constraints and issues include the Section 404 permit requirements that resulted from the City's Salt River channelization project, NPDES requirements, and other Clean Water Act provisions.

As a primary design objective, the Rio Salado project must attempt to achieve "zero impact" on existing groundwater contamination. This objective is reflected in the recommendation for design criteria that will isolate the lake from the local groundwater system by limiting or controlling seepage from the lake.

To further define specific design recommendations and criteria, specific geotechnical, geophysical, and hydrogeological investigations were performed for this project. These studies provided greater understanding of subsurface conditions and groundwater flow

characteristics. Details of these studies were provided in TM8 and are summarized later in this report. These studies, in addition to recommended predesign investigations and ongoing monitoring programs discussed in later sections, are intended to help meet the objective of "zero impact."

Section 3
Water Demands

The base water demands for the Town Lake are lake evaporation and seepage (infiltration through the bottom and sides of the lake). Additional water demands include irrigation water for landscaping the Rio Salado project developments and creation of artificial wetlands. These additional demands could be met through withdrawal of Town Lake water, if available, but are not considered in the base demand.

Evaporation

Evaporation rates in the Phoenix area are among the highest rates found in the United States. Data on monthly pan evaporation rates for the Phoenix area from 1960 to 1991 reveal strong seasonal fluctuations, with the lowest rates occurring in mid-winter and the highest rates occurring in late spring and early summer. Recent data (1989 through 1991 records) suggest that, due to "heat island" effects, the evaporation rate in Phoenix has been increasing since the mid 1970s.

Evaporation rates are influenced by solar radiation, relative humidity, temperature, wind, atmospheric pressure, and other factors. In general, the smaller and more shallow a body of water, the higher the evaporation rate. Hence, a correlation factor is often used to relate pan and lake evaporation. For this evaluation, lake evaporation is estimated as 70 percent of pan evaporation rates.

Figure 3-1 illustrates monthly evaporation demand estimated for a 200-acre lake. The annual average evaporation demand for the selected lake would be approximately 1.1 million gallons per day (mgd). The monthly rates would vary from 0.4 mgd in December to 1.7 mgd in July.

Seepage Losses

A detailed discussion of the potential loss of water in the subsurface from alternative Town Lake arrangements was presented in the Feasibility Study, TM8. Field programs, including drilling and monitoring of groundwater levels, allowed calculations of potential seepage losses. Based on the work described in TM8, Town Lake configurations without seepage control may be expected to lose an average of approximately 0.2 feet/day per square foot of lake area. The actual seepage range varies depending on the depth of the water in the lake and the location. The rates are lower between about Priest Drive and Mill Avenue and are higher east of Mill Avenue to McClintock Drive. As described in Appendix A of TM8, these estimates are approximate (-50% to +100%) and do not account for reduction over time due to siltation and subsequent clogging. With appropriate seepage control measures, seepage may be reduced to approximately

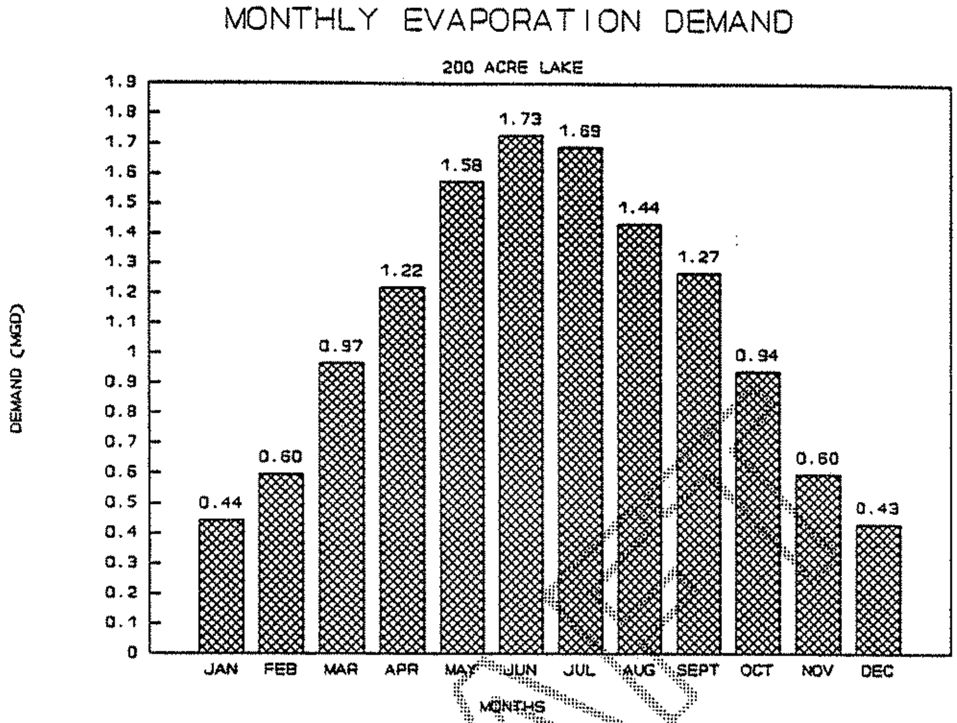


Figure 3-1

0.01 feet/day/per square foot. Three seepage control methods were investigated for this report. Slurry trench cutoff walls, liners, and well recovery systems are described in Section 4. Again, these estimates are approximate, but the lake bed lining systems would be expected to provide the narrowest range in potential seepage by nature of their suitability to a construction standard.

In summary, without seepage control or under conditions of collecting seepage with wells, annual seepage may range in the order-of-magnitude of 16,000 ac-ft (14.1 mgd) for a lake surface area of 200 acres. With effective seepage controls, annual seepage for a 200-acre lake may range in the order-of-magnitude of 400 ac.ft. (0.4 mgd). Actual seepage will vary with clogging and natural variability within the geologic and man-placed materials.

Landscape Irrigation

The demand for landscape irrigation water depends on the size of the area to be irrigated, vegetation type, and method of irrigation. Landscaping plans have not yet been developed, so no site-specific estimates have been made. However, landscape irrigation is an important water demand, and therefore merits consideration. Turf irrigation requires relatively large quantities of water compared to many types of landscape materials and therefore is used as an illustration to provide a conservative estimate for potential landscape irrigation demand.

The annual irrigation requirement for bermuda lawn overseeded with winter rye grass is approximately 6 ac-ft per acre. A bermuda grass lawn that is not overseeded in winter requires approximately 4.5 ac-ft per acre.

The total irrigation requirement per 100 acres of turf is expected to range from 10 ac-ft per month (0.1 mgd) in December to 107 ac-ft per month (1.2 mgd) in July. An estimate of average annual turf irrigation is 600 ac-ft per 100 acres of turf area (0.5 mgd).

An additional landscape-related demand to be considered is the proposed wetlands/expansion area downstream of the lake as described in the *Wildlife Habitat Master Plan* (HNTB, October 1990). This report does not quantify water needs, however based on the acreage of open water, and planting areas, a rough approximation of the average monthly demand ranges from 0.04 mgd in December and January to 0.17 mgd in June and July.

Total Water Demand

The total base demand for source water is the sum of evaporation and seepage demands described above. Figure 3-2 illustrates the relative magnitude of these monthly source water demands for 200-acre lake. The average demand is about 1.5 mgd; the peak month demand is about 2.2 mgd.

These estimates of water demand are approximate and will vary with weather conditions, types and amounts of landscaping, sedimentation and scouring of the lake bottom, seepage control, and lake management practices. For instance, fountains, sprayers, and other aesthetic water features and aeration devices may increase rates of evaporation. Average pan evaporation rates vary by about 15 percent from year to year based on the evaporation data used for this study.

For planning purposes, a safety factor should be added to these estimated demands. Including a safety factor of 50 percent, the average demand is about 2.3 mgd. In a peak month the average demand will increase to 3.3 mgd. When not needed to replace evaporation and seepage, additional available source water could be used to satisfy irrigation needs.

The application of ASR facilities to this project would provide storage capability for responding to seasonal and operational variations on demand. This would allow the lake water source demand to consider only average demand and reduce the need for a safety factor.

TOTAL MONTHLY DEMAND

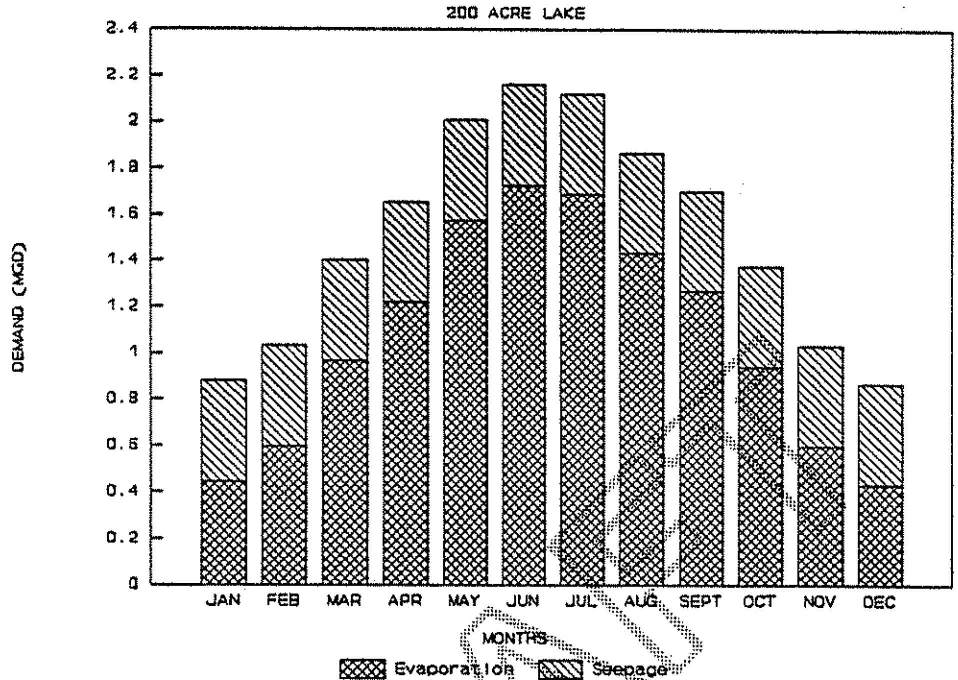


Figure 3-2

Continuing monitoring of the lake's water balance after construction is recommended, and will likely be required as part of an Aquifer Protection Permit (APP). Monitoring of the evaporation rate will require measurement of temperature, humidity, windspeed and direction, and solar radiation. Both standard evaporation pans and floating-type pans should be incorporated into the monitoring program. The floating pans will be more accurate than standard pans, and can be used for a short time to calibrate the standard pan rate for long-term monitoring.

Section 4
Physical Facilities

The physical components of Town Lake include 1) the dams or impoundment structures—the main downstream dam and the upstream dam which will serve to limit the upstream extent of the lake, increase the average depth, and act as retention/detention facilities to intercept urban stormwater runoff; 2) seepage control and lining systems; 3) stormwater bypass and management systems; and, 4) channel bank modifications required to create shoreline, access, boating facilities and other user amenities. In addition, facilities to manage the lake water quality will be required.

This section will summarize the recommendations of the Feasibility Study portion of this project, describe the general design concepts and recommend predesign activities that will further define the design requirements of the facilities. During the Feasibility Study a series of Technical Memorandums were produced (TMs 1 through 8). These documents provided the basic information summarized below. Revisions resulting from new information and additional study are also presented where appropriate.

Impoundment Structures

The most important structural component of the lake is the dam. During the feasibility phase of the project, various dam types were evaluated in detail using specific project criteria, including hydraulic and sediment transport-related flood control impacts, life cycle costs, aesthetics, reliability, safety, and operational flexibility (TM4).

The potential dam and gate alternatives that were considered for the Rio Salado project include three basic configurations:

- Movable gates
- Fixed weirs
- Fuse plugs

The alternatives considered for each basic configuration include tainter gates; bascule or bottom-hinged leaf gates; inflatable dams, both water- and air-filled; ogee crest weirs; labyrinth weirs; and fuse plug configurations with sections set at different blowout elevations and with mechanical gates for passing lower, more frequent flows.

Several alternatives were eliminated after preliminary evaluation. Tainter gates did not meet flood control criteria. Water-filled inflatable dams were eliminated from further consideration for safety and operational constraints. Labyrinth weirs were eliminated because of hydraulic and sediment transport constraints.

Based on the findings of the detailed evaluations, three alternatives were presented to the Rio Salado advisory committee. These alternatives were:

- Air-inflatable rubber dam
- Combination bascule (leaf gate) and multiple fuse plug
- Side channel weir

Following consideration by the committee, a 16-foot-high air-inflatable rubber dam was selected. The dam was evaluated assuming it consisted of four 210-foot-long dam segments, with three intermediate piers. Each pier would be 18 feet high, with a 5-foot top width and 1:1 side slopes. In addition to the main impoundment dam, similar dams were recommended at the upstream end of the lake to act as stormwater retention structures and limit the lake area and depth. The inflatable dam configurations are shown schematically in Figure 4-1. Each dam segment should be independently operable to allow flexibility for low flow and sediment passage, and to be able to exercise each segment for maintenance checks. One of the manufacturers of air-inflatable dams claims that the dam could be overtopped by about 6 feet without inducing instability.

Some of the key advantages and disadvantages of the air-inflatable dam relative to fixed weir and fuse plug options are outlined below.

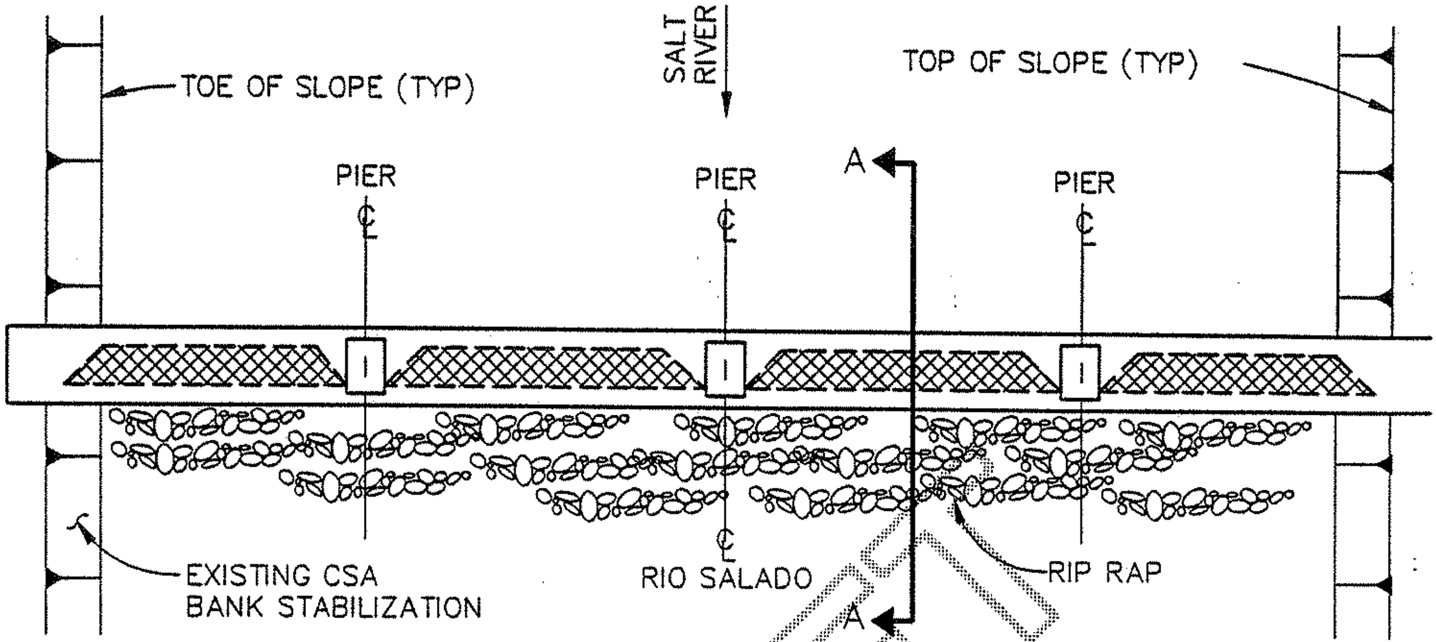
Advantages

- Dam should perform well during anticipated flood events
- Dam backwater effects are minimal
- Construction and design is not complex because:
  - Long spans require fewer piers
  - Suitable foundation conditions exist
- Operations and maintenance is less complicated because:
  - Dam deflates without electrical power
  - Rubber material withstands sand erosion in high velocity flooding
  - Less sediment trapped by dam

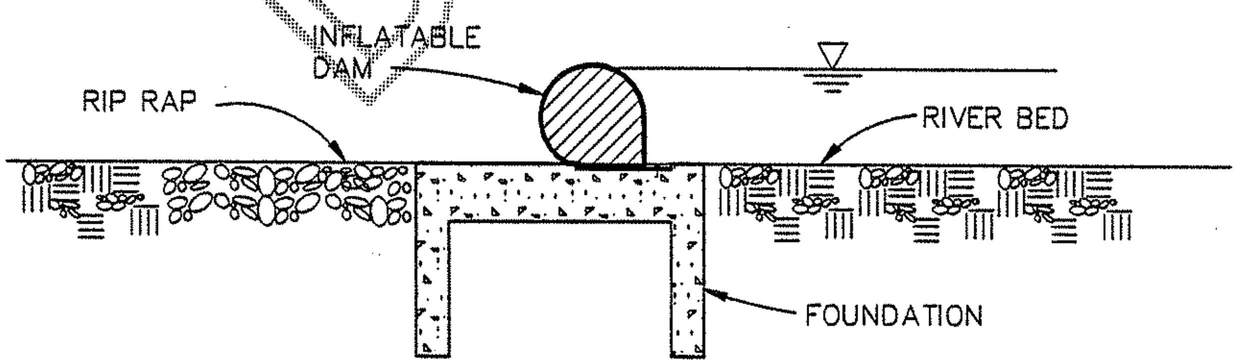
Disadvantages

- Long material delivery time
- Untested design parameters, including:
  - Dam height exceeds tallest U.S. installation
  - Design life of rubber bag is unproven
  - Some potential for vandalism
- Manufacturers/suppliers are limited

As currently proposed the project includes a downstream 16-foot-high inflatable rubber dam constructed near the existing soil cement grade control structure between Priest Road and Mill Avenue and three inflatable dams upstream connected by concrete



PLAN
NTS



SECTION A-A
NTS

FIGURE 4-1
INFLATABLE DAM DETAIL

floodwalls at the confluence of Indian Bend Wash (IBW) and the Salt River (see Figure 4-2).

Impoundment Dam Instrumentation and Control

To preserve the flood control function of the Salt River channelization, the impoundment dams must offer flexible and reliable means of deflation and provide the minimum possible obstruction to flood flows. Both manual and automatic inflation/deflation controls may be installed. A typical installation may include several independent automated safety systems such as:

- A Programmable Logic Controller (PLC) operated valve system to maintain the water and pressure levels for preselected operating conditions. This system may be configured to interface with SRP and FCDMC ALERT or SCADA telemetry systems.
- A water elevation actuated valve controlled by a device such as a float/counterweight or pressure transducer to deflate the dam in the case of high upstream water surface.
- Rupture disks to safeguard against overinflation.

Depending on the degree of control, redundancy, and operational criteria desired, each of the rubber dam sections or bags can be independently plumbed and controlled. The conceptual design recommendation of the Bridgestone Engineered Products Company, a vendor of inflatable dams, included at a minimum, a single 900 CFM blower with 6-inch piping for the downstream dam. They indicated that resultant inflation and deflation times of 86 and 40 minutes respectively could be expected.

For safety and redundancy, at least two blowers should be installed at each dam location and each bag should be independently plumbed and controlled. The selection and final design of the systems should be coordinated with SRP, ADWR, and FCDMC.

Impoundment Dam Predesign Activities

Prior to finalizing the design of the impoundments, several pre-design investigations are recommended to confirm or modify the criteria and assumptions used for this concept design. These activities include both geotechnical and hydraulic investigations.

Geotechnical Investigations

The main dam location is near a cement stabilized alluvium (CSA) grade control structure. This structure may be incorporated into the dam foundation. Geotechnical evaluations are recommended to assess the foundation requirements for each dam and the characteristics of the grade control structure. In addition, the capability of the

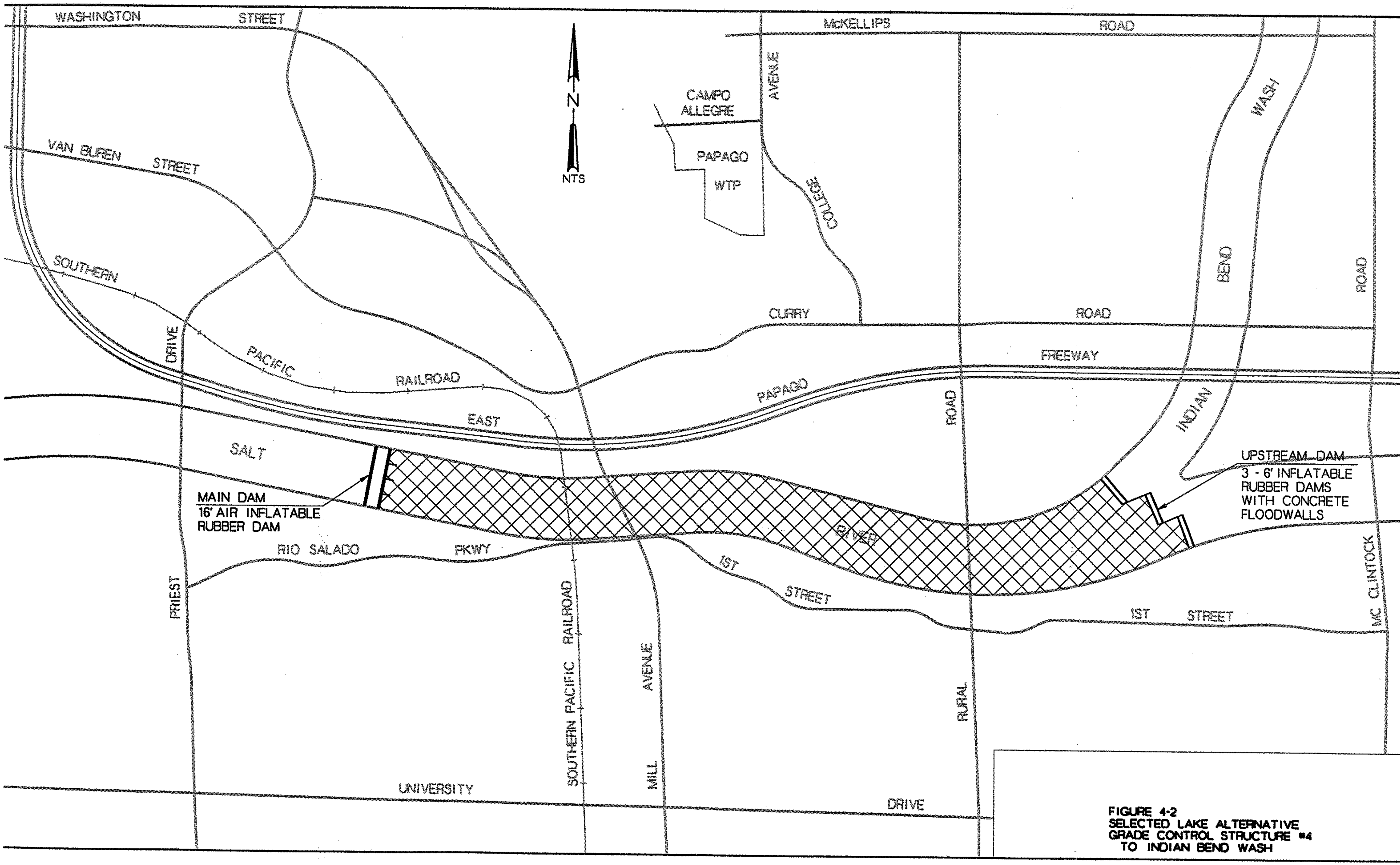


FIGURE 4-2
SELECTED LAKE ALTERNATIVE
GRADE CONTROL STRUCTURE #4
TO INDIAN BEND WASH

newly constructed bank protection to withstand rapid drawdown conditions should be confirmed. Specific activities include:

- Review ADOT data from construction of the soil cement grade control structure including as-built plans, geotechnical report, construction records, and photos taken during construction.

- Drill core holes through the grade control structure to obtain information on the structure, the rock below the structure, and the interface between the structure and the rock.

- Drill soil borings and rock cores along the proposed upstream and downstream dams. For preliminary design 8 borings are recommended; 4 at the downstream dam and 4 at the upstream dam. Borings or rock cores should be extended a minimum of 10 feet into competent bearing material.

- Perform laboratory testing of samples collected during soil borings and rock coring. Testing will be performed for geotechnical parameters required for preliminary design of the dam foundation and abutments.

- Perform a preliminary analysis of the dam's foundation system and abutments. The preliminary analysis will include evaluation of the proposed foundation systems for bearing capacity, settlement, lateral loading resistance, lateral stability, uplift pressures, and seepage.

Hydraulic Investigations

The primary purpose of the channelization of the Salt River is to provide flood control. Prior to final design, a detailed hydraulic analysis of the Salt River from I-17 to Price Road should be prepared that reflects the final dam and bank configuration. A sediment routing/scour analysis of the same reach should be included. In addition a dynamic model simulating the rapid deflation of the dams may be required by ADWR Division of Dam Safety.

Impoundment Dam Costs

The contingencies for the dams are based on estimates provided by Bridgestone Company, a supplier of air-inflatable rubber dams. Detailed cost information provided in TM4 and TM8 was updated to incorporate the additional cost of the upstream dam configuration proposed by Tempe staff. The results are summarized in Table 4-1 below.

Table 4-1 Impoundment Cost Opinion	
16-foot inflatable rubber dam (downstream)	$6,880,000
6-foot inflatable rubber dam (upstream)	4,260,000
Foundation and upstream floodwall	720,000
TOTAL	$11,780,000

Seepage Control

To reduce seepage from the lake, three general methods were considered:

- Lining the lake, thus reducing seepage through the bottom and sides of the lake.
- Constructing cutoff walls along the lake boundary, thus reducing the seepage through the aquifer beneath the lake.
- Collecting the seepage with wells.

These methods are discussed in the following paragraphs.

Linings

There are many alternatives for lining materials, including those constructed in place such as compacted clay, soil cement, or asphalt, and those manufactured offsite such as PVC and geosynthetic clay. The differences between these types are the cost, ease of installation, hydraulic consistency of the finished liner, and resistance to scour. All of these factors will need to be evaluated during final design. For example, to prevent damage to the lining during river flows, the liner could be placed below the anticipated scour depth and covered with the channel bed material. A less expensive, less scour resistant lining should be compared to a more expensive, scour resistant lining that would not need to be buried as deep. For purposes of evaluation, a buried depth of 3 feet is assumed. Consideration should also be given to placing a scour-resistant lining near places of potentially high scour such as grade control structures, bridge piers and dams, and a less scour-resistant material at other locations.

A description of several lining options and design considerations follows. Typical permeabilities are shown in units of centimeters per second (cm/s) for comparison. Resultant losses for various lake configurations were estimated and are presented in a later section.

Compacted Clay Lining

Compacted clay lining should consist of approximately 1 to 2 feet of compacted clay imported to the site. The clay would be placed in thin lifts and compacted with several passes of equipment to achieve a consistent low permeability lining. The clay lining should be protected from scour and will require continuous watering during construction and when the lake is empty to prevent cracking and desiccation of the clay. A volume of in-situ channel material equal to the volume of clay would be removed to maintain the channel profile. Despite significant labor cost for installation, a clay lining could be the least expensive alternative if a nearby source of material is available.

Geosynthetic Clay Lining

A geosynthetic clay lining is a layer of bentonite clay between two geotextile membranes. The material is manufactured offsite and shipped in rolls. The material is installed by unrolling it on the prepared surface. Seams require overlapping. The resulting lining could be more consistent than a constructed-in-place lining with permeabilities on the order of 10^{-8} cm/s. A disadvantage of the geosynthetic clay lining is because it is thin, it could more easily be damaged by scour than the compacted clay.

PVC Lining

The PVC lining is similar to the geosynthetic clay lining in that it would arrive onsite in rolls, be unrolled on a prepared surface, and overlapped. The difference is that the overlaps of PVC lining must be cemented together. The PVC lining would require a geotextile over the top to protect the lining from scour similar to the compacted or synthetic clay. The cost of a PVC lining is similar to the geosynthetic clay lining.

Soil Cement and Polymer Asphalt

Other constructed-in-place lining alternatives are soil cement and polymer asphalt. The soil cement is a mixture of the river sands and gravels, cement and water with less cement and water than typical concrete. The material would be placed and compacted similar to the compacted clay liner. Permeabilities of less than 10^{-5} cm/s can be expected with additives to prevent cracking. The polymer asphalt is constructed using paving equipment similar to that used for construction of an asphalt roadway. Polymers are added to reduce the permeabilities of the lining. Permeabilities of less than 10^{-9} cm/s have been reported with this type lining. Both the soil cement and polymer asphalt linings would have greater scour resistance than the clay or PVC linings and would require less scour protection.

A typical section for liner placed beneath the channel bed is shown in Figure 4-3.

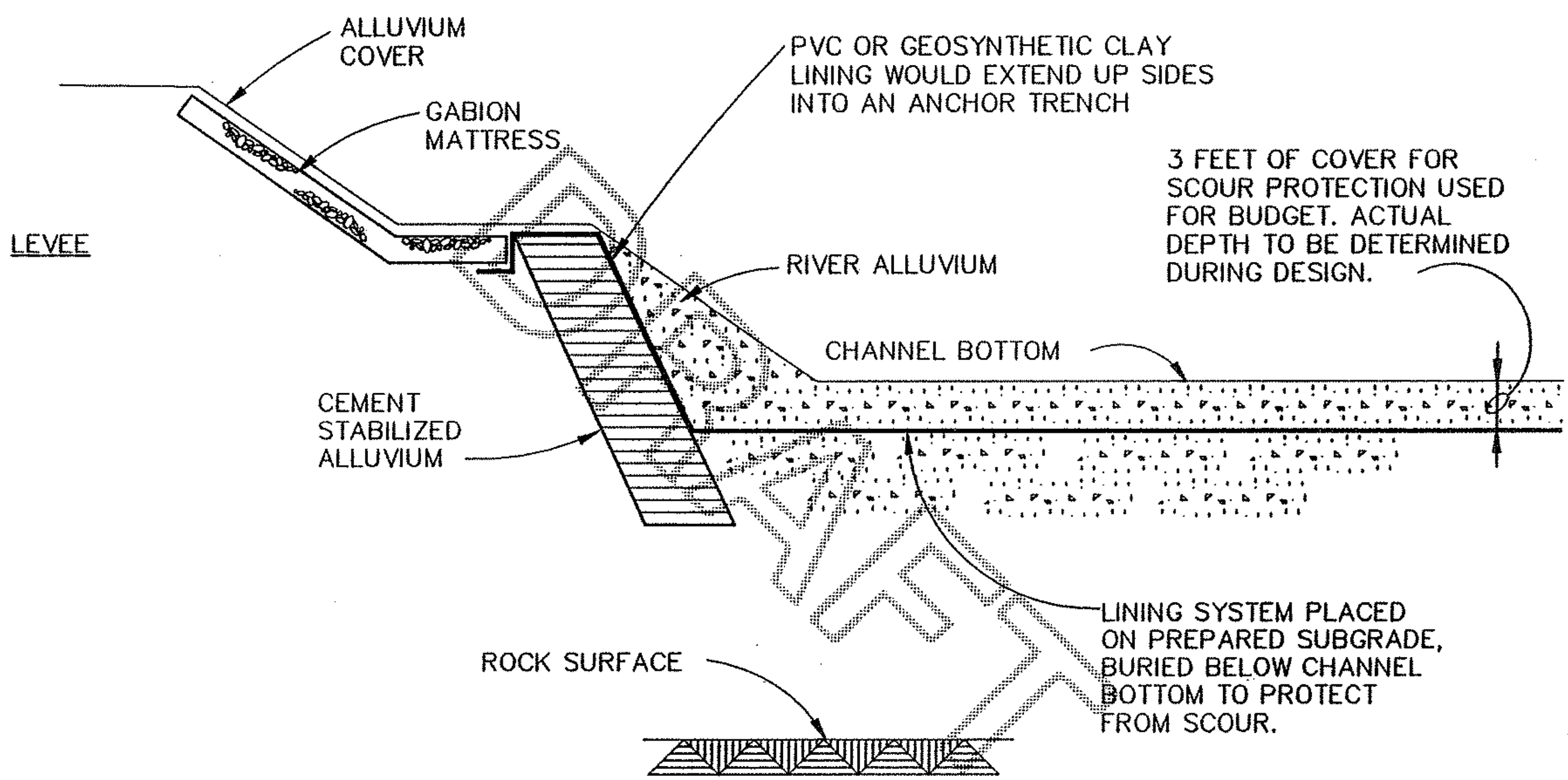


FIGURE 4-3
CONCEPTUAL LAKE LINER DETAIL

Cutoff Walls

A cutoff wall involves the construction of a low-permeability, below-grade wall along the north and south sides of the lake. The most effective cutoff wall is a full cutoff of the aquifer beneath the site which would extend from the bottom of the cement stabilized alluvium (CSA) to rock or some other low permeability contact. Partial cutoff walls, extending only part-way to rock would also reduce the seepage rate by reducing the available area for the water to flow. Past experiments (USBR, 1977) have shown that a partial cutoff wall, extending 50 percent of the depth to rock may reduce seepage 25 percent; a cutoff wall extending 80 percent of the depth to rock may reduce seepage by 50 percent.

Under some lake configurations, the high water level will be above the CSA. To reduce the seepage rate through the gabions at the sides of the lake, the gabions above the CSA should be grouted. During pre-design, the effects of rapid drawdown (lowering the water level) in the lake on the stability of the levees should be analyzed.

There are various methods of constructing cutoff walls including cutoff trenches, sheet piling, mixed-in-place concrete pile curtains, slurry walls, and grouting of alluvium. Based on available subsurface information, the slurry wall method appears to be the most appropriate and cost-effective method for the Rio Salado site.

The slurry wall method is illustrated in Figure 4-4. This technique uses a water-bentonite mixture to support the sides of a trench. The trench is excavated by a backhoe with the excavated material placed beside the trench. Backfill material, typically a well-graded sand and gravel is mixed with bentonite and placed in the trench. The backfill displaces the slurry and forms a low permeability barrier. Permeabilities of less than 10^{-6} cm/s are typical for slurry walls. A practical depth limit is 60 feet below the ground surface for slurry walls constructed with a backhoe. Greater depth walls can be constructed by using specialized equipment.

The cost of the slurry wall depends on the amount of slurry needed to fill unforeseen large voids, caving of trench wall, the occurrence of large boulders, and the general nature of the material available for backfill. At the Rio Salado site some slurry loss and caving of the trench wall should be expected. A large percentage of the excavated material is probably suitable for backfill after the larger cobbles and boulders are removed.

Well Recovery

Well recovery is a third option for controlling seepage losses from Town Lake. A preliminary recovery design consists of 10 wells situated around the perimeter of the lake. Each well captures a portion of the seepage flow, and discharges it back to the lake (Figure 4-5). One variation of this scheme is to collect the seepage in a network of pipes and deliver the combined flow to Tempe's Papago Water Treatment Plant.

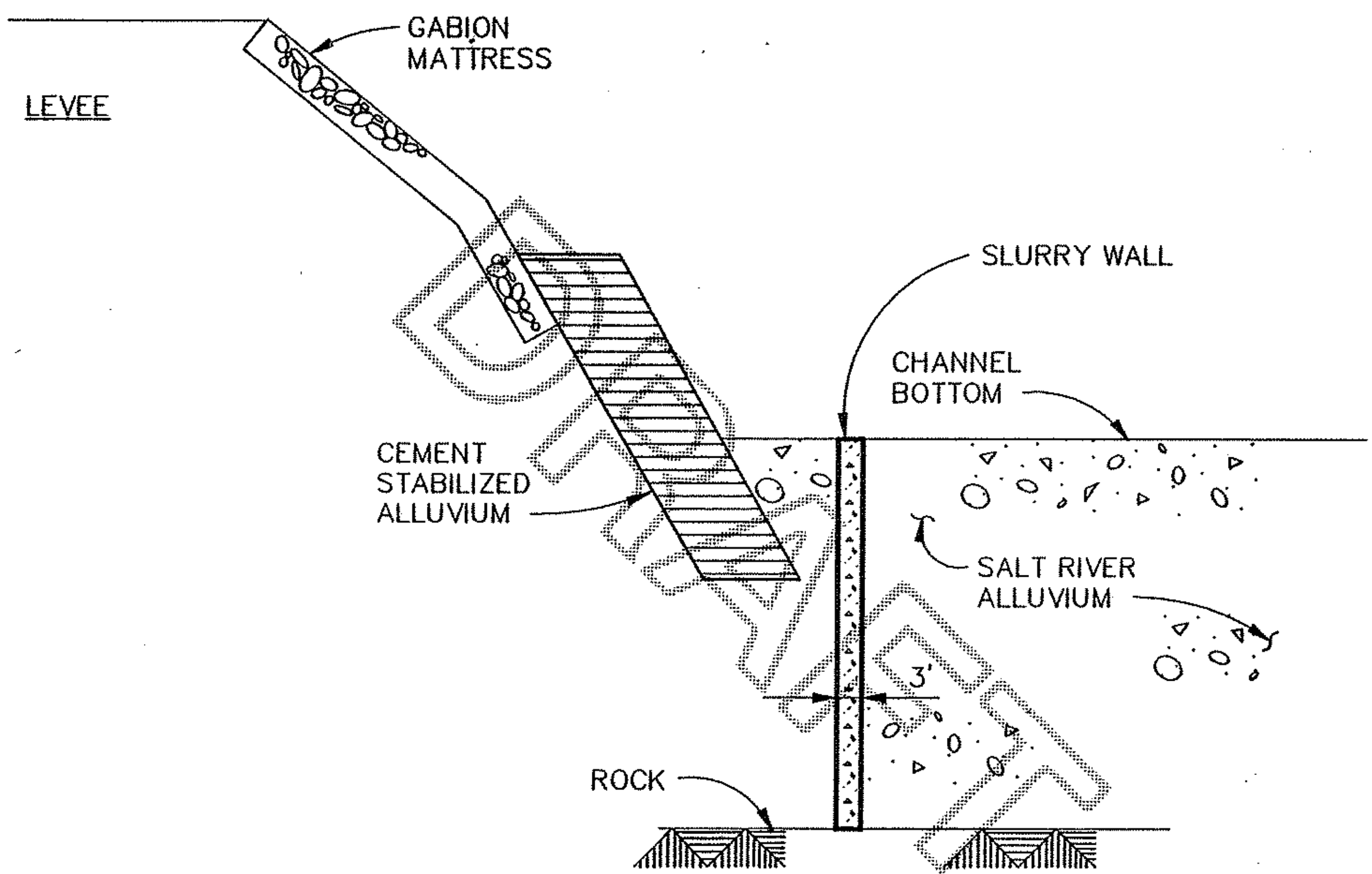


FIGURE 4-4
SLURRY CUT-OFF WALL

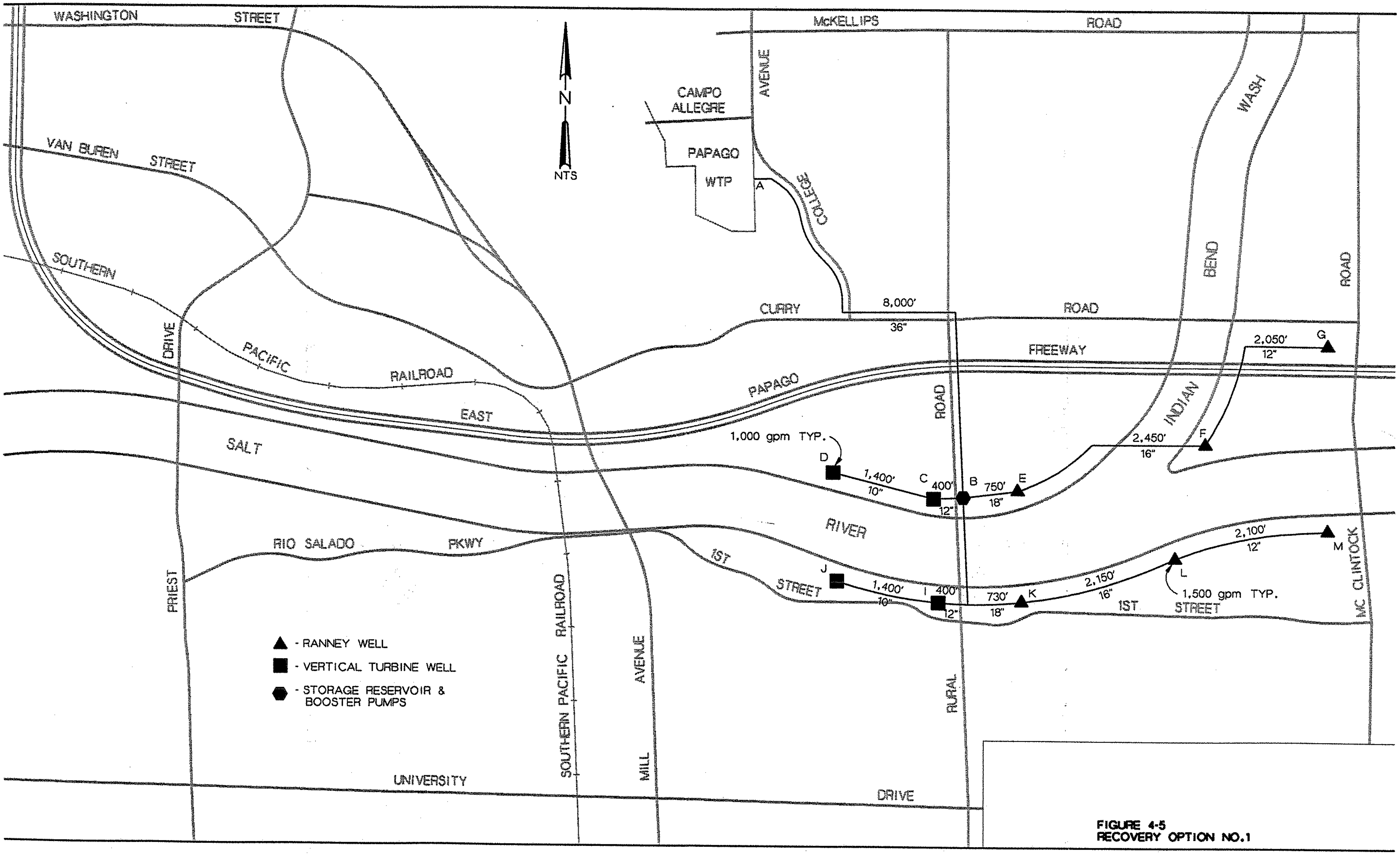


FIGURE 4-5
RECOVERY OPTION NO.1

From the treatment plant, the water would be distributed for potable use.

Two types of wells are used for the recovery system. "Ranney" wells (Figure 4-6) can be installed west of Rural Road, where the depth of the wells are constrained by shallow bedrock. Ranney wells are constructed with horizontal casings placed radially from a central pumping facility. Conventional vertical turbine wells are planned east of Rural Road where depth to hardrock permits deeper well construction.

Preliminary estimates of well yields indicate that four Ranney wells pumping at 1,000 gpm, and six vertical wells pumping at 1,500 gpm, may be sufficient to capture the infiltration losses. Additional hydraulic testing is required during preliminary design to refine the estimates of required well yield.

Figure 4-7 is a schematic diagram of a typical well installation, discharging directly to the lake. A conceptual cost estimate for the 10-well recovery system is $2.61 million dollars plus approximately $200,000 per year to operate.

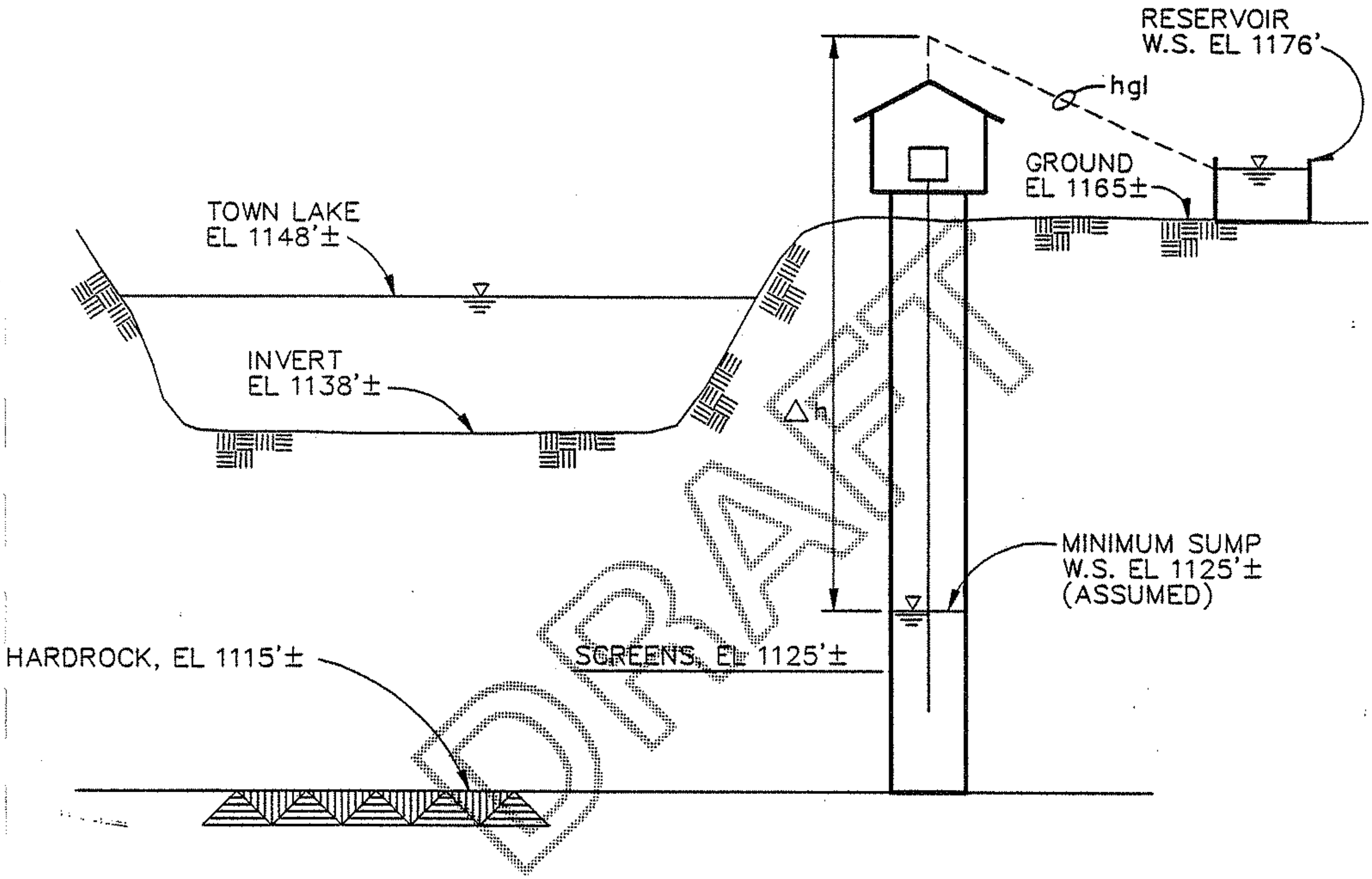
Alternatively, a pipe network ranging in size from 10 inches to 36 inches in diameter may be used to collect the well flow and convey it Tempe's Papago Water Treatment Plant north of the river. Figure 4-8 shows this concept. The estimated cost of the collection and conveyance system is $5.48 million dollars plus $170,000 per year to operate. While this well recovery alternative requires significantly less capital cost, the O&M costs are substantial. In addition, pumped recovery of seepage does not clearly meet the design objectives of isolating the lake from the local aquifer. APP permitting would be much more demanding and ongoing monitoring requirements would be significant by greater than required for a cutoff/liner system.

Seepage Control Predesign Activities

Hydrogeologic Investigations

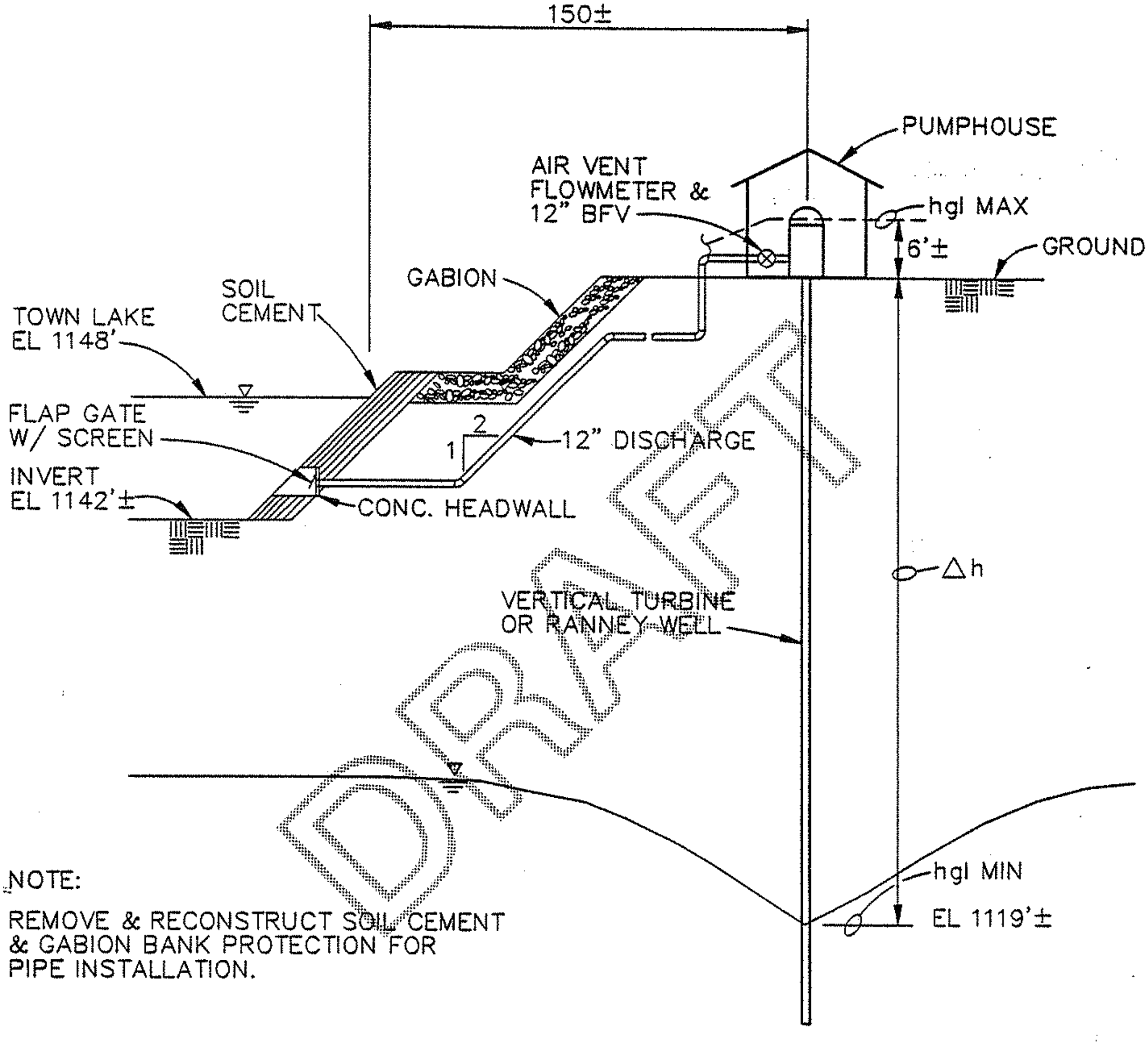
The choices between the seepage control options depend strongly on the distribution of hydraulic conductivity of materials beneath the lake. The current interpretation is that granite and sandstone materials of low hydraulic conductivity are present at depths of less than 40 feet in the area between Priest Drive and Mill Avenue. These conditions appear to make this area favorable for cut-off walls, if needed, and unfavorable for wells.

Of particular importance is the extent and hydraulic conductivity of breccia materials at depths of 35 to 100 feet in the area between Mill Avenue and McClintock Road (TM8). These materials may not extend east of Rural Road but could extend to the half-way point between Rural and McClintock Roads where Indian Bend Wash enters the Salt River. If these breccia materials have high hydraulic conductivity, they would make cut-off walls ineffective, but may allow for effective vertical wells. Thus, the parameters needed to evaluate the effectiveness of cut-off walls (extent and hydraulic



RANNEY WELLS

FIGURE 4-6
RANNEY WELLS

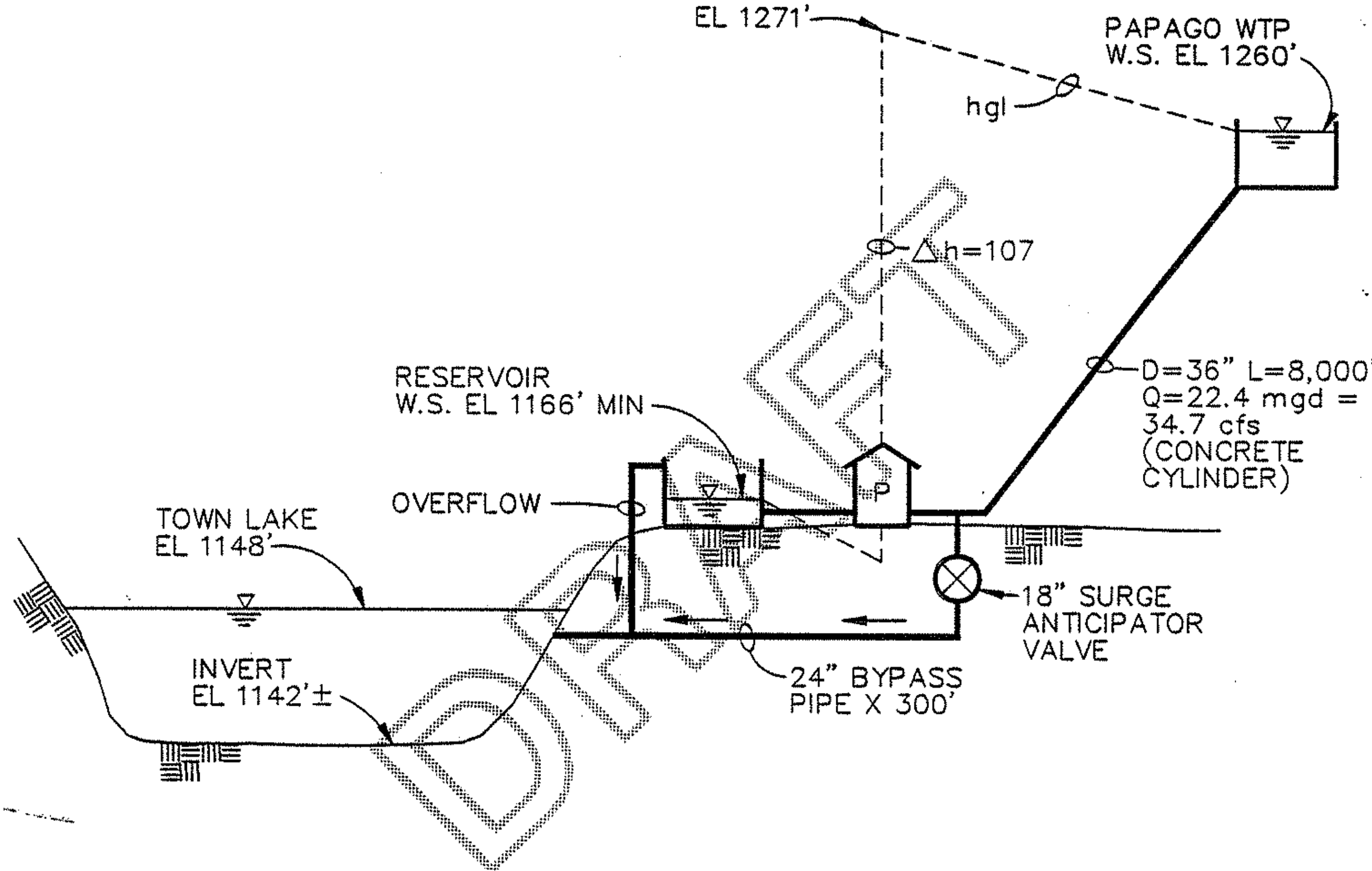


NOTE:

REMOVE & RECONSTRUCT SOIL CEMENT & GABION BANK PROTECTION FOR PIPE INSTALLATION.

RECOVERY ORTION NO. 2

FIGURE 4-7
RECOVERY OPTION NO. 2



LAKE TO WTP RESERVOIR & PUMPS

FIGURE 4-8
LAKE TO WTP RESERVOIR
AND PUMPS

conductivity of the breccia materials) are the same as those needed to evaluate the effectiveness of vertical wells.

Testing of hydraulic conductivity will be needed for predesign as well as for permitting (unless the bed liner option is chosen) for the area east of Mill Avenue. The extent of the breccia materials can be investigated with dual-wall drilling as was done in Phase II with the addition of continuous coring in selected boreholes. Testing of hydraulic conductivity can be reliably accomplished with pumping tests. The following predesign investigations are necessary to further evaluate the pumped system of seepage control:

- Drill boreholes and install 2-inch blank and steel casing at 17 sites. These sites will primarily be in the riverbed between Mill Avenue and McClintock Road.

- Install and pump five test wells in the breccia materials. During installation, continuous wireline core will be collected from three of the test well boreholes to depths of 200 feet. Coring will allow identification of the breccia materials as opposed to alluvial sand and clay fill of younger geologic materials. This evaluation was not conclusive based on drill cuttings alone from the Phase II drilling. Five 100-foot deep test wells should be installed with 8-inch steel blank and slotted casing. Each of the wells should be located adjacent to existing 2-inch piezometers and pumped at rates between 50 and 100 gallons per minute for either 12 or 24 hours. Water levels will be measured in selected wells during the pumping period for each well and also during an equal amount of time of recovery for each well. Four of the tests should include 12 hours pumping and 12 hours recovery, and 1 test should include 24 hours pumping and 24 hours recovery. Water pumped during the tests will be conveyed away from the pumping sites.

The data from this work will be used to:

- Resolve uncertainty about the character of the breccia materials as opposed to younger alluvial clay and sand materials.

- Refine the maps of extent of the breccia materials.

- Estimate hydraulic conductivity of the breccia materials.

Based on the above interpretations, groundwater model simulations will be conducted to refine estimates of lake seepage losses under conditions of cut-off walls or vertical wells and Ranney collector wells. The cost-effectiveness of each seepage control option can then be determined and compared to the cost of bed lining which has been assumed to be effective at seepage control.

The data collected in this work and the interpretations derived from the groundwater model simulations will provide the basis for predesign. Data from the two previous phases of work would also be incorporated.

Geotechnical Investigations

In addition to the hydrogeologic investigations described above, several specific geotechnical activities are recommended. These activities would provide detailed information on the characteristics of the river bed and banks. The results of these investigations will provide the data needed for final design of the seepage control structures. Specific activities are described for both cut-off walls and lake liners.

Slurry Cut-off Walls

- Review ADOT data from construction of river channel bank protection including as-built plans, geotechnical report, construction records, and photos taken during construction.
- Evaluate stability and seepage characteristics of the cement stabilized alluvium and the gabion mattress bank protection under different lake conditions.
- Excavate pits near the slurry wall alignment. The purpose of the test pits is to determine the construction excavation requirements for the slurry wall and obtain material samples for testing.
- Perform laboratory testing of recovered soil samples required for design of the slurry wall including grain size analysis, clay content, moisture content, and atterberg limits.
- Drill 5 to 10 cores through the cement stabilized alluvium bank protection to perform permeability test and evaluate seepage and strength characteristics.
- Explore area commercial, private, and City-owned borrow sources for fine-grained materials to include in the slurry mix.
- Perform slurry mix design tests using the material proposed for slurry wall construction.

Lake Lining

- Review ADOT data from construction of river channel bank protection including as-built plans, geotechnical report, construction records, and photos taken during construction.

- Explore area commercial, private and city-owned borrow sources for suitable low permeability material for lining and lining cushion sand.

- Perform a detailed evaluation of proposed lining systems alternatives. The evaluation will include degree of seepage control provided, material availability, cost, constructability, expected design life, and appearance. Preliminary construction details will be developed for the recommended alternative.

Seepage Control Costs

Detailed cost information for liners and cutoff walls was presented in TM8. Table 4-2 below summarizes that information and includes the well options presented earlier in this section.

Table 4-2
Seepage Control Costs

	Capitol Cost	Annual Cost
Slurry Wall/Liner Combination	$14,300,000	
Well Collection—Lake Return	2,610,000	200,000
Well Collection—Papago Delivery	7,130,000	370,000

Stormwater Management

Stormwater represents both a potential resource and a potential threat to the Rio Salado project. Stormwater is a source of additional water to the lake, but pollutant loads carried in runoff discharges may result in adverse lake water quality impacts. The implementation of stormwater management practices can enhance the resource value of runoff discharges while minimizing potential impacts to lake water quality.

As expected for a desert environment, the average storm volume, intensity, and annual number of storms in Phoenix are low compared to other parts of the nation. The average storm produces 0.42 inches of rain over 8.1 hours. In addition, the time between storm events is long, averaging 579 hours, or just over 24 days. Rainfall occurs 1.4 percent of all hours in Phoenix, based on the average storm duration and time between storms.

The major sources of urban stormwater that affect the Rio Salado site include:

- Indian Bend Wash
- Price Road Drain
- Tempe/Scottsdale

- Mesa
- Salt River Pima-Maricopa Indian Community

The two largest watersheds are Indian Bend Wash and the Price Road Drain. Indian Bend Wash drains a major portion of Scottsdale north of the Rio Salado site, while the Price Road Drain conveys stormwater from much of Mesa, Chandler, and Gilbert, south of the Salt River. In addition, 14 existing stormdrain outfalls have been located that discharge into the Salt River in the reach proposed for Town Lake.

Stormwater Quality

During the initial phase of the Rio Salado project, local data on stormwater quality from urban areas were obtained from the City of Tempe, the Arizona Department of Transportation (ADOT), the Flood Control District of Maricopa County (FCDMC), and the City of Mesa. The data are from grab samples collected during wet and dry weather conditions and from the Price Road Tunnel. In all, data from 111 samples were provided from 23 sites. Data from FCDMC included 6 wet-weather samples from 5 sites and 16 dry-weather samples from 6 sites. One dry-weather sample was provided by the City of Mesa. Subsequent to that TM additional samples of water were provided by Tempe staff for outfalls in the project area.

These data indicate that local wet-weather samples contain higher levels of total suspended solids, biological oxygen demand, organic nitrogen, nitrate, ortho-phosphorous, and copper, compared to median urban data reported by the EPA. The local wet-weather samples contain lower concentrations of lead and zinc, and nearly equal concentrations of total phosphorous compared to median urban data.

The pollutant concentrations from the dry-weather samples were typically lower than the wet-weather and tunnel samples. The data appear to indicate that dry-weather flows contribute a much smaller pollutant load compared to wet-weather flows. The data also suggest that detention storage in the Price Road Tunnel may provide some pollutant removal, especially for heavy metals. Copper, lead, and zinc concentrations from tunnel samples were below detection limits in dry-weather samples. One grab sample taken from the Price Road Tunnel, however, showed extremely high fecal coliform concentration, exceeding 90,000 CFU/100 ml. This sample may indicate high variability of stormwater quality from individual sources.

Stormwater Management Options

A range of stormwater management options were evaluated in TM5. The options included wet detention ponds, dry retention ponds, and bypass and diversion devices. Five alternatives were recommended for further consideration, as described below.

Alternative 1—No Action. Under this scenario, existing stormwater outfalls will continue to discharge directly to the Salt River Channel.

Alternative 2—Pump from the Price Road Drain. The Price Road Tunnel is an 18-foot-diameter inverted siphon located adjacent to Price Road. Discharges from this tunnel may pose a significant threat to the lake water quality during high flows. Two pumps with a combined capacity of 10 cfs have been installed in a permanent concrete structure near 5th Street and Price Road in Tempe. The pumps are currently used by ADOT to periodically drain the tunnel for maintenance and inspection. The pumps discharge stormwater into an existing 72-inch Tempe storm drain beneath the Price Frontage Road. The storm drain outfalls at the Salt River channel.

The affect of dewatering the Price Road Tunnel is to reduce the average annual quantity of stormwater to the Rio Salado site by approximately 8 percent, and the pollutant load from the source by about 45 percent. Alternative 2 would have an inconsequential effect on the average annual flow-weighted concentration of pollutants from all sources, but would reduce the single event loading from large events.

Alternative 3—Alternative 2 Plus an Upstream Dam and Retention Pond. The construction of an upstream dam and retention basin at the east end of the Rio Salado site would be beneficial for stormwater management. The dam could be used to impound or divert stormwater flows in the Salt River channel, including runoff originating from Indian Bend Wash, Price Road, Mesa, and the Salt River Pima-Maricopa Indian Community (SRPMIC).

Much of the pollutant load in urban stormwater is bound to sediment particles. Providing even small volumes of detention storage may, through settling, reduce pollutant loads downstream. A 5-foot dam would impound approximately 290 acre-feet of stormwater based on the width and slope of proposed channel improvements. The basin would remove roughly 80 percent of the pollutant loads from upstream sources, and reduce the average stormwater input to Rio Salado by approximately 28 percent.

Alternative 4—Alternative 3 Plus a South Bank Bypass. Alternative 4 includes the improvements discussed in previous alternatives, plus a bypass system to intercept and divert a portion of the water in Tempe's existing storm drains along the south side of the Salt River. A bypass system with a design capacity of twice the "average" storm would remove about 80 percent of the annual pollutant load. On that basis, a system for bypassing Tempe's existing outfalls requires a capacity of about 200 cubic feet per second (cfs).

Alternative 5—High Capacity Bypass. Alternative 5 is similar to Alternative 4. In this alternative, bypass pipe is constructed adjacent to the south hard bank to intercept and divert stormwater discharges around the lake. Alternative 5, however, includes a diversion/inlet structure behind the upstream dam to divert and bypass stormwater flows from the Salt River. Alternative 5 provides the greatest flexibility and control over stormwater input to the lake, at the highest cost.

Recommended Stormwater Management Alternative

Based on the selected location of Town Lake and information obtained subsequent to the completion of TM5, refinements to the original south bank bypass alternative (Alternative 4) were investigated and are presented in this section. The refinements include modifications to the south bypass concept, improvements to Dorsey and Miller outfalls near the upstream dam at Indian Bend Wash, and options for monitoring and/or mitigating discharges from the Papago Freeway (currently under construction). Figure 4-9 is a sketch of the existing and proposed stormwater features including the names, locations, and sizes of the affected outfalls. This figure was developed from Tempe drainage maps, CRSS channelization drawings, discussions with Tempe staff, and site reconnaissance.

South Bank Bypass

A modified south bank bypass pipe is one option for intercepting and diverting discharges from south Tempe. The modified bypass extends from Rural Road to Grade Control Structure 4, collecting discharges from four existing outfalls: Farmer (72"), Ash (54"), Mill S. (24"), and Rural S. (66"). The bypass is approximately 6,700 feet long, assuming it is parallel and adjacent to the existing south bank improvements.

The bypass is designed to intercept the full design discharges from Farmer and Ash drains to avoid hydraulic grade conflicts near their outfalls. Examination of as-built drawings and discussions with Tempe engineering staff indicate that a proposed lake elevation of 1148.5 will submerge the Farmer and Ash outfalls, existing manholes on the outfalls, and existing and proposed street drains from Rio Salado Parkway, between Hardy Drive and College Avenue. The bypass extends east from Ash Avenue to Rural Road, diverting discharges from Mill South and Rural South outfalls. Diverting discharges equivalent to twice the average storm runoff will reduce the average pollutant load to the lake by about 80 percent as discussed in TM5.

The size of the proposed south bank bypass is based on estimates of storm discharges from south Tempe. Data relative to the actual and/or design discharges were not available, so discharges were estimated from outfall design drawings and statistical hydrology data presented in TM5. The capacities of Farmer and Ash drains are estimated at 355 and 195 cfs, respectively, assuming a full-flowing pipe. Bypass flow rates (twice the average storm discharge) from the Mill South and Rural South outfalls have been estimated at 6 cfs and 47 cfs, respectively. The bypass flow rates are based on an estimated average storm runoff of 97 cfs from south Tempe (TM5), distributed by area among all outfall pipes.

The capacity of the bypass is also a function of its slope. Tabulated pipe sizes, below, assume a profile grade of 0.00146 ft/ft, which is equivalent to the slope of the river channel and slopes dictated by elevations of the existing outfalls. Neither the actual ground surface profile, nor the presence of conflicting structures, utilities, easements,

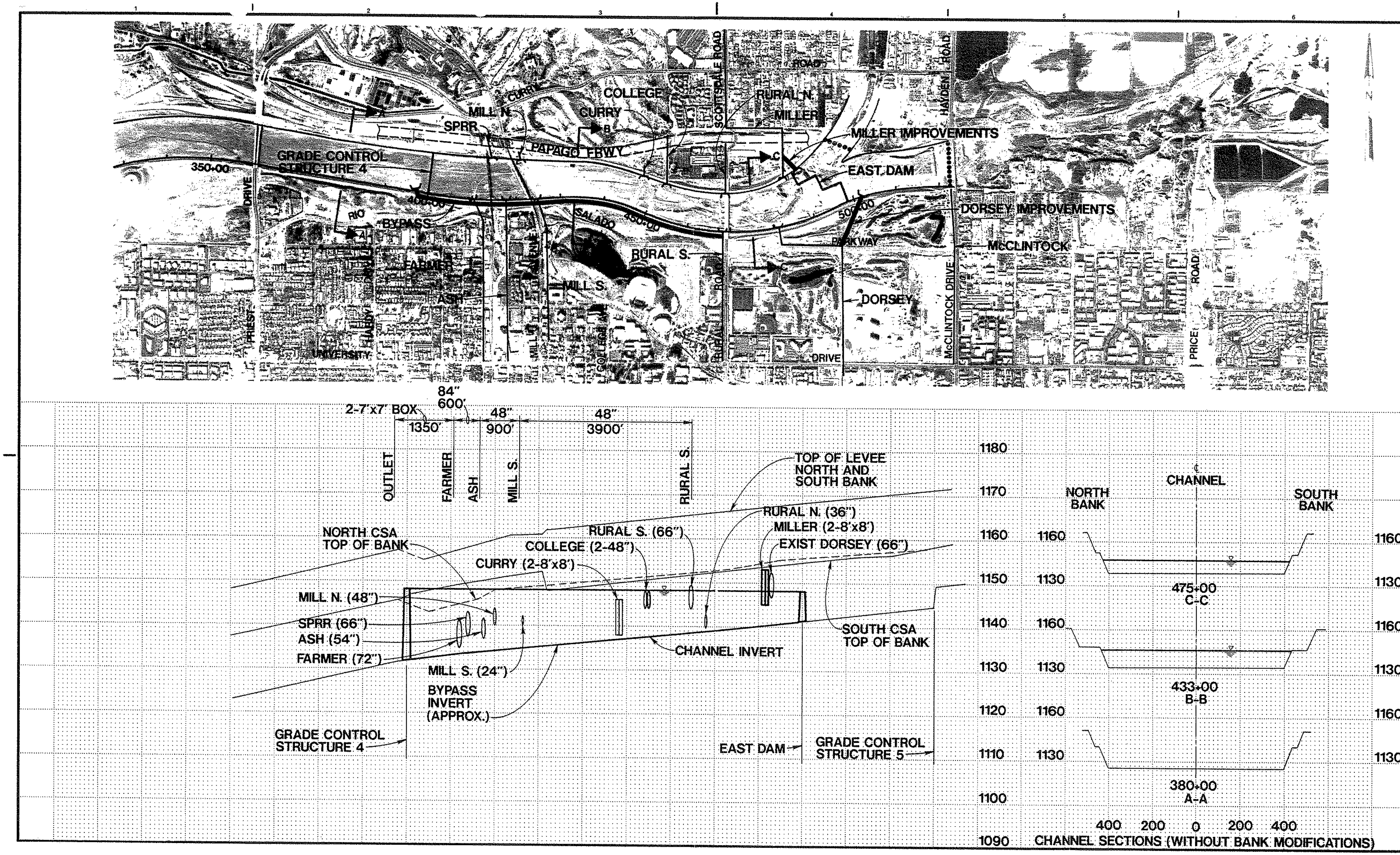


FIGURE 4-9
STORMWATER PLAN/PROFILE DETAIL

etc. were evaluated when selecting the design slope. Additional information is necessary as part of preliminary design.

Table 4-3
Conceptual Bypass System
(100 Percent of Ash and Farmer Drains)

Segment	Length (ft)		Flow (cfs)	Slope Size (ft/ft)
Rural S. to Mill S.	3,900	47	0.00146	48" dia
Mill S. to Ash	900	53	0.00146	48" dia
Ash to Farmer	600	248	0.00146	84" dia
Farmer to G.C. #4	1,350	603	0.00146	2.7'x7'box

Significant cost savings may be realized by diverting only the first-flush flows from Ash and Farmer drains, estimated at 31 cfs and 54 cfs, respectively. Under these conditions, the bypass would consist of a 60-inch pipe between Ash and Farmer and a 72-inch pipe west of Farmer, but require reconstruction of existing manholes and street drains on Rio Salado Parkway. The cost and feasibility of these drainage modifications was not evaluated.

Diversion structures are required at the junction between existing drains and the proposed bypass. The diversion structure intercepts low flows while providing capacity for discharge of high flows directly to the lake. Figure 4-10 is a schematic of a typical diversion structure. Cost estimates assume that two structures are provided, one at Rural South, and the other at Mill South drains.

Dorsey Outfall Revisions

The Dorsey Outfall is a 66-inch south Tempe drain, midway between Rural and McClintock Roads. The existing drain currently discharges to an unlined, open channel near the Karsten Golf Course at Rio Salado Parkway. The channel flows west approximately 1,100 feet, before turning north and passing through the south river bank improvements.

Reconstruction and realignment of the Dorsey outfall may be one option for eliminating direct discharges to the lake from the Dorsey drain, and reducing the size and length of the bypass pipe. Revisions to the Dorsey outfall include the installation of roughly 1,300 feet of new 66-inch pipe and a new outlet and headwall through the south bank (see Figure 4-9). Improvements to the Dorsey Drain would result in discharges to the Salt River east of the proposed upstream dam. A preliminary evaluation of the existing and proposed outfall elevations indicates that the improvements are hydraulically feasible, however, land profiles, ownership and the

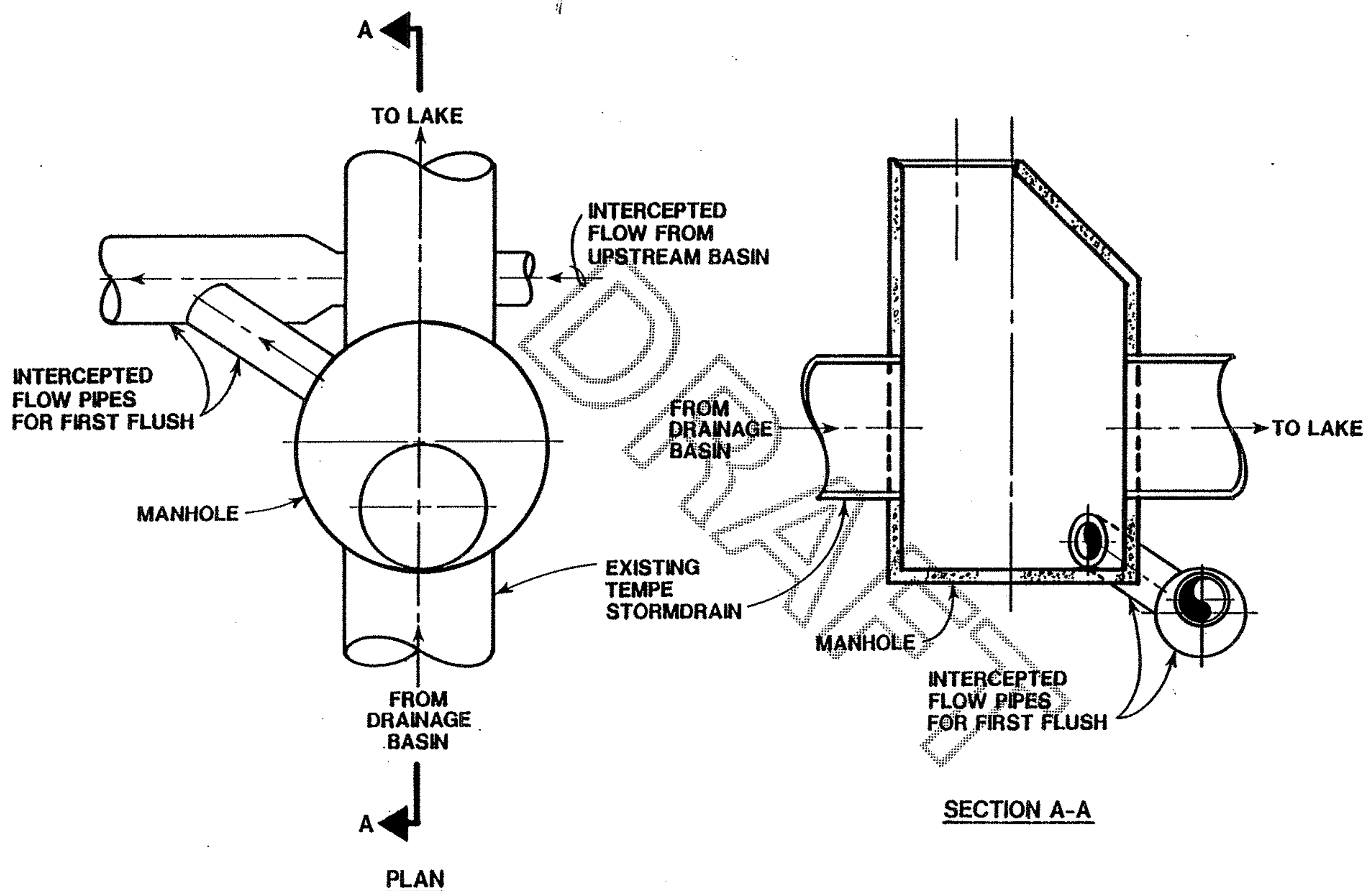


FIGURE 4-10
STORMWATER/DIVERSION STRUCTURE

potential for conflicting structures or utilities were not investigated.

Miller Outfall Revisions

The 66-inch Miller Outfall drains most of urban Tempe north of the Salt River. The Miller Outfall currently discharges to the Salt River about 300 feet downstream of the proposed east (upstream) dam. Reconstruction of the Miller Outfall was recently completed in conjunction with drainage improvements for the Papago Freeway. The outfall was enlarged from a 66-inch pipe to a double 8'X8' box culvert to accommodate the freeway drainage.

One option for eliminating discharges from most of urbanized North Tempe and the Papago Freeway between Scottsdale Road and IBW is the reconstruction and realignment of the Miller Outfall. Improvements would include construction of a new 600 foot long open channel to direct runoff east of the upstream dam. A new double box culvert, headwall, and outlet is required through the north bank soil cement.

North Tempe and Papago Freeway

Five additional outfalls drain portions of urbanized North Tempe, the Papago Freeway, and undeveloped areas of Papago Park into the proposed Town Lake. The outfalls include the Southern Pacific Railroad (66"), Mill N. (48"), Curry (2-8'X8'), College (2-48"), and Rural N. (36").

Runoff from the Papago Freeway will be discharged to Town Lake through three outfalls. Between Scottsdale Road and IBW, drainage is discharged to the Miller Outfall discussed earlier. Freeway Drainage in the vicinity of College Avenue is discharged through one of the two 48-inch outfalls at College. Runoff west of College, in the vicinity of Mill Avenue, is discharge through the 48-inch Mill N. drain.

Runoff from the freeway corridor will likely be of poor water quality, particularly high in petroleum and rubber hydrocarbons, and suspended solids. However, the drainage area, and hence the volume of runoff from a typical storm is small. Assuming an approximate drainage area of 55 acres (Mill Ave to IBW), a runoff coefficient of 90 percent, and an average storm of 0.42 inches (TM5), the Papago Freeway would generate 1.7 acre-feet of runoff to Town Lake. Runoff from the Papago Freeway represents about 3.5 percent of the total volume runoff from urbanized Tempe (51 acre-feet in TM5) during an average storm.

Options to prevent direct freeway discharges to the lake include the construction of a bypass device similar to the south bank improvements, or the construction of retention ponds on the north bank to capture low flows. Excess land acquired by ADOT may be available for basin construction between the freeway and Town Lake. A third option is to monitor the quantity and quality of freeway runoff, deferring construction options to a later date. The value of intercepting or bypassing freeway discharges depends on the intended use of the lake. More intensive uses (e.g. full or partial body contact, fishing, or urban SRP reservoir) may ultimately require freeway drainage improvements.

Stormwater Control Predesign Activities

The recommendations for stormwater control presented above are based on limited information on the design and performance of the existing stormdrain systems, the effluent water quality, right-of-way and utility constraints, and other design issues. During predesign these issues should also be investigated in greater detail. Changes that may be caused by the construction of the Papago Freeway should also be evaluated.

Table 4-4 Stormwater Control Costs	
South Bank Bypass	$2,259,000
Dorsey Outfall	480,000
Miller Outfall	570,000
Subtotal	$3,309,000

Section 5
Source Water Options

Potential Sources

The potential sources of water for the Rio Salado Town Lake are reclaimed wastewater, the Salt River, Salt River Project water, stormwater, and groundwater. Reclaimed water is the most probable source of water, either through direct reuse or indirectly through water exchanges. Direct reuse of reclaimed water occurs in supply alternatives that physically pipe the reclaimed water from the City's water reclamation facilities to the Town Lake. Indirect reuse of reclaimed water occurs in supply alternatives that use aquifer storage and recovery (ASR) technology to transform the water in legal and technical terms from reclaimed water into groundwater. Indirect reuse is also considered in alternatives that are based on trading reclaimed water for other physical sources of water. Considering the options for direct and indirect reuse of reclaimed water, the potential sources of supply include the Salt River, Salt River Project, Central Arizona Project, urban stormwater, reclaimed water, and groundwater.

Each potential water source has unique considerations related to quantity and quality. Source water considerations include reliability, average annual volume, seasonal supply fluctuations, water quality, and legal and institutional issues.

All supply options included in this study are based on filling the lake by capturing receding Salt River flows. In other words, following any Salt River flow event that requires the lowering of the inflatable dams, the dams would be inflated to capture a pool of water behind the dam at the conclusion of the river flow event. Other sources of water considered herein are intended to serve as makeup water for lake evaporation and seepage losses, supply to other water features such as wetlands, and irrigation demands.

Source water considerations follow for each potential source. TM3 provides further information regarding these sources. In cases of factual differences, the information that follows supersedes that presented in TM3.

Salt River

Runoff in the Salt River has a high degree of annual and seasonal variability. Occasional, beneficial flows may be expected during winter months, but excess runoff is unusual during the summer. Beneficial flows are defined here as those which do not require the lowering of the dams. Beneficial flows typically range from zero in summer to as much as 760 ac-ft per month during the winter. Annually, the beneficial flow may be as high as 4,300 ac-ft.

Because of an unusually wet winter and ongoing modifications to Roosevelt Dam, the Salt River Project has released more water than usual from Granite Reef Dam into the river during winter 1991 and spring 1992. The largest spills have been over 13,000 cfs, although the average has been approximately 2,000 to 3,000 cfs. Releases could continue into the summer of 1992. As construction continues on the dams over the next few years, releases may continue to be higher and more frequent than historical records would suggest.

Salt River water quality is generally high except for periodic high fecal coliform count. Historically, metals and nutrient concentrations have been low. Except when intercepted by infiltration and evaporation losses in the riverbed, spills over Granite Reef Dam are a direct source of water to Rio Salado.

These spills, considered "run of the river" water, are appropriable surface water supplies. They may be passed through the lake system as dilution and circulation without appropriation, however, capture of the water for consumptive use is subject to the appropriation process. This type of activity would likely result in protests by senior downstream appropriators.

Salt River Project Water

The direct use of SRP water is not a viable option since Rio Salado development is likely to occur outside SRP boundaries. Attractive indirect uses include an in-line reservoir or a water trade via the exchange of recharge credits associated with reclaimed water.

The quality of SRP water is reported to be similar to Salt River surface water, and assumed to be of identical water quality at its source. Surface water in SRP canals is frequently augmented with groundwater from SRP wells. The groundwater is frequently higher in TDS and nitrate levels than surface water. Agricultural return flows frequently contain detectable quantities of nutrients from fertilizers and toxics from pesticides. In addition, the quality of SRP water is affected by the conveyance system. Warm, shallow water moving slowly in open canals provides an opportunity for algae growth, aquatic weeds, and other water quality transformations.

Central Arizona Project

CAP water is considered a long-term potential source of water to Rio Salado. The City of Tempe has an annual CAP allocation of 4,315 ac-ft which equates to a monthly supply of 475 ac-ft. The quality of CAP water is among the highest of any potential source. It is not likely however that CAP water, without the construction of a dedicated pipeline, could reach the lake without mixing with SRP water. Thus the actual water quality of this "traded" water source would equal that of SRP water.

Urban Stormwater

Stormwater is a nuisance water source. The timing and volume of runoff is not easily controlled, and the water quality is poor. Runoff is expected to be high in suspended solids, nutrients, and metals and some organic chemicals.

Very little reliable data exist regarding the relationship between rainfall and runoff for small storm events in the Phoenix metropolitan area. Most available hydrologic information is for large storm events. In TM3, some simple watershed parameters were estimated for use in predicting average annual runoff. The calculations were cursory estimates at best; however, they provide order-of-magnitude predictions of the volume of urban runoff that may impact the lake. The estimated potential annual runoff volumes range from about 1,000 ac-ft. to 10,000 ac-ft.

Urban runoff is the least desirable source of water for the Rio Salado Project, both in terms of quantity, timing of flow, and quality. Water quality from storm drains varies widely. Existing data are based on single grab samples. The data show a large variability. No flow measurements were taken, so discharges at the time of sampling are not known.

In general, at the measured storm drains, discharges are high in suspended sediments (TSS) and associated metals. Nutrients (N and P compounds) are high as well, rivaling secondary wastewater effluent characteristics. Toxic organic compounds and pesticide residues have not been detected in Phoenix and Tempe area storm drains. Average storm drain metal values exceed ADEQ criteria for the protection of aquatic and wildlife for cadmium, copper, lead, and zinc. Arsenic levels could also be a problem.

Reclaimed Water

Reclaimed water is one of the most reliable sources of water to Rio Salado. The potential supply is assumed to be nearly constant, at up to 3,360 ac-ft per year [for the existing Kyrene Water Reclamation Facility (WRF) at 3.0 mgd], or 6,720 ac-ft per year for the proposed North Plant WRF. The Kyrene WRF was designed for future expansion from 3.0 to 6.0 mgd. The actual flow being diverted to the Kyrene WRF during 1992 will average 2.6 to 2.8 mgd. Population growth or additional interceptor sewer diversions will be necessary to achieve 3.0 mgd or greater flows at the Kyrene WRF. Direct reuse of water reclaimed at these facilities has the disadvantage of having high nutrient levels (primarily phosphorus) that will promote algae and aquatic weed growth in the lake. If not under intensive management, the lake could develop seasonal aesthetic and odor problems. The supply alternatives based on direct reuse include considerations of additional treatment processes that could be constructed to reduce phosphorus concentrations in the reclaimed water, thus diminishing the potential aesthetic problems that could result from direct reuse.

Limited information is available regarding the phosphorus concentration in the Kyrene WRF reclaimed water during the plant's first three months of operation. Additional sampling and testing is ongoing. For planning purposes this report assumes that effluent phosphorus concentrations without additional treatment, would be in the range of 4 mg/l. A range of 2 to 5 mg/l has been observed by City staff.

Groundwater

The direct use of groundwater is not a viable option due to conservation constraints imposed by the Groundwater Management Act. Groundwater may be used indirectly through recharge and recovery operations or the exchange of recharge credits involving reclaimed water. As much as 4,603 ac-ft per year may be available from Tempe's existing wells (384 ac-ft/month). Groundwater is generally of high quality in terms of nutrients, especially phosphorous, compared to other sources. TDS levels, an indicator of inorganic contents, are moderately high.

Water Quality Issues

Detailed evaluations and water quality modeling were presented in TM7. Stormwater quality was discussed in TM5. The results of those studies are summarized and explained where appropriate in this section.

The water supply options described above vary in water quality. This section will summarize the potential effects on Town Lake of using the following sources of water:

- Salt River Project water from the Tempe canals.
- Reclaimed wastewater from the Kyrene WRF. The proposed North Plant WRF water quality is assumed to equal the Kyrene WRF.
- Kyrene WRF water following several levels of advanced phosphorus removal.
- Recovered groundwater. (The indirect use of recovered water for Town Lake would be made possible by recharge and recovery or by trading of reclaimed water for Salt River project water.)

The critical difference between these categories of water is in their probable effect on the growth of free-floating algae and/or attached aquatic weeds. Fertilization potential, as measured by the concentration of nitrogen and phosphorus compounds, varies greatly among the sources. Direct use of reclaimed water has the highest fertilization potential followed by reclaimed water, and then Salt River project water. Groundwater has the least potential for stimulating adverse levels of aquatic plant growth. Average water quality for these sources is given in Table 5-1.

Table 5.1 Source Waters for Town Lake				
Parameter	Average Water Quality			
	Reclaimed Water[a]	SRP Water[b]	Recovered Water[c]	Stormwater[d]
Total Suspended Solids (TSS) (ppm)	2.00	15.80	0.01	43.18
Total Dissolved Solids (TDS) (ppm)	790	338	1,000	533
Total Phosphorus (TP) (ppm)	4	0.137	0.020	0.160
Total Nitrogen (TN) (ppm)	10	4.5	5	4,840
F. Coliform (cfu/100 ml)	2.2	10	0.010	1,642
Arsenic (ppm)	<0.005	0.003	0.009	0.005
Cadmium (ppm)	<0.005	<0.001	0.002	0.001
Chromium (ppm)	<0.010	0.005	0.010	0.014
Copper (ppm)	<0.010	0.008	0.025	0.025
Lead (ppm)	NA	0.003	NA	0.003
Mercury (ppm)	<0.0002	<0.0001	NA	<0.001
Selenium (ppm)	<0.0005	<0.001	0.004	<0.001
Silver (ppm)	NA	<0.001	NA	0.003
Zinc (ppm)	0.038	0.014	0.061	0.160

[a] Kyrene WRF projected quality
[b] From City of Tempe intake data
[c] From City of Tempe well data
[d] As developed in TM 5

NA = Data not available

In the hot climate of the low-elevation desert southwest, lakes have a long growing season and undergo extended periods where the warm surface water forms a stable layering in the lake known as stratification. During the summer stratified period, the natural cleansing processes of lake mixing and oxygenation are blocked from the deeper, cooler portions of the lake. As a result, nutrient enhancement of algal growth will create problems of oxygen depletion in deeper water, increased nutrient and metals release from the sediment (fueling further growth and possible toxicity), and occasional summer fish kills.

The average summer growing season conditions of the lake when filled with different source waters can be compared in Table 5-2. The water quality effects of stormwater additions from an average storm are included for each option as well. The ratios of available nitrogen and phosphorus in the source waters and stormwater indicate that algal growth for Town Lake will be most strongly controlled by the availability of phosphorus. Note that higher water clarity projected for a source water alternative is strongly associated with a decreased potential for oxygen depletion and decreased probability of blue-green algae dominance (Table 5-2). These factors taken together demonstrate a significant range in projected quality of lake water based on the different source water alternatives. The empirically derived relationships used to develop these water quality predictions are based on lake morphometry and nutrient inputs.

Additional treatment processes for greater levels of phosphorus removal could be applied to the Kyrene WRF. A high degree of phosphorus removal would be required to achieve noticeable lake benefits; however, significant direct benefits to lake water quality could be achieved by rigorously pursuing this option (Figure 5-1). Significant Kyrene WRF phosphorus removal (below 0.5 ppm total phosphorus) would yield comparatively high quality water as a primary source for Town Lake (i.e., compare Figure 5-1 with Secchi Depth values in Table 2). Noticeable improvements in lake quality could be further expected if effluent phosphorus concentrations were reduced to below 0.5 ppm (Figure 5-1).

The water quality of urban lakes in the Phoenix/Tempe area is variable but falls within the ranges shown in Figure 5-1 and Table 5-2. Area lakes, although usually smaller than Town Lake and of different morphometry, are maintained with the same variety of source waters (reclaimed effluent, recovered groundwater, etc.) under consideration for the Rio Salado project. Based on local experience, and as supported by water quality projections, the City can expect that Town Lake will experience one to several feet in transparency during the summer months with water quality variability influenced primarily by the differences in source water. The beneficial uses of Town Lake will be influenced by the water supply alternatives in that swimming will be inappropriate for any of the alternatives and boating and fishing could be influenced by lake fertilization and additions of fecal coliform bacteria. Stormwater may temporarily boost fecal coliform counts in Town Lake and preclude full body contact recreation. Aquatic weed or algae growth in a lake filled with reclaimed effluent could impair boating or fishing activities.

Table 5.2 Steady-State Conditions and Stormwater Effects, Town Lake Effect of Different Source Waters						
Parameter	Reclaimed Water Filled	Reclaimed Water Plus Stormwater[c]	SRP Water Filled	SRP Water Plus Stormwater[c]	Recovered Water Filled	Recovered Water Plus Stormwater[c]
TSS (ppm)	0.020	5.9	0.1	6	<.001	5.8
TDS (ppm)	790	742	338	374	1000	913
Chlorophyll a (ppm)	0.304	0.269	0.041	0.055	0.017	0.038
Transparency (ft)	1.8	1.9[a]	3.7	3.4[a]	6.2	4.3[a]
Prob. anoxia	0.99	0.86	0.72	0.55	0.29	0.40
Prob. BG dominance	0.99	0.79	0.60	0.46	0.10	0.25
TP (ppm)	0.364	0.322	0.052	0.068	0.013	0.036
TN (ppm)	6.077	5.811	2.735	3.092	3.038	3.339
F. Coliform (cfu/100 ml)	2.2	261[b]	10	267[b]	0.010	259[b]
Arsenic (ppm)	<0.005	0.002	0.001	0.002	0.006	0.004
Cadmium (ppm)	<0.005	0.002	<.001	0.000	0.001	9,991
Chromium (ppm)	<0.010	0.005	0.001	0.003	0.007	0.006
Copper (ppm)	<0.010	0.008	0.002	0.006	0.018	0.014
Lead (ppm)	NA	0.001	<.001	0.001	<.001	0.001
Mercury (ppm)	<0.0002	0.000	<.001	0.000	<.001	0.000
Scicnium (ppm)	<.005	0.002	<.001	0.000	0.003	0.002
Silver (ppm)	NA	0.001	<.001	0.001	<.001	0.001
Zinc (ppm)	0.029	0.054	0.008	0.036	0.047	0.057

[a] Less than required clarity, MCHD swimming regulations
[b] Exceeds ADEQ full-body contact criteria
[c] New steady-state conditions following the addition of water from an average storm

Figure 5-1 to be added

Figure 1

Local shallow, urban lakes, such as Town Lake experience a long growing season with the proven potential for objectionable growths of algae and aquatic weeds. Water quality is likely to be seasonally predictable, with the greatest plant density and worst water quality during the summer. However, the timing of specific water quality problems, such as floating mats of blue-green algae, shorezone growths of filamentous algae, mats of submerged aquatic weeds, or severe oxygen depletion (and resultant fish kills) cannot be accurately predicted. In the Phoenix area, these types of water quality problems are likely to occur with little warning. Effective management for Town Lake must be based on a continuous water quality monitoring program and response plan coupled with an active, ongoing management program.

Predesign Activities

The most critical predesign activities associated with water quality are to complete the laboratory tests necessary to evaluate the level of advanced phosphorus removal potentially available for the Kyrene Plant and to acquire more complete phosphorus data, in general, for the source waters. Groundwater from wells potentially available for recovered water supply should be tested for phosphorus and nitrogen concentrations. Kyrene Plant phosphorus levels are also imprecisely known and more effluent samples should be tested for phosphorus content.

Section 6
Supply Alternatives

During the summer of 1991 the study team developed 13 scenarios for delivering the principal sources of water to the lake. The principal sources were the existing Kyrene WRF, the proposed North Plant WRF, and SRP canals. Information on these alternatives was presented in Workshop Two. At that time, City staff proposed two additional scenarios for water supply.

The 15 scenarios were developed from the three primary supplies, including options of aquifer recharge and recovery using surface spreading basins at various sites; well injection aquifer recharge and recovery; direct reuse of WRF product water; and several schemes for trading reclaimed water for surface water (SRP water).

During the workshop and follow-up meetings on the issue of supply options, it became apparent that:

- The lake supply options must be coordinated with ongoing City-wide water resource management planning. The City-wide water planning involves decisions regarding City participation in regional wastewater facilities (91st Avenue) in comparison with expanded and additional City-owned reclamation facilities. Reuse of physical water or traded water rights based on reclaimed water exchanges is critically important to the water conservation aspects of the Rio Salado project.

- The quantity of water required to maintain a lake was a key unknown. The water required was uncertain because (1) the location (size) of the lake had not been selected and (2) the estimates of seepage losses (lake infiltration losses) based on available data had a wide range of uncertainty. Overall, it was estimated that a lake would require from 1 to 12 mgd of supply water on an annual average basis. This wide range of required water had a significant impact on which supply options were feasible to consider, as well as an impact on overall water resource planning.

- City staff needed more information regarding the range of possible supply scenarios before a single plan could be recommended to the City Council for implementation.

The result of these circumstances led the City to conclude that field studies were necessary to better define the lake location and water requirements. These field studies have now been documented in TM8, the Rio Salado Town Lake Feasibility Study. TM8 provided the basis for the City's selection of a lake located between Grade Control Structure 4 and the confluence of Indian Bend Wash. TM8 also established the water demands for the preferred lake alternative which is the basis for continuing interest in the following supply alternatives. The City also concluded that the Engineering Report (this document) would not recommend a preferred supply alternative, rather it would present alternatives that could be evaluated as elements of the broader scale water resource planning efforts. The City directed that the following water supply alternatives be developed in this Engineering Report.

Alternative 1—Direct Reuse from Existing Kyrene WRF

This alternative has the following variations:

1a. Direct reuse of existing plant reclaimed water
1b. Direct reuse of additionally treated reclaimed water

Alternative 2—Indirect Reuse from Existing Kyrene WRF

This alternative has the following variations:

2a. Recovered water from surface spreading ASR facilities
2b. Recovered water from injection recharge ASR facilities

Alternative 3—Direct Reuse of Proposed North Plant WRF

This alternative has the following variations:

3a. Direct reuse of proposed plant reclaimed water
3b. Direct reuse of modified plant (additionally treated) reclaimed water

Alternative 4—Indirect Reuse of Proposed North Plant WRF

This alternative is based on injection recharge technology at an injection site remote from the proposed North Plant WRF site.

Alternative 5—SRP Urban Reservoir

This alternative is a "flow through" concept for SRP water, wherein the lake would be used as an equalizing reservoir in the SRP supply system.

This alternative has the following variations:

5a. "Flow through" equalizing reservoir concept.
5b. "Flow through" equalizing reservoir concept with partial supply to the Papago Water Treatment Plant.

Physical Components of Supply Alternatives

To further develop design concepts and estimates of capital, operation, and maintenance costs for the proposed water supply alternatives, five components of these alternatives are described in the following section. The physical facilities are:

- Supply pipeline from Kyrene WRF to lake
- AWT improvements at either Kyrene or North Plant WRFs
- AWT additions to meet drinking water standards for injection well recharge/recovery
- Supply pipeline to the Papago WTP
- Other pipelines and pump stations

Where appropriate this report presents "Probable" costs and "Contingent" costs for project components listed above. Definitions of terms and limitations of cost estimates presented in this report are addressed in Section 9. In general, these estimates have been developed without benefit of detailed engineering, and are therefore approximate in nature. For example, in Alternative 5b, the pipeline cost that is estimated for the pipeline that delivers captured seepage water from the lake to the Papago WTP has a "Probable" cost that includes an assumption regarding the footage of pipeline that will probably, based on limited information, require rock excavation. The "Contingent" cost for this pipeline includes additional footage of rock excavation that could possibly occur, thus increasing the cost estimated for the pipeline. Additional geotechnical fieldwork, as part of the predesign phase of this pipeline would be useful in determining the engineer's estimate for the pipeline prior to bidding the project. In most cases it is not appropriate at this time to investigate and refine the "Contingent" cost estimates. These refinements should occur as the City reaches a decision regarding the preferred supply alternative.

A discussion of each component follows.

Supply Pipeline from Kyrene WRF to Lake

Alternatives 1a, 1b, 2a, and possibly 2b require a pipeline for conveyance of Kyrene WRF reclaimed water from the WRF to the lake. The Kyrene WRF is located on Guadalupe Road just east of Kyrene Road. The distance from the WRF to the lake is approximately 5 miles.

The options for routing the pipeline are:

- **Railroad route.** This alignment parallels the railroad tracks and uses the railroad right-of-way to the maximum extent possible between Guadalupe Road and 13th Street. North of 13th Street the route uses Farmer Avenue. This route is the shortest distance between the WRF and the lake and would also require the least surface restoration (pavement cutting and replacement). Extensive negotiations with the railroad may be required to permit the pipeline because it is somewhat unusual to request extensive parallel use of railroad right-of-way. Other than the costs associated with acquisition of railroad permits and right-of-way, the railroad route is the preferred alignment based lower construction cost and traffic maintenance issues.

- **Street route.** This alignment has been evaluated in the event that negotiations with the railroad would result in unacceptably high permit and right-of-way costs. This alignment emphasizes use of City of Tempe street rights-of-way to the maximum extent possible, minimizing the need for right-of-way acquisition. Some consideration has been given to pipeline location outside of paved areas, but in general this analysis may include more pavement restoration than will actually be required in final design to establish an upper boundary condition for planning purposes.

No consideration is given here for a pipeline that conveys Kyrene WRF reclaimed water from the existing storm sewer outlet (near the I-10 crossing of the Salt River) to the Town Lake. This is a distance of approximately 4 miles and has the disadvantage of potential contamination of reclaimed water due to stormwater and street drainage mixing with the supply to the lake.

Table 6-1
Construction Cost Estimate

	Railroad Route ($ mil)	Street Route ($ mil)
25,000 feet of 18-inch D.I.P. with 3 feet of cover	2.79	
30,000 feet of 18-inch D.I.P. with 3 feet of cover		3.86
Surface Restoration	0.26	1.20
Casing crossings at: Guadalupe Road Baseline Road Southern Avenue Broadway Road University Drive	1.10	0.63
Elevated Crossing at I-360	0.17	0.17
Total	4.32	5.87

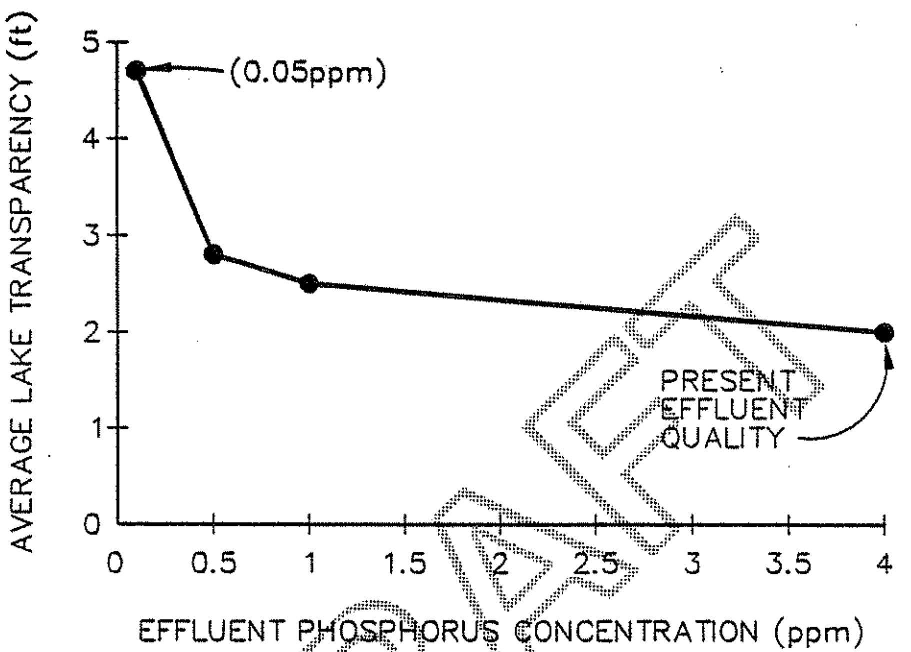
This study assumes that the existing service pumps at the Kyrene WRF could be modified to meet the pumping conditions required to deliver reclaimed water to the lake. The lake is approximately 50 feet lower in elevation than the WRF. A detailed hydraulic analysis will be required during predesign to determine if portions of the pipeline should be designed for pressure- or gravity-flow conditions. An 18-inch-diameter pipeline is consistent with a future design flow capacity of 6 mgd. An allowance is also necessary to accommodate modifications to the pump control and distribution valves. Total estimated cost for the pump station modifications is under $20,000.

AWT Additions for Phosphorus Reduction

Alternatives have been considered for reducing the nutrient concentrations in the reclaimed water prior to discharge to the lake. The purpose of these alternatives is to consider ways for directly reusing Kyrene WRF water but achieve a higher lake water quality than would be possible with reuse of the reclaimed water "as-is." The lake water quality models indicate that phosphorus may be selected as a controlling nutrient related to lake transparency as shown in Figure 6-1. By reducing the amount of phosphorus in the reclaimed water, the predictive model for transparency indicates improved water clarity.

The Kyrene WRF was designed to achieve Class H water standards. In Arizona, this standard allows for unrestricted agricultural use of reclaimed water. Phosphorus reduction is not usually a specific design objective for Class H water reclamation, however, some phosphorus reduction can be expected from the treatment processes that are in place. The design criteria for the WRF states a discharge limit (criteria) of 3 to 5 mg/l for total phosphorus. Additional phosphorus can be removed from the Kyrene WRF reclaimed water by a variety of processes. These additional treatment steps, or advanced waste treatment (AWT) additions have been developed for phosphorus removals down to 1 mg/l, 0.5 mg/l, and 0.05 mg/l.

The existing Kyrene WRF has a design capacity of 3 mgd. Actual flows during initial operation during 1992 are in the range of 2.6 to 2.8 mgd. The treatment facilities consist of screening, activated sludge with nitrogen removal facilities, and effluent filtration. Primary disinfection is provided by ultraviolet light. Waste sludge and scum are currently discharged to the 91st Avenue Wastewater Treatment Plant. The Kyrene WRF is designed to meet the discharge limits shown in Table 6-2:



LAKE TRANSPARENCY AS RELATED TO LEVEL OF PHOSPHORUS REMOVAL

FIGURE 6-1
LAKE TRANSPARENCY AS RELATED TO LEVEL OF PHOSPHOROUS REMOVAL

Table 6-2 Kyrene WRF Water Quality Design Objectives	
Parameter (mg/l, unless noted)	**Design Discharge Limit (mg/l, unless noted)**
BOD_5	2.0
TSS	2.0
Organic Nitrogen	1.4
Ammonia Nitrogen (N)	0.1
Nitrate - Nitrogen (N)	8.5
Total Nitrogen (as N)	10.0
Total Phosphorus (as P)	3-5
Turbidity (NTU)	1.0
Fecal Coliform (CFU/100 ml)	2.2
Enteric Virus (PFU, 40 l)	1
Alkalinity	147

Consideration is being given to using the effluent from the Kyrene WRF as the primary supply for the Rio Salado Town Lake project. Based on limnological modeling, it appears that phosphorus would be the limiting nutrient for this system. The following section identifies options for adding phosphorus removal facilities to the existing Kyrene WRF. Since the proposed North Plant WRF is similar to the Kyrene WRF the proposed process additions could be considered appropriate for either plant. The North Plant WRF has the advantage that should these processes be considered, they could be integrated into the project prior to construction.

Treatment Alternatives

Treatment alternatives have been studied to achieve effluent phosphorus concentrations of 1.0, 0.3, 0.1, and 0.05 mg/l. Treatment technologies considered for phosphorus removal include:

- Metal salt precipitation
- Lime precipitation
- Biological removal
- Continuous flow microfiltration
- Wetlands treatment
- ASR

Metal Salt Precipitation. Chemical precipitation using aluminum or iron coagulations is an effective means of phosphorus removal. While the exact coagulation reactions are complex, the primary reaction is combining orthophosphate with the metal cation. Aluminum ions combine with phosphate ions as follows:

$$Al_2(SO_4)_3 \bullet 14.3H_2O + 2PO_4^{=} = 2AlPO_4 + 3SO_4 + 14.3H_2O$$

The molar ratio for Al to P is 1 to 1 for this reaction. However, competing reactions, including reactions with alkalinity require a greater than stoichiometric alum dosage. Full scale operating experience at other facilities indicates that effluent phosphorus concentrations of 1.0 mg/l can be achieved at alum to phosphorus dosage of 1:1 (molar). The weight ratio of commercial alum to phosphorus is 9.7:1. To achieve additional phosphorus removal, molar ratios as high as 15:1 have been required.

In wastewater reclamation applications, alum or iron salts can be added directly to the aeration basins, upstream of the secondary clarifiers, or upstream of tertiary clarification. Because a large percentage of the phosphorus is contained within the biological floc, effluent filtration required to reliably achieve a phosphorus concentration of less than 1.0 mg/l. Based on an assumed influent P concentration of 4 mg/l, estimates of an additional chemical sludge production are presented in Table 6-3 for varying alum dosages.

Table 6-3
Alum Sludge Production

Effluent Phosphorus Concentration (mg/l)	Alum Dosage Required (mg/l)	Alum Cost ($/day)	Chemical Sludge Produced	
			dry lbs/day	gpd[a]
1.0	50	$81	432	11,000
0.3	65	$106	552	14,000
0.1	70	$113	590	15,000
0.05	90	$146	726	18,500

[a] Volume of chemical sludge at WRF design WAS concentration of 4,770 mg/l.

Values for the chemical sludge produced only consider the $AlPO_4$ and $Al(OH)_3$ precipitates formed by the alum addition process. These values do not consider the possibility that solids removal efficiency may be improved by the addition of alum to the secondary process. Depending upon alum dosage and the original solids removal efficiency, some plants have experienced an increase of 20 to 40 percent in sludge production. Because the current solids removal efficiency for the plant is high, the overall impact on solids production will be primarily due to the chemical precipitates formed by alum addition.

Based on design criteria in the Kyrene WRF operations manual, the design solids production rate is 3.65 dry tons per day, or 183,000 gallons at the design waste activated sludge concentration of 4,770 mg/l. Based on the estimates of chemical precipitate presented in Table 6-3, the overall sludge production for the Kyrene WRF would be increased by 6 to 10 percent depending upon alum dosage.

Effect on Secondary Process

Alum or iron salt coagulants could be added to the secondary process or upstream of new tertiary clarifiers at the Kyrene WRF. Addition of alum to the secondary process will increase the percentage of inert solids in the secondary system, and may reduce the capacity of the secondary treatment system.

The Kyrene operations manual states that the design solids retention time (SRT) is 6.2 days. This value appears to include the volume of the anoxic zone. From Table 6-3, at an alum dosage of 70 mg/l, the mass of chemical sludge produced is 590 lbs/day. Therefore, the mass of inert solids in the secondary system will be increased by 3,660 pounds (6.2 days x 590 lbs/day). The design mixed liquor solids inventory is 40,700 pounds (including the anoxic zone). Therefore the effective solids retention time will be reduced by approximately 9 percent (3,660 ÷ 40,700).

The design SRT of 6.2 days could be maintained by increasing the mixed liquor suspended solids concentration to offset the addition of the inert chemical precipitates. To ensure no net reduction in SRT for biologically active solids, the mixed liquor suspended solids concentration would need to be increased from the design value of 2,495 mg/l to about 2,700 mg/l.

Based on the estimates of chemical sludge produced, it appears that operational modifications could be implemented to the Kyrene WRF secondary process that would permit the addition of alum to the secondary process, and still achieve the required SRT for nitrification.

Figure 6-2 presents a process flow schematic for Option A. Alum feed facilities are already in place at the Kyrene plant. Chemical feed piping would need to installed to permit the addition of alum upstream of the aeration basins and upstream of the secondary clarifiers. Full scale stress testing could be conducted to determine:

- Actual SRT required for nitrification
- Impact of alum on secondary process and sludge production
- Alum dosage required to achieve varying levels of effluent phosphorus concentration
- Secondary system performance and reliability at higher MLSS concentrations

If stress testing determines that the desired effluent phosphorus concentration cannot be achieved without adversely impacting the performance of the secondary process,

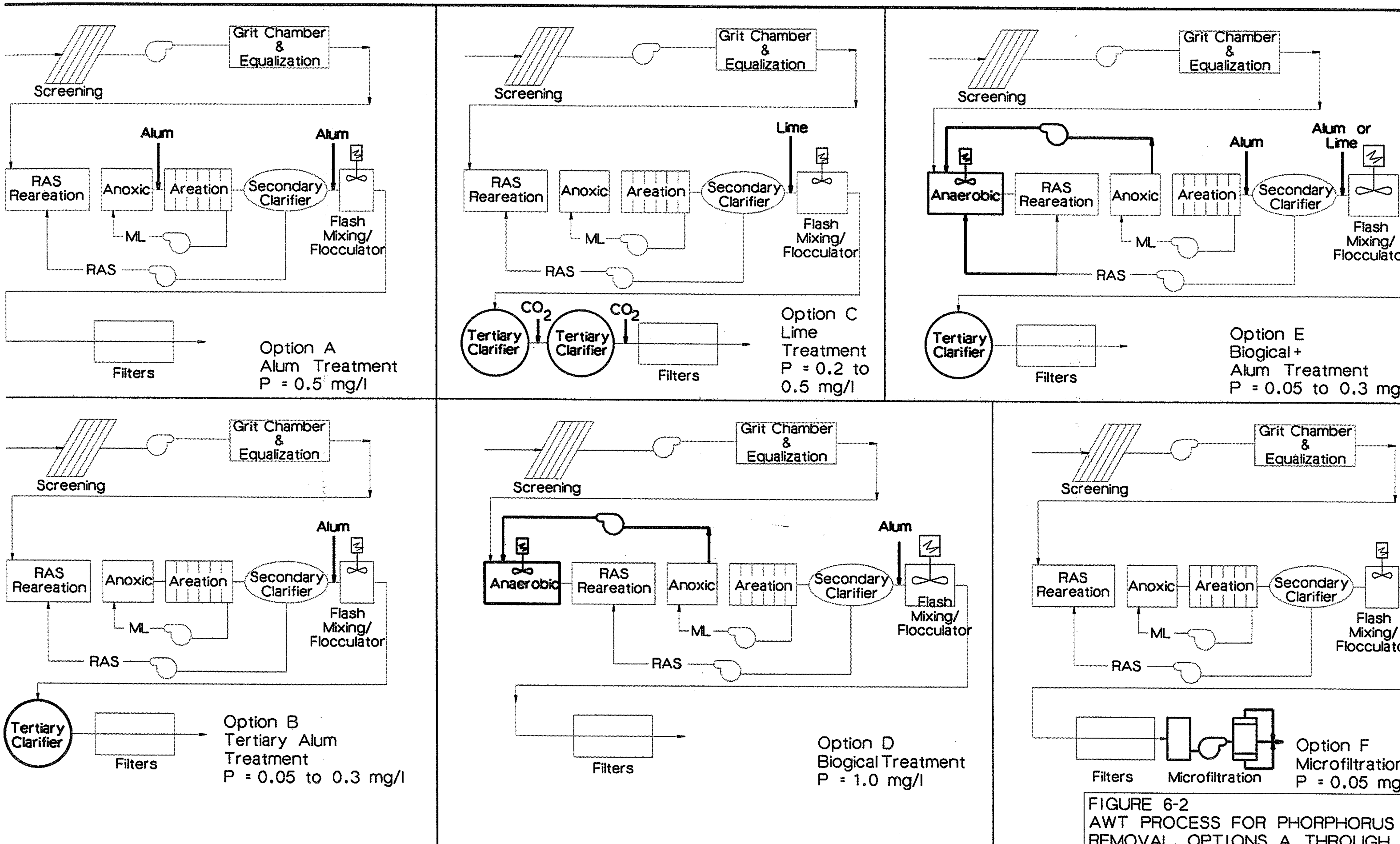


FIGURE 6-2
AWT PROCESS FOR PHORPHORUS REMOVAL, OPTIONS A THROUGH E

tertiary clarifiers could be added downstream of the existing secondary clarifiers. At a design overflow rate of 600 gpd/ft^2, two 60-foot diameter clarifiers would be required. A flow schematic for this option is presented in Figure 6-2, Option B.

Lime Precipitation. Alum addition has been used to achieve phosphorus concentration of 0.05 mg/l in low alkalinity waters (e.g., Rock Creek, Oregon). Optimum removal efficiency is achieved at a pH of 6.5. Excessive alkalinity will require very high alum dosages to achieve this pH. Pilot scale evaluations of alum treatment by the City of Las Vegas, Nevada, indicate that the minimum phosphorus concentration that can be achieved for the relatively alkaline Colorado River water is 0.2 mg/l.

If it is determined that excessively high alum dosages are required to achieve the target phosphorus concentration, consideration should be given to lime treatment. When added to wastewater, lime increases the pH and reacts with carbonate alkalinity to precipitate calcium carbonate. The calcium ion also reacts with orthophosphate to form calcium hydroxyapatite. A pH in the range of 9.5 to 11.5 is required to remove the major fraction of phosphorus, and lime dosages of 150 to 300 mg/l are typical.

Recarbonation prior to filtration would be required to stabilize the wastewater. Recarbonation can be achieved in one or two stages. Excess lime is precipitated at a pH of 9.5, and carbonate is converted to bicarbonate for stabilization.

Figure 6-2 Option C presents a process flow schematic for the lime treatment option. Based on the experience of other utilities, it is expected that an effluent phosphorus concentration of 0.2 mg/l can be achieved with this process. However, because of its complexity and higher cost relative to the alum precipitation options, no estimates of capital and operating costs have been developed.

Biological Removal. Modifications to the activated sludge process have been developed to permit biological removal of phosphorus. There are a number of variations including:

- Phostrip
- Modified Bardenpho
- A^2O process
- Capetown and modified Capetown processes
- Virginia Initiative Process (VIP)

All of these processes require the presence of an anaerobic zone for phosphorus removal. In the absence of oxygen, fermentation by facultative organisms produces acetate and other fermentation products. These products are preferred and readily assimilated by microorganisms capable of biological phosphorus removal. Because of their ability to assimilate these fermentation products, these microorganisms have a competitive advantage compared to "normal" activated sludge microorganisms.

To provide soluble BOD required for production of fermentation products needed by the phosphorus removing organisms, anoxic zone effluent is recycled to the anaerobic zone. The anoxic zone effluent has relatively low levels of nitrate, and relatively high levels of phosphorus are stored in the microorganisms recycled to the anaerobic zone. Stored phosphorus is released in the anaerobic zone, and metabolized by the phosphorus microorganisms. Because the mixed liquor entering the aerobic zone is relatively "starved" for phosphorus, enhanced removal of phosphorus is achieved in the aerobic zone.

There are a number of variations of the anaerobic/anoxic/oxic (A^2O) process. For the Kyrene plant, new complete mixed anaerobic zone(s) could be added upstream of the existing anoxic zones. The required detention time would be approximately one hour, and would require a 3 mgd recycle pump.

Figure 6-2 Option D presents a process flow schematic for this option. This process is capable of reliably achieving an effluent phosphorus concentration of 1 mg/l. Alum feed would also be provided for phosphorus removal during process upsets or to reduce effluent phosphorus to less than 1 mg/l. If a very low concentration of phosphorus is desired, or if it is determined that addition of alum to the secondary process is undesirable, then tertiary clarifiers could be used to remove the alum precipitate (see Figure 6-2 Option E).

Continuous Flow Microfiltration. Continuous flow microfiltration (CMF) has been pilot tested at the Reedy Creek WWTP in Orlando, Florida, and has produced effluent phosphorus concentrations in the range of 0.05 mg/l. Pretreatment with alum, at dosages much less than stoichiometry would predict, are required for phosphorus removal. CMF is a patented technology that is owned by the Memtec America Corporation. This process is shown in Figure 6-2, Option F.

Conventional membrane technologies include reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF), and microfiltration (MF). Reverse osmosis membranes have played a significant role in polishing wastewater for sensitive applications such as aquifer storage and recovery, and recreational lakes. The largest of these installations is the 15 mgd RO system at Orange County (California) Water District's Water Factory 21. Reverse osmosis membranes are designed to remove ionic size particles, having molecular weights greater than 100. Microfiltration is design to remove much larger particles, having molecular weights in excess of 100,000 to 500,000, and particle sizes of 0.1 to 0.5 micrometers. Alum is used to precipitate and flocculate remaining phosphorus in the tertiary effluent to produce particles that can be removed by the CMF system.

Conventional membrane systems operate in crossflow mode to minimize membrane fouling and to suspend dissolved solids in the feed water. Crossflow mode requires that a significant fraction (10 to 75 percent) of the feed water bypasses the membrane. For this reason, their recovery rate is the range of 25 to 90 percent, whereby contaminants are concentrated and discharged as a reject or brine. CMF operates in direct flow, which reduces energy costs by as much as 60 percent. Conventional membrane systems usually require chemical cleaning to remove bacterial fouling and restore flow performance. The CMF membrane is cleaned through gas backwashing. This method eliminates bacterial fouling, and provides a flux rate of 0.5 to 0.9 gpm/sq. meter without the use of crossflow.

Facility requirements for the CMF system would be very similar to those required for a conventional membrane filtration system. Civil and structural requirements are minimal because of its modular skid-mounted construction. The majority of the facility costs will be associated with the CMF equipment. The largest modular unit has a membrane surface area of 900 square meters, and nominal capacity of 650,000 gpd. At the design flowrate of 3 mgd, 6 of these units would be required. Each unit has a footprint of 160 square feet. Actual site space requirements will be approximately 3 to 5 times the modular units footprints or 3,000 to 5,000 square feet.

Pilot testing would be required to determine design criteria such as flux rate, phosphorus removal efficiency, alum dosage, and operating pressure. Figure 6-2, Option F, presents a flow schematic for this process scheme.

Wetlands Treatment

The use of wetlands for post secondary treatment of wastewater can, in many instances offer a cost-effective alternative to more traditional treatment methods. For this project constructed wetlands (WTS) were considered for polishing reclaimed water from the Kyrene or North WRF. As described earlier, the objective for this application would be to reduce nutrient loading in the lake, specifically phosphorus concentrations. While WTS has been shown to be effective at removing many constituents, removal rates for phosphorus are highly variable and somewhat unreliable. Assuming a flow rate of 3 mgd and an influent concentration of 4 mg/l the WTS models predict that about 1,500 acres of wetlands would be required to reduce the TP concentration to 0.1 mg/l (loading rate of 2.76 $g/m^2/yr$).

Also, an aging effect has been detected in wetlands from 2 to 25 years after loading begins with significant decreases in removal efficiencies. One additional problem with WTS for TP reduction is the tendency of these systems to discharge or "burp" high concentration effluent occasionally, unpredictably, and without apparent cause. For these reasons, WTS was not considered further for source water nutrient reduction. Wetlands may, however have other uses and benefits for project components such as riparian zone mitigation.

Aquifer Storage and Recovery

ASR provides an excellent mechanism for reduction in phosphorus via either surface spreading basins or well injection. The recovered water could approach 0.05 mg/l phosphorus. Actual test results would have to demonstrate this capability. ASR is not considered further in this section as a treatment process in and of itself. Rather, the benefit of ASR (with phosphorus reduction) is credited in the supply alternatives that include an ASR component.

Cost Estimates for AWT (for Phosphorus Reduction)

Biological removal of phosphorus will reduce or eliminate alum purchase costs substantially. At the current cost for alum of $130 per dry ton, the unit cost for alum removal of phosphorus is $0.85 per pound of phosphorus removed (assuming a weight ratio of 13:1 is required to reduce phosphorus concentration to 1 mg/l). Assuming an influent phosphorus concentration of 4 mg/l, the yearly alum cost to provide an effluent phosphorus concentration of 1 mg/l is $23,000.

Sludge disposal is the other primary operating cost of alum treatment. Dewatering and disposal will be necessary if sludge cannot be discharged to the 91st Avenue Plant, or if the cost is prohibitive. Assuming 600 dry pounds is produced each day, approximately 1 yard of dry sludge (at 30 percent solids) will require disposal. At a tipping fee of $15 per yard, the annual disposal cost is about $6,000.

Further sampling is recommended to establish the validity of the assumed 4.0 mg/l phosphorus concentration in the reclaimed water.

All estimates of capital and operating costs have been prepared assuming that additional sludge produced by chemical addition can be discharged to the 91st Avenue Plant. No cost is included for sludge dewatering or disposal.

Option A. Option A would require the addition of the following facilities:

- Chemical feed piping to deliver alum to the aeration basins and secondary clarifier

The estimated construction cost for this option is $10,000.

Option B. Option B would require the addition of the following facilities:

- Two 60-foot diameter clarifiers
- Chemical sludge pumping station

The cost estimate for this option assumes that sufficient head is available for the new tertiary clarifiers to operate upstream of the existing filters without repumping.

The estimated construction cost for this option is $ 1,300,000.

Option C. Option C would require the addition of the following facilities:

- Lime feed system
- CO_2 storage and feed system
- Four 60-foot diameter clarifiers
- One 63,000 gallon recarbonation basin

The estimated construction cost for this option is $2,500,000

Option D. Option D would require the addition of the following facilities:

- Two 62,500 gallon anaerobic basins
- Two anaerobic cell mixers (30 hp each)
- Anoxic mixed liquor recycle pumps (7.5 hp each)
- Piping gallery and piping to connect raw sewage piping to new anaerobic cells, and to connect new anaerobic basin to existing aeration basin.

The estimated construction cost for this option is $728,000.

Option E. Option E would combine the facilities required for Biological Removal (Option D) with the chemical treatment facilities described for Options B or C.

Anticipated process performance and estimated capital costs are presented in Table 6-4.

Option F. Option F would require the addition of the following facilities:

- 4,000 to 5,000 sq.ft. building
- Five 750,000 gpd skid mounted CMF units
- Air backwash system
- Surge tank and feed pumps

The estimated construction cost for this option is $3,500,000 to $4,500,000.

Table 6-4 Process Performance/Cost Summary				
Option	Description	Estimated Construction Cost	O&M Cost	Effluent Phosphorus Concentration (mg/l)
A	Alum addition to existing secondary process	$10,000	$35,000	0.5
B	Alum addition and new tertiary clarifiers	$1,490,000	$60,000	0.05[a] to 0.3
C	Lime precipitation/tertiary clarifiers/recarbonation	$2,870,000	$90,000	0.2[a]
D	Biological removal	$835,000	$7,000	1.0
E	Biological removal/combined with: Option B Option C	 $2,325,000 $3,705,000	 $42,000 $67,000	 0.05[a] 0.05[a]
F	Continuous flow microfiltration	$4,600,000	$275,000	0.05[a]

[a] Pilot testing required for effluent phosphorus concentration goal less than 0.5 mg/l.

AWT Additions for Drinking Water Standards (Injection Well Recharge/Recovery)

Aquifer storage and recovery (ASR) is a component of supply alternatives 2b and 4. Aquifer storage and recovery of reclaimed water using well recharge technology is being considered in comparison with surface spreading basins. In instances where large parcels needed for surface spreading basins are not available or if the available land is not suitable for surface recharge, then it is appropriate to consider injection well technology. Compared to spreading basins, the design and operation of recharge wells are more sensitive to site-specific factors related to aquifer conditions, source water quality, groundwater quality, and the regulatory requirements related to water quality. Many of these factors have uncertainties that will require field investigations, laboratory analyses, geochemical modeling, pilot recharge well operations, and finally negotiations with regulating agencies to develop the design criteria for a full-scale facility. The sensitivity of these factors and the associated uncertainties greatly affects the facility requirements and results in a wide range of possibilities for a reuse plan using ASR via recharge wells.

The primary elements of an ASR system using recharge wells are:

- Pretreatment facilities
- Recharge wells
- Recovery wells

- Connecting pipelines

These facilities are described in further detail in the following sections.

Pretreatment Facilities

Well recharge requires that the water being injected must not degrade the water quality of the receiving aquifer or cause an unacceptable rate of clogging in the recharge wells. Since the aquifers underlying Tempe are drinking water quality, the reclaimed water should meet drinking water standards at the time it is injected into the aquifer. Additionally, the reclaimed water must have a concentration of suspended solids low enough to reduce the rate of clogging to an acceptable level. Another requirement for operation of recharge wells is maintaining a residual of disinfectant in the source water to control microbial growth in the well during injection. Chlorine is typically the disinfectant chosen. Disinfection facilities located at the plant are preferred from a capital cost and operations standpoint, although disinfection facilities located at each injection well is an alternative. In either case, provisions to maintain a disinfectant residual in the well between periods of recharge is also important.

Five pretreatment alternatives have been considered for purposes of establishing the range of possibilities associated with well recharge. The five alternatives are:

- Additional disinfection
- GAC adsorption with disinfection
- Lime treatment, granular-activated carbon (GAC), and disinfection
- Nanofiltration and disinfection
- Lime treatment, reverse osmosis (RO), and disinfection

All five alternatives incorporate the existing treatment processes including filtration. These five alternatives, respectively, represent the minimal realistic, probable, and contingent possibilities for pretreatment requirements.

Option A—Additional Disinfection Prior to Injection. The effluent quality at the Kyrene WRF and North Plant WRF may meet drinking water standards with the single addition of disinfection. Current discharge requirements of turbidity of less than 1.0 NTU and total nitrogen (as N) less than 10.0 mg/l also meet the drinking water standards. Discharge requirements for pathogens (fecal coliform and enteric virus) are low and it is possible that the standards for drinking water could be met with additional disinfection prior to injection. It is unknown whether the effluent can consistently meet the standards for trace inorganic (primarily heavy metals) or trace organic substances (primarily volatile organic compounds), but it is uncommon for municipal wastewater to exceed drinking water standards for trace substances in reclaimed water where municipalities have pretreatment requirements for industrial dischargers. Industrial pretreatment requirements are particularly important for the effluent produced at the North Plant which will have a larger share of industrial dischargers. To obtain approval from regulatory agencies for this alternative the agencies will likely require assurances that sufficient controls on dischargers or contaminant barriers exist in the treatment process to ensure that exceedance of the standards does not occur. The major concern is whether there are enough safeguards built into the system to ensure that drinking water standards are continuously met at the point of injection even if occasional upsets occur in the quality of the sewage influent or in individual processes within the treatment system. Another concern will be whether the disinfection process would produce disinfection by-products (DBPs) (such as trihalomethanes) to exceed the forthcoming requirements of the EPA for DBPs.

Option B—GAC Adsorption and Disinfections. In this option, GAC is used as a filter media similar in concept to a rapid sand filter. The GAC acts to attract very fine solids from the process stream. The contactors are designed without backward provisions and the GAC life in the adsorption process is much greater than in the adsorption process.

Option C—Lime Treatment, GAC, Disinfection. The precedent set at existing injection recharge well facilities using reclaimed water is to include lime treatment, filtration, and granular-activated carbon in the treatment process. Lime treatment removes trace inorganics (heavy metals) and phosphorus, and is highly effective at killing virus and bacteria due to high pH levels. The GAC process is effective at removing soluble organic materials, typically the refractory organics, left behind from the other treatment processes, such as pesticides, herbicides, synthetic organics, humic acids (trihalomethane precursors) and detergents. In addition, GAC can remove trace metals, chlorinated hydrocarbons, and organic phosphorus compounds. Total Organic Carbon (TOC) concentrations will be reduced to approximately 1 to 5 mg/l which reduces the potential for producing disinfection byproducts. This process system is proven technology for recharge wells, even for cases where the recovered water is used for potable purposes.

Option D—Nanofiltration and Disinfection. Nanofiltration is emerging technology similar to reverse osmosis. With nanofiltration the membranes pass higher molecular weight molecules than RO membranes and operate at lower pressure.

Nanofiltration is currently being tested at the Kyrene WRF with encouraging preliminary results.

Option E—Lime Treatment, Reverse Osmosis (RO), Disinfection. New regulations being promulgated in California for injection well recharge are requiring reductions of TOC concentrations to <2.0 mg/l for reclaimed water. TOC is used as an indicator parameter for organic substances. The only proven technology for reliably achieving such a low concentration of TOC with reclaimed water is RO. Therefore, RO would be considered for contingency purposes, in case ADEQ should adopt a similar TOC standard as California. RO is a demineralization process using membrane technology which removes about 95 percent of dissolved inorganic and organic substances. Since RO is effective at removal of such a wide range of contaminants it can be considered as a backup to the treatment processes used earlier in the system.

Pretreatment Cost Estimates. Capital and operating costs for the five pretreatment alternatives are shown in Table 6-5.

Table 6-5
Estimated Costs for Injection Pretreatment Alternatives

Alternative	Anticipated Effluent TOC mg/l	Estimate for 3.0 mgd Facilities ($ millions)	
		Construction	Operation
Option A Additional Disinfection	> 10	0.12	0.05
Option B GAS Adsorption/ Chlorination	5 to 10	5.00	1.14
Option C Lime, Gas Chlorination	1 to 5	10.75	1.90
Option D Nanofiltration/ Chlorination	1 to 3	3.95	0.82
Option E Lime/RO/Chlorination	< 1	18.85	2.04

Recharge Wells

Recharge wells must be located away from known sources of groundwater contamination, where aquifer conditions provide a suitable thickness of saturated granular material (to accept the water), where adequate aquifer storage space is available, and outside the immediate capture zone of production wells pumping water for potable purposes. The wells must be spaced far enough apart to prevent excessive hydraulic interference during injection. Each well site must have access for well drilling equipment and room for permanent water disinfection facilities.

For planning purposes, recharge wells for the Kyrene WRF have been sited in the vicinity of the City's "Hardy Farm" property, approximately 1 mile south of the WRF.

Further hydrogeological investigation and negotiations with ADEQ may allow siting at the Kyrene WRF property. The studies and negotiation would be in regard to impacts on a known groundwater contamination plume just north of the site. Recharge wells for the North Plant WRF could be located within the 3-square-mile area bounded on the east and west by Rural Road and Priest Drive, and on the north and south by

Broadway Road and the Superstition Freeway. These locations are sufficiently distant from known aquifer contamination and existing production wells that ADEQ APP permitting will be likely. In addition, available information indicate suitable aquifer conditions, reasonable depths to water, and sufficient aquifer thickness may be present here.

Construction of recharge wells is similar to production wells except that the well casing and perforated casing must be non-corrosive materials due to the corrosive effects of the disinfectants (typically chlorine) in the injection water. The casing openings and filter pack grain size are also typically larger than for production wells. The recharge wells must be equipped with conductor pipes for recharging and vertical turbine pumps for redevelopment. Pumping and surging for redevelopment will be required at regular intervals to mitigate the effects of clogging. The frequency of redevelopment will depend on quality of the recharged water, aquifer conditions, and the recharge rate. Typical frequencies for redevelopment range from weekly to once every three months. Finding a means to dispose of the water pumped during redevelopment will be an important factor in well site selection and development. Typical ways of disposal could include discharge to sanitary sewers, storm drains, dry wells, or small percolation basins.

Recharge Well Cost Estimates. Estimates of costs for a recharge wellfield having a total capacity of 3.0 mgd for both the Kyrene WRF and North Plant WRF locations have been prepared. Recharge rates for the wells are estimated at one-half their expected yield during pumping. An additional well is included at each location for operation during redevelopment of other wells and for standby purposes. Recharge well estimates include the costs for well construction, pumping and electrical equipment, onsite piping and appurtenances, offsite piping for pumped water disposal and site development and fencing. For offsite piping it was assumed that a connection to a sewer or storm drain was made within 800 feet of the site. An automated system for maintaining a disinfectant residual in the well during periods of downtime is also included in the costs. Estimates for monitoring well facilities were made based on five monitoring wells constructed in each primary aquifer for each group. Monitoring wells are assumed equipped with a locking vandal-proof cover, water level recording equipment, and permanent pumping equipment installed for collecting water samples. Each monitoring well location will consist of a nest of two wells, screened at two different intervals (one in each of two primary aquifers).

For the cost of operations, a redevelopment schedule of one hour of pumping once every week is assumed for each well. Also included in operations is the maintenance of pumping, electrical, and instrumentation and control equipment. The costs for monitoring assumes quarterly sampling and laboratory testing of the recharge source water and groundwater at each nest of monitor wells (two samples per well).

Facility size assumptions and estimated capital and operations costs for a 3.0 mgd injection well and monitoring system are shown in Table 6-6.

Table 6-6 Estimates for 3.0 mgd Recharge Well System		
	Probable	Contingent
Number of Injection Wells	4	5
Recharge Well Casing Diameter/Depth	16-inch/500 feet openings @ 250 to 500 ft.	16-inch/500 feet openings @ 250 to 500 ft.
Recharge Well Capital Costs	$1,323,000	$2,200,000
Annual Recharge Well Operations Costs ($)	$61,000	$72,000
Number of Monitor Wells	8	10
Monitor Well Diameter/Depth	4 @ 6-inch/300 feet 4 @ 6-inch/500 feet	5 @ 6-inch/300 feet 5 @ 6-inch/500 feet
Monitor Well Construction Costs ($)	$486,000	$608,000
Annual Monitor Well Operations Costs ($)	$35,000	$42,000

Recovery Wells

For recharge well aquifer storage and recovery projects, current ADWR regulations require recovery wells to be located within the area of influence of the recharge facility. ADWR currently interprets this to mean within one-half mile of the recharge facility. To allow flexibility to meet peak demands, a peaking factor of 2.0 is assumed for planning purposes. This means a 3.0 mgd injection system would be equipped with a 6.0 mgd recovery system. The location and well site requirements for recovery wells are similar to those for the recharge wells discussed previously, except disinfection facilities or piping for redevelop flows are not required. The construction requirements for the recovery wells would be similar to production wells used by the City.

Recovery Well Cost Estimates. Estimates of a recovery wellfield having a total capacity of 6.0 mgd for both the Kyrene WRF and North Plant WRF locations have been prepared. Recovery rates are estimated based on pumping rates typical for production wells in the area. An additional well is included at each location for standby purposes. Recovery well estimates include the costs for well construction, pumping and electrical equipment, onsite piping and appurtenances, and site development and fencing.

Estimated cost of operations includes the power costs for pumping and routine maintenance of pump and wellhead equipment.

Facility size assumptions and estimated capital and operations costs for a 6.0 mgd recovery system are shown in Table 6-7.

Table 6-7
Estimates for 6.0 mgd Recharge Well System

	Probable	Contingent
Number of Recovery Wells	4	5
Recovery Well Casing Diameter/Depth	16-inch/500 feet	16-inch/500 feet
Construction Costs ($)	$1,050,000	$1,640,000
Annual Operations Costs ($)	$125,000	$135,000

Potential Recovery Well Cost Savings. Potential cost savings could be realized by moving the point of recovery closer to the point of use. Lawsuits are pending and legislation has been occasionally proposed to change ADWR regulations to allow recovery of recharged water at remote locations so long as it is located within the service area of the recharging entity. Should the lawsuits or legislation accommodate this change of interpretation, a benefit would be a reduction in the length of pipelines required and the possibility of using existing production wells for recovery.

Another potential cost-saving measure is to have two or more dual-purpose injection/recovery wells located within the same well site. Each well would be equipped for injection and for pumping into the distribution system. Opportunities to share electrical switch gear, piping, and measurement equipment would be available. Additional savings are possible if the number of wells required could be reduced. Further hydrogeological fieldwork is necessary to verify these savings potentials.

Supply Pipeline to Papago WTP

Alternative 5b incorporates a pipeline for transmission of recovered Town Lake seepage losses to the Papago Water Treatment Plant.

This transmission system includes a central wet well storage reservoir that collects water from the seepage recovery wells, a booster pump station, and pipeline to the Papago WTP. This pipeline has been sized at 36 inches in diameter and is approximately 8,000 feet in length. This route is within City right-of-way. This area of the City is known for shallow rock and higher pipeline excavation costs associated with the rock.

The estimated cost of the collection and conveyance system is shown in Table 6-8. The cost for the seepage recovery wells is not included. The recovery well system is further described in Section 4. The well system is an additional $2.61 million in capital and $0.2 million per year in operations and maintenance. The contingent estimates assume a greater quantity of rock excavation.

Table 6-8 Estimated Costs, Collection and Conveyance System				
	Probable Cost ($ million)		Contingent Cost ($ million)	
Component	Capital	O & M	Capital	O & M
Wet Well and High Lift Pumps	2.33	0.17	2.33	0.17
Pipelines	2.95		3.15	
TOTAL	5.28	0.17	5.48	0.17

Pipelines and Pump Stations

Many of the alternatives require pipelines and pipe networks to connect the various major components. For planning purposes these estimates for pressure pipes ranging from 12 inches to 18 inches are $75 per foot for pipelines with minor surface restoration, and $95 per foot for pipelines in developed areas (more significant surface restoration). Additional allowances are included for crossings of major streets, canals, utilities, and freeways.

Pump station costs have been estimated using a capital cost factor of $2,000 per installed horsepower of pumping capacity, with a minimum cost of $20,000. Operating cost is based on electrical energy cost of 7 cents per kilowatt hour plus consideration of annual labor requirements for maintenance.

Permitting Issues

A variety of permits are required to implement the Rio Salado project. Some of the permits may or may not be required, depending on the source water used to fill Town Lake. Following is a description of the permits and their applicability to the project.

National Pollutant Discharge Elimination System Permit

The National Pollutant Discharge Elimination System Permit (NPDES) is administered by the U.S. EPA. The Arizona Department of Environmental Quality (ADEQ) prepares the preliminary draft permit using technical information supplied by the applicant.

A NPDES permit is required for point source discharges to waters of the U.S. Both EPA and ADEQ consider the Salt River to be waters of the U.S. This permit is required for all sources of water that contain any contaminants. All of the potential water sources would require a NPDES permit except Salt River water. The water discharged will have to meet the requirements of Title 18, Chapter 1, Article 1, Water Quality Standards for Navigable Waters.

Section 404 Permit

A Clean Water Act Section 404 Permit is required when altering or disturbing an area greater than one acre within the 100-year floodplain of a water of the U.S. The 404 Permit is administered by the U.S. Army Corps of Engineers with input from various federal and state agencies. This permit will be required for construction of Town Lake and is independent of the water source.

Reclaimed Wastewater Reuse Permit

A Reclaimed Wastewater Reuse Permit, administered by ADEQ, is required when reclaimed wastewater is used for beneficial purposes. For the Rio Salado project, a reuse permit is required if reclaimed water is used for landscape or turf irrigation outside the 100-year floodplain. Any use of reclaimed water within the 100-year floodplain requires a NPDES permit. An annual water balance must be prepared to obtain a Reuse Permit.

Aquifer Protection Permit

An Aquifer Protection Permit (APP) is required for surface impoundments (Town Lake) and underground storage and recovery projects. The water source used will affect the monitoring requirements of the APP. APPs are issued by ADEQ. A hydrogeology report is required to obtain an APP.

Dam Safety Permit

Dam Safety Permits (DSPs) are required for construction of dams that exceed 6 feet in height and 50 acre-feet of storage. DSPs will be required for construction of the dams that form Town Lake. The Arizona Department of Water Resources (ADWR) administers the dam safety program in Arizona. ADWR reviews dam designs prior to issuing the permit. The water source will not affect the permits.

Underground Storage and Recovery Permit

An Underground Storage and Recovery (USR) Permit is required when water is recharged, stored underground, and then recovered. During the USR Permit processing, ADWR coordinates with ADEQ who will be processing the APP concurrently. The hydrogeology report prepared for the APP is submitted to ADWR for the USR Permit. Reclaimed water is the only water source currently being considered for underground storage and recovery.

Appropriation Permit

An Application for a Permit to Appropriate Surface Waters (Appropriation Permit) is required if Salt River water is stored within Town lake. The ADWR administers the appropriation of surface waters. Use of other water sources in Town Lake would not require an Appropriation Permit.

Aquatic Wildlife Stocking Permit

To stock Town Lake with fish, an Aquatic Wildlife Stocking Permit is required from the Arizona Game and Fish Department. The permit will describe the types and amounts of fish allowed in Town Lake.

Supply Alternative Evaluations

Alternative 1a—Direct Reuse from Kyrene WRF

This alternative uses the reclaimed water from the existing Kyrene WRF as the primary source of supply for the lake. Water from the Kyrene WRF is conveyed to the lake via a 5-mile pipeline that follows the railroad alignment described earlier. Since this alternative does not include water storage, the peak demands for lake supply (evaporation and seepage losses) must be met by the Kyrene WRF. On a summer day, the peak lake demand is about 2.1 mgd compared to the current capacity of the Kyrene WRF at 3.0 mgd. This would leave up to 0.9 mgd available for landscape irrigation or current other dedicated uses. The available 0.9 mgd is sufficient to maintain about 75 acres of grass during July (the peak month for irrigation demands).

Because nutrients (nitrogen and phosphorus) are highest in reclaimed water compared to other sources, this alternative results in the lowest lake transparency (water quality). Lake transparency is predicted to average 2 feet or less during midsummer. Significant problems associated with algae and aquatic weeds are likely with this water source.

The estimated costs for this alternative are shown in Table 6-9. A generalized layout is shown in Figure 6-3.

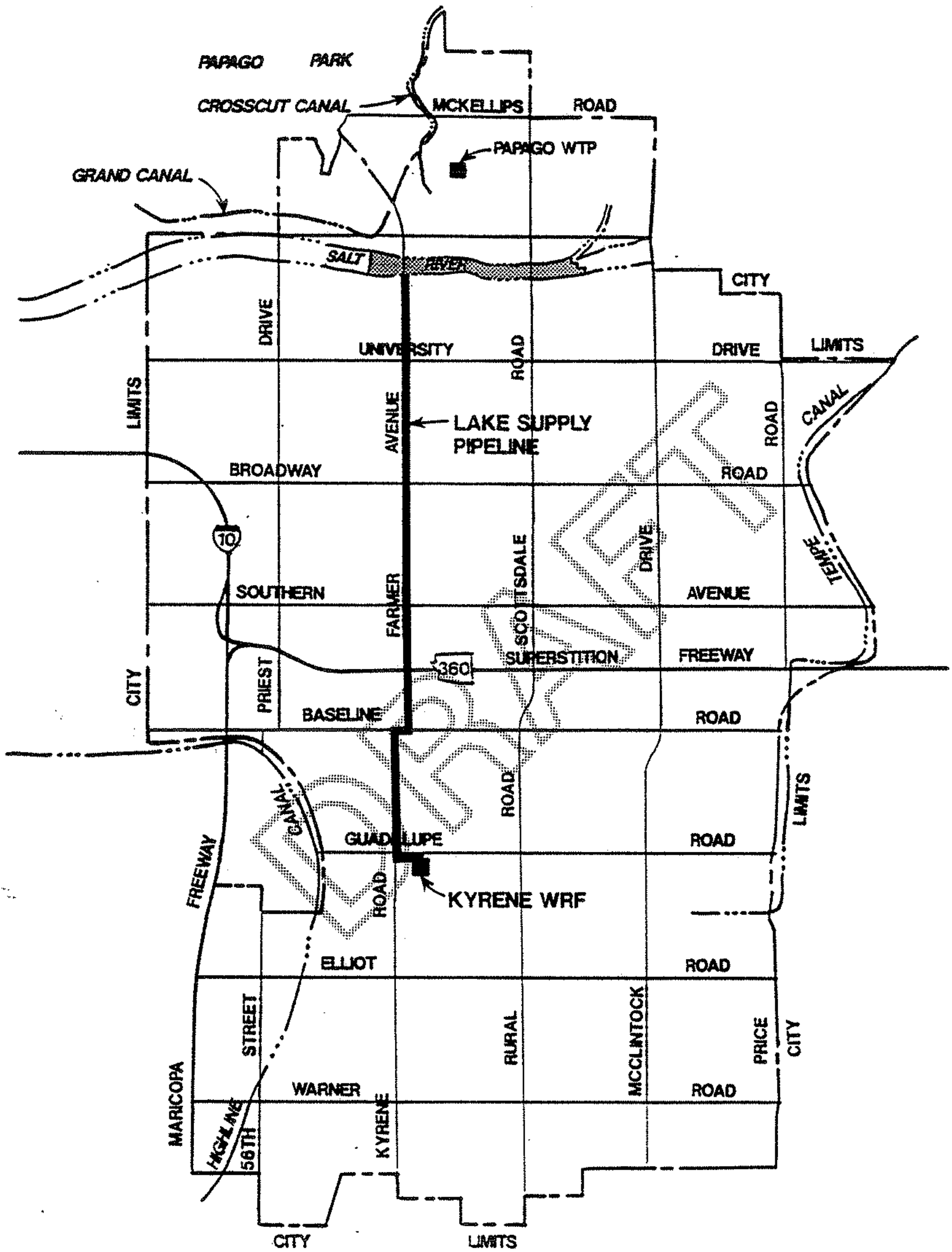


FIGURE 6-3

WATER SUPPLY ALTERNATIVE 1

Table 6-9 Alternative 1a—Direct Reuse from Kyrene WRF				
Supply Component	Probable Cost ($ million)		Contingent Cost ($ million)	
	Capital	O&M/yr	Capital	O&M/yr
Pipeline	4.32		5.87	
Pump Station	0.02	~	.02	~
TOTAL	4.34	~	5.89	~

The probable cost scenario described above is based on the "railroad" pipeline alignment. If easement costs associated with the railroad alignment become prohibitive, an alternative pipeline route could be considered. The contingent cost scenario is based on a pipeline route that is predominately within street rights-of-way and thus includes higher costs associated with pavement replacement and other higher costs of restoration of improved surfaces. Other routes could be considered for the pipeline (using canal ROW) that could result in construction cost within the range shown for probable and contingent scenarios.

Alternative 1b—Direct Reuse of Kyrene WRF Water After Additional AWT

This alternative is the same as Alternative 1a except that additional treatment processes have been added at the Kyrene WRF to reduce phosphorus concentrations in the reclaimed water. After additional treatment, reclaimed water is piped to the lake. There are five subalternatives producing varying levels of phosphorus in the reclaimed water. Each increment of phosphorus reduction improves the water quality (transparency) of the lake. The most significant improvement in lake water quality would result from producing phosphorus concentration to below 0.05 mg/l (Figure 6-3).

The estimates below are based on phosphorus reduction to 0.5 mg/l and 0.05 mg/l.

Table 6-10 Alternative 1b—Phosphorus Reduction to 0.5 mg/l				
Supply Component	Probable Cost ($ million)		Contingent Cost ($ million)	
	Capital	O&M/yr	Capital	O&M/yr
AWT	0.01	0.04	0.01	0.04
Pipeline	4.32		5.87	
Pump Station	0.02	–	0.02	–
TOTAL	4.35	0.04	5.90	0.04

Table 6-11 Alternative 1b—Phosphorus Reduction to 0.05 mg/l				
Supply Component	Probable Cost ($ million)		Contingent Cost ($ million)	
	Capital	O&M/yr	Capital	O&M/yr
AWT	2.32[a]	0.04	4.60[b]	0.07
Pipeline	4.32		5.87	
Pump Station	0.02	–	0.02	–
TOTAL	6.66	0.04	10.49	0.07

[a]Option E—Biological Removal with Alum
[b]Option F—Microfiltration

Alternative 2a—Indirect Reuse of Kyrene WRF After Surface Spreading ASR

This alternative is based on piping Kyrene WRF reclaimed water approximately 1-1/2 miles south to the City's "Hardy Farm" site for surface spreading aquifer storage. Aquifer storage at this site is currently being investigated for feasibility. Initial phase results are encouraging for recharge in excess of 3.0 mgd. This alternative contemplates that recovered water would have to be pumped within 1/2 mile of the spreading basins in accordance with current DWR guidelines. Thus recovered water would have to be pumped from the Hardy Farm site to the lake. A generalized layout is shown in Figure 6-4.

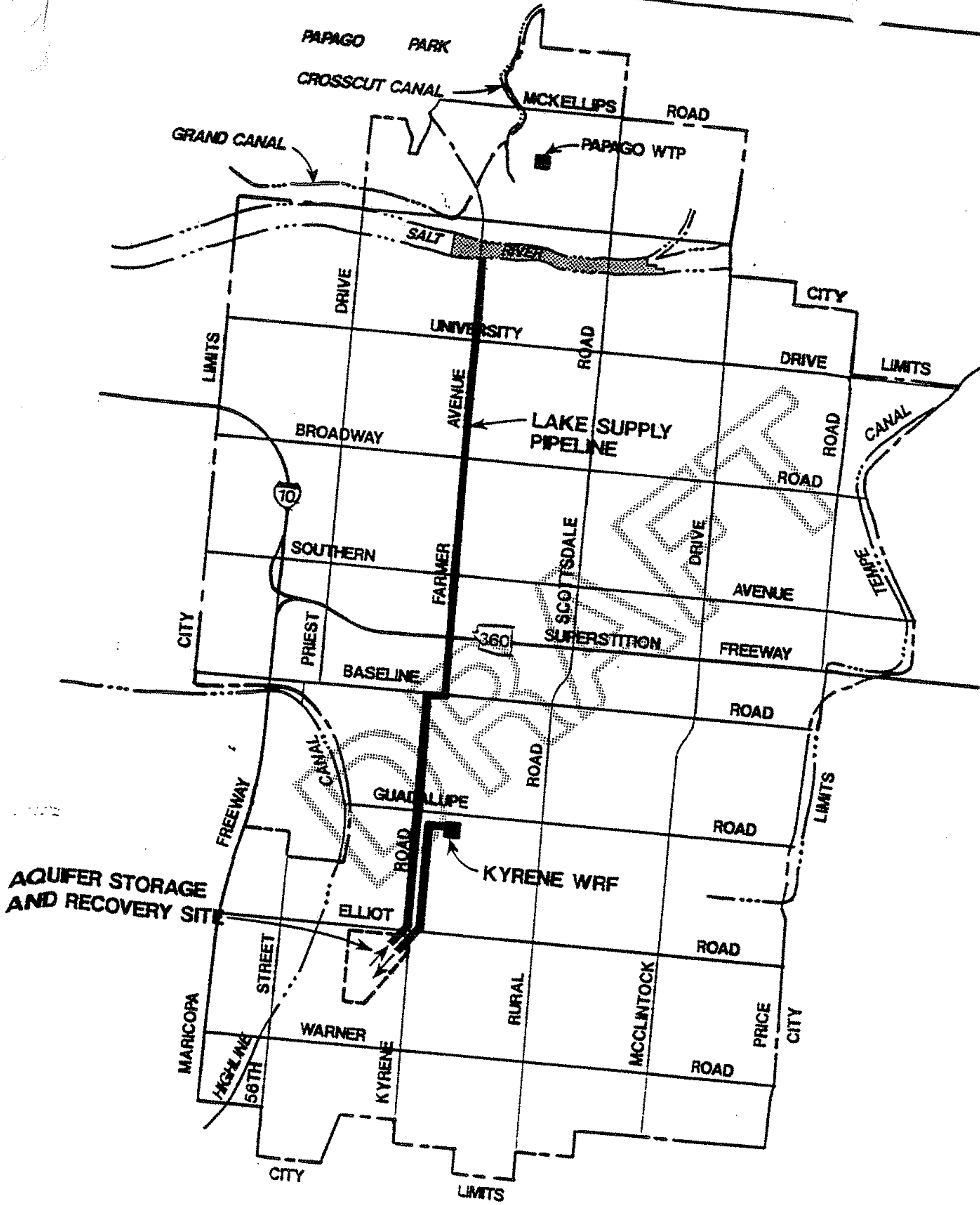


FIGURE 6-4
WATER SUPPLY ALTERNATIVE 2

Aquifer storage and recovery of reclaimed water provides for equalization of the winter to summer water demands of the lake and irrigated areas. With ASR, recharge could occur at a relatively steady rate over the year, while recovery (aquifer pumping) would occur at variable rates commensurate with the demand for water on any given day. In any year, the quantity pumped could not exceed the amount recharged. The recovered water would yield relatively high quality lake conditions, due to soil treatment and aquifer adsorption. Summer transparency could be among the best of any of the supply alternatives.

Table 6-12
Alternative 2a—Indirect Reuse of Kyrene WRF

Supply Component	Probable Cost ($ million)		Contingent Cost ($ million)	
	Capital	O&M/yr	Capital	O&M/yr
Loop Pipeline: WRF to ASR Site	1.65		1.65	
Spreading Basins	0.17	0.02	0.67	0.02
Monitoring Wells	0.35	0.02	0.49	0.03
Recovery Wells	1.05	0.13	1.05	0.13
Pump Station	0.04	~	0.04	~
Pipeline: WRF to lake	4.32		5.87	
TOTAL	8.08	0.17	9.77	0.18

Alternative 2b—Indirect Reuse of Kyrene WRF After Injection ASR

This alternative is the same as Alternative 2a except that injection well aquifer recharge technology is proposed instead of surface spreading basins. Injection wells require very little land area compared to surface spreading basins. Injection wells may require additional reclaimed water treatment prior to injection.

Table 6-13 Alternative 2b—Injection ASR at Hardy Farm				
Supply Component	Probable Cost ($ million)		Contingent Cost ($ million)	
	Capital	O&M/yr	Capital	O&M/yr
Loop Pipeline: WRF to ASR Site	1.65		1.65	
Injection, Recovery & Monitoring Wells	2.86	0.22	4.45	0.25
Pump Station	0.04	–	0.04	
Pipeline: ASR Site to lake	4.32		5.87	
Pretreatment	3.95[a]	0.82	10.75[b]	1.90
TOTAL	12.82	1.04	22.76	2.15

(a) Based on injection pretreatment Option D
(b) Based on injection pretreatment Option C

The contingent cost associated with this alternative relates to the need for additional treatment processes at the Kyrene WRF. Injection well clogging rates, and the frequency of redevelopment, is related to the quality of the water injected. The need for additional treatment can only be determined by pilot studies.

It is expected that recovered water from the ASR facilities would be of higher quality than the injected water. The water is improved in the saturated soils due to chemical adsorption processes. These chemical transformations over time could produce recovery water quality similar to groundwater. As a result, lake water quality (transparency) could be the best of any of the supply alternatives.

Alternative 3a—Direct Reuse of North Plant WRF

The process flow schematic for the proposed North Plant WRF is similar to the existing Kyrene WRF. Lake water quality is therefore assumed to be relatively poor and equal to that of the supply alternative using the Kyrene WRF. The primary difference between Alternatives 1a and 3a is the much shorter pipeline. A generalized layout is shown in Figure 6-5.

Since this alternative does not include flow equalization, the City's water resource planning for the North Plant must consider uses for North Plant WRF water beyond the requirements of the lake.

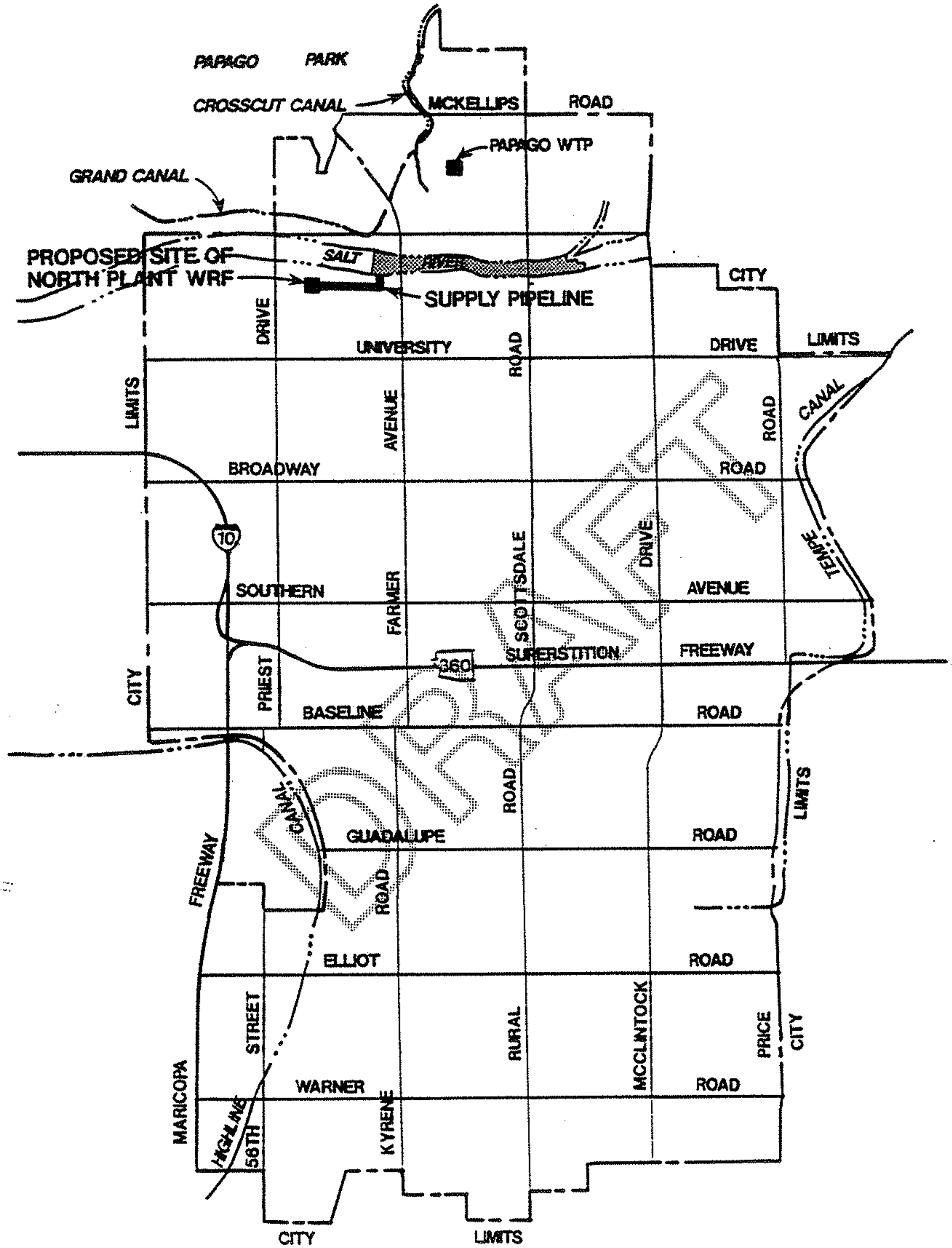


FIGURE 6-5

WATER SUPPLY ALTERNATIVE 3

Table 6-14 Alternative 3a—Direct Reuse of North Plant WRF		
Supply Component	Probable Cost ($ million)	
	Capital	O&M/yr
Pipeline	0.28	~
TOTAL	0.28	~

Alternative 3b—Direct Reuse of North Plant WRF Water After Additional AWT

This alternative produces lake water quality similar to Alternative 1b. Additional treatment processes are proposed to further reduce phosphorus concentrations in the reclaimed water below levels that are achievable with the North Plant WRF as currently proposed. Since it may be possible to incorporate the treatment process modifications into the plant design prior to bidding and construction of the facilities it is expected that the modifications at the North Plant WRF would be less costly than modifications to the existing facilities at the Kyrene WRF. Further, since the processes could be integrated into the design prior to construction, this alternative focuses on reducing phosphorus to the lowest concentration of 0.05 mg/l.

Table 6-15 Alternative 3b—North Plant with Phosphorous Reduction				
Supply Component	Probable Cost ($ million)		Contingent Cost ($ million)	
	Capital	O&M/yr	Capital	O&M/yr
Pipeline	0.28		0.28	
AWT	3.71[a]	0.07	4.60[b]	0.28
TOTAL	3.99	0.07	4.88	0.28

(a)Based on phosphorous reduction Option E
(b)Based on phosphorous reduction Option F

Alternative 4—Indirect Reuse of North Plant WRF After Injection ASR

This alternative is similar to Alternative 2b in the potential for yielding lake water quality with relatively high transparency. The difference between the alternatives are (1) the source of reclaimed water is the proposed North Plant WRF instead of the existing Kyrene WRF, and (2) the injection well site would be north of the Superstition Freeway rather than the Hardy Farm site. A generalized layout is shown in Figure 6-6.

Table 6-16
Alternative 4—Indirect Reuse of North Plant WRF After Injection ASR

Supply Component	Probable Cost ($ million)		Contingent Cost ($ million)	
	Capital	O&M/yr	Capital	O&M/yr
Loop Pipeline: WRF to ASR Site	6.97	–	6.97	–
Injection, Recovery & Monitoring Wells	2.86	0.22	4.45	0.25
Pretreatment	3.95[a]	0.82	10.75[b]	1.90
TOTAL	13.78	1.04	22.17	2.15

[a] Based on injection pretreatment Option D
[b] Based on injection pretreatment Option C

Alternative 5a—SRP Urban Reservoir

This alternative uses SRP water from the Tempe Canal as the source of supply for the lake. In this alternative the lake is considered an equalizing reservoir on the SRP canal system. Water would flow into the lake from the Tempe Canal and be stored in the lake as needed prior to release to the Grand Canal. SRP has indicated that the canal system could benefit from the ability to move water from the Tempe Canal to the Grand Canal. The City has also indicated that there would be additional benefit associated with using the lake in an equalizing mode giving SRP the ability to instantaneously withdraw up to 35 cubic feet per second (cfs) for up to 6-hour periods to supply the Grand Canal. Because of the large volume of water in the lake compared to this rate of demand, water levels in the lake would only have to fluctuate a few inches to accommodate this equalizing use. A generalized layout is shown on Figure 6-7.

Water quality in the lake would be the same as the SRP canal system.

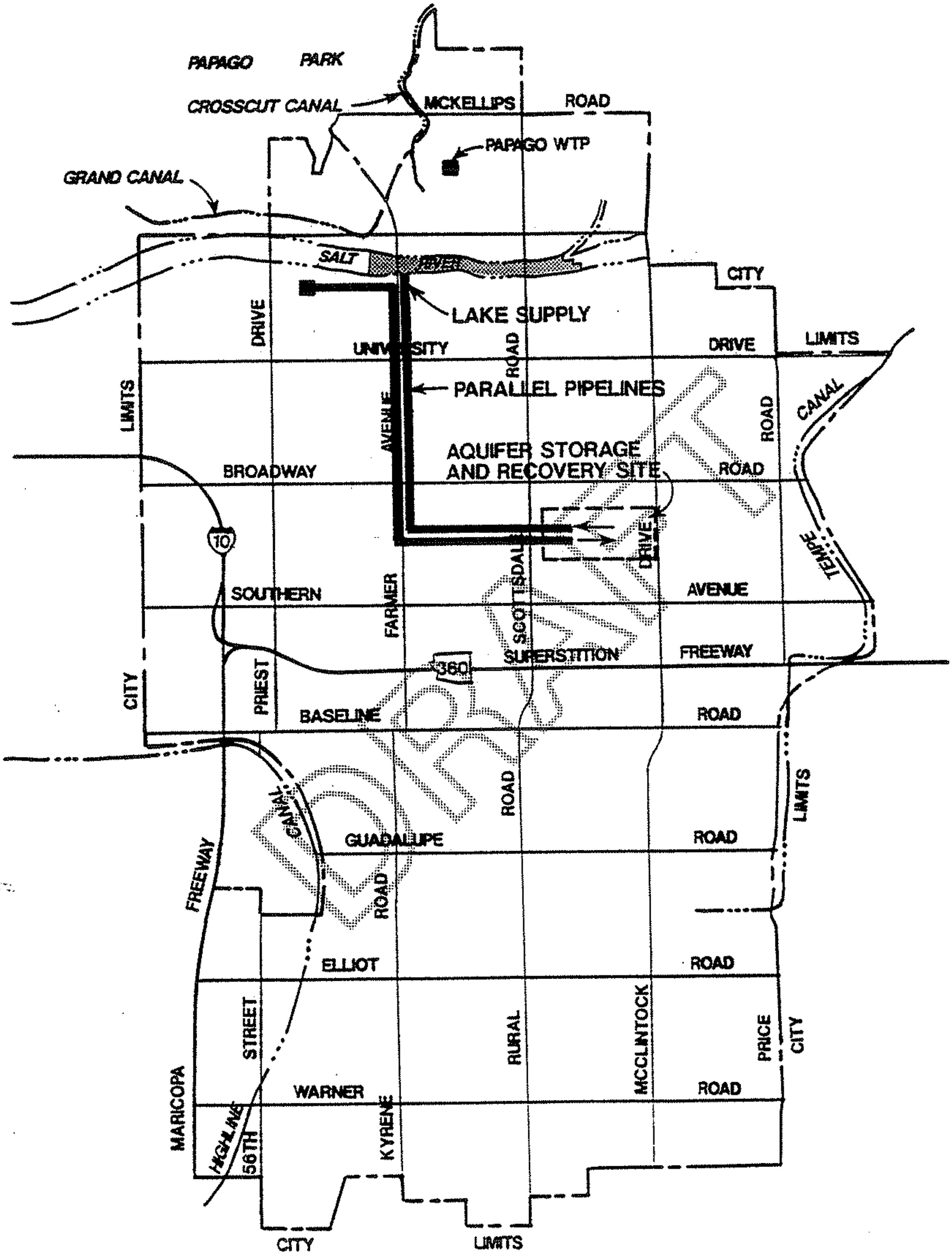


FIGURE 6-6
WATER SUPPLY ALTERNATIVE 4

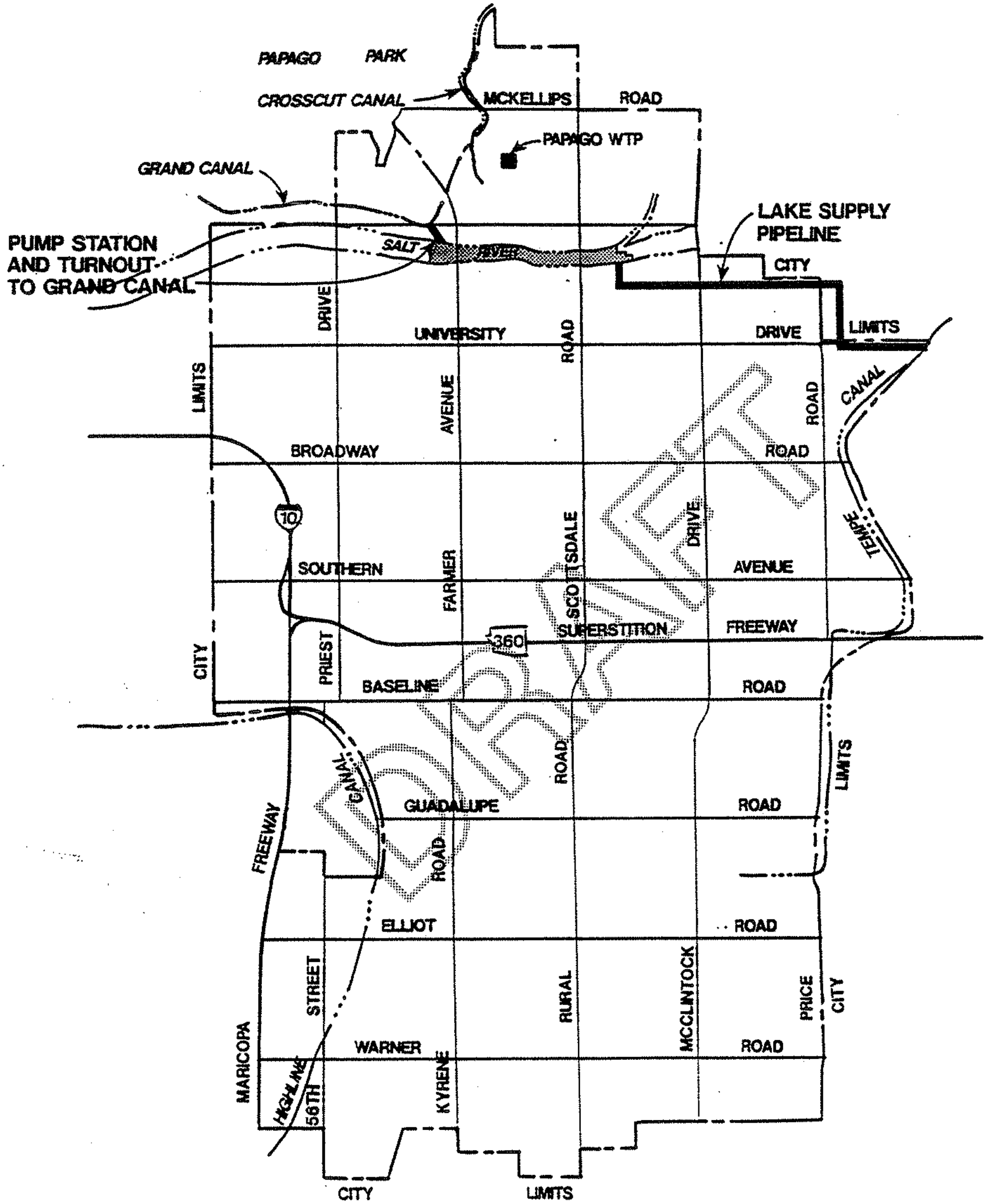


FIGURE 6-7
WATER SUPPLY ALTERNATIVE 5

Table 6-17 Alternative 5a—SRP Urban Reservoir		
Supply Component	Probable Cost ($ million)	
	Capital	O&M/yr
Tempe Canal and Pipeline Turnout	5.83	–
Grand Canal Turnout and Lift Station	2.24	0.01
TOTAL	8.07	0.01

Because the lake is created using SRP water, the City would be required to remove as much storm drainage into the lake as possible. SRP has an ongoing program to eliminate stormwater entry into the canal system. Existing storm drains that currently discharge to the Salt River channel (within the reach of the lake) may have to be completely rerouted.

Unresolved issues with this alternative are the source and mechanism for providing water to SRP to replace lake losses, operations, and maintenance.

Alternative 5b—SRP Urban Reservoir with Partial Supply to Papago WTP

This alternative is the same as Alternative 5a except that the lake seepage control system is a network of Ranney and conventional wells that intercept lake seepage losses, and the collected water is pumped to the Papago Water Treatment Plant. At times when the Papago WTP is not operating the collected seepage would be returned to the lake.

Table 6-18 Alternative 5b—SRP Urban Reservoir with Partial Supply to Papago WTP				
Supply Component	Probable Cost ($ million)		Contingent Cost ($ million)	
	Capital	O&M/yr	Capital	O&M/yr
Tempe Canal Turnout and Pipeline	5.83		5.83	
Grand Canal Turnout and Lift Station	2.24	0.01	2.24	0.01
Seepage Recovery System	See seepage discussion in Section 4			
Collector Pump Station and Pipeline to Papago WTP	5.28	0.17	5.48	0.17
TOTAL	13.35	0.18	13.55	0.18

The contingent cost scenario for this alternative includes allowances for additional rock excavation for the pipeline from the collector system to the Papago WTP. The seepage recovery system costs are an additional $2.61 million capital cost and $0.2 million operations and maintenance.

Alternative Evaluation Matrix

The matrix shown in Table 6-19 summarizes information presented in this section plus Sections 3, 4, and 5, related to the supply alternatives. The parameters are:

- **Potential beneficial uses.** The anticipated range of beneficial uses that will be supported by the lake depends on the ability of each source to meet regulatory and aesthetic constraints.
- **Probable average lake transparency.** The transparency of the water is used here as an indicator of general water quality. It is implicitly assumed that most other narrative quality measures such as number and extent of algal blooms, odors, fish kills, as well as numeric parameters, are relatively well predicted by the transparency.
- **Costs.** Conceptual-level costs described in previous sections are summarized. Both capital and basic operations and maintenance costs are shown.
- **Anticipated permits.** The major permits, requiring significant investments of time and/or expense to coordinate are the APP, reuse, and NPDES

Table 6-19
Alternative Evaluation Matrix

Evaluation Parameter	Supply Alternative*								
	1a	1b	2a	2b	3a	3b	4	5a	5b
Potentially available beneficial lake uses:									
Boating	yes	yes	yes	yes	yes	yes	yes	yes	yes
Fishing	maybe	yes	yes	yes	maybe	maybe	maybe	yes	yes
Swimming	no	no	maybe	maybe	no	no	maybe	no	no
Probable Average Lake Transparency (ft)	1.9 ft.	2.5 - 5	6.2	6.2	1.9	2.5	6.2	3.7	3.7
Water Supply Cost ($x1000)									
Capital									
O&M									
Major Permits Anticipated:									
APP	yes	yes	yes	yes	yes	yes	yes	maybe	yes
Reuse	yes	yes	yes	yes	yes	yes	yes	maybe	maybe
NPDES	yes	yes	yes	yes	yes	yes	yes	maybe	maybe
Permitting "complexity" Low, Moderate, High	L	L	M	H	L	L	H	M	H
Appropriate Level of stormwater protection: Low, Moderate, High	L	M	M	M	L	M	M	H	H
Related stormwater protection cost									
Degree of SRP participation required	L	L	L	L	L	L	L	H	H
Water rights trades required to effect supply	no	no	no	no	no	no	no	maybe	maybe
ASR provides seasonal equalization	no	no	yes	yes	no	no	yes	NA	NA
Seepage control option Cutoff, Lines, Recovery	C,L,R	C,L,R	C,L,R	C,L,R	C,L,R	C,L,R	C,L,R	C,L,R	R
Lake water quality management requirements Low, Moderate, High	H	M	L	L	H	M	L	M	M
Flexibility and Reliability Low, Medium, High	M	M	H	H	M	M	H	L	L
Public Perception and Acceptance	L	M	H	H	L	M	H	H	H

*Alternatives
1a—Direct Reuse from Kyrene WRF
1b—Direct Reuse of Kyrene WRF Water After Additional AWT
2a—Indirect Reuse of Kyrene WRF After Surface Spreading ASR
2b—Indirect Reuse of Kyrene WRF After Injection ASR
3a—Direct Reuse of North Plant WRF
3b—Direct Reuse of North Plant WRF After Additional AWT
4—Indirect Reuse of North Plant WRF After Injection ASR
5a—SRP Urban Reservoir
5b—SRP Urban Reservoir with Partial Supply to Papago WTP

permits. In addition, the general anticipated level of complexity of the permit process for each alternative is evaluated. This list is not exhaustive and other permits may actually be required.

- **Recommended level of stormwater management and costs.** The risks associated with stormwater discharges into the lake reflect the "costs" of episodic non-support of designated lake uses and the sensitivity of the lake to the pollutant loading caused by the stormwater.

- **Degree of SRP participation required/water rights trades.** This parameter reflects the degree to which the source water is subject to control by outside interests. Participation by SRP, Mesa, Scottsdale, or an Indian Community, entails constraints on the use of the source to meet the need of that entity.

- **ASR storage.** ASR provides a storage mechanism that facilitates seasonal and operational storage. This storage would allow the City more flexibility in managing the resource.

- **Seepage control options.** This parameter illustrates constraints on the seepage control methods applicable with each source.

- **Lake water quality management.** The appropriate choices of options for managing the quality of the lake water vary with the source, uses, and sensitivity to variations in quality. This parameter is a general indication of the intensity of management required and therefore the relative costs.

- **Flexibility/reliability.** The flexibility and reliability of each source depends on the susceptibility of that source to shortage, outage, variation in quality and regulatory/institutional control. Lower values reflect a need for more conservative design and increased risk of *non-support of designated uses*.

- **Public acceptance.** Public perception regarding issues such as the quality of effluent and the responsible use of water resources is difficult to estimate. This parameter reflects possible sensitivity of the source alternatives to public perception.

Section 7
Lake Management

Maintaining an attractive, stable lake environment that consistently delivers the greatest benefits to Tempe, requires a proactive management program. The program should be flexible, with a variety of management tools, and it should be responsive to changing water quality conditions. An effective management program will mitigate the natural degradation of Town Lake, including oxygen depletion, stratification, algae and weed growth, nutrient and metals concentrations, unpleasant odors, and the accumulation of shoreline trash. A water quality monitoring program is essential to anticipate and alleviate undesirable conditions.

Six management techniques are described in this section. Most of these techniques have been implemented at existing lake features in the Phoenix metropolitan area, and are considered appropriate for Town Lake:

- Artificial circulation
- Hypolimnetic withdrawal
- Dilution and flushing
- Mechanical harvesting
- Chemical control
- Fish population

Additional components of the plan should include preventive techniques such as control of resident and migratory waterfowl populations, landscaping to minimize runoff and erosion, trash collection, and fisheries management. All of the techniques described in this section are appropriate, regardless of the primary and maintenance water source. The frequency, intensity, and cost of management activities will be tailored to the project, depending upon the characteristics of the source water and the intended uses of the lake.

All the water supply alternatives under consideration for Town Lake will support aquatic vegetation and free-floating algae. The estimates of total system productivity indicate that some options (direct use of reclaimed water) will have a large potential for creating objectionable over-fertilization of the lake. It should be recognized that management techniques are not likely to influence Town Lake water quality to the same degree as the choice of primary water supply. Management and restoration techniques can mitigate predictable problems and respond to changing conditions but, for the most part, they will have little influence on the overall productivity of the system. Nutrient content, especially phosphorus and nitrogen, of the source water will dictate the average quality and appearance of Town Lake more than any other single factor.

Description of Lake Management Techniques

A brief discussion of lake management techniques is provided below. Advantages and disadvantages of the technique are discussed, and conceptual cost estimates are provided where appropriate.

Artificial Circulation

Algae growth typically occurs in warmer, sunlit water near the surface of a lake. As the biomass grows, some of the algae settles into darker, more stagnant water below the surface (hypolimnion). Bacterial decay and organic bottom mud deplete the dissolved oxygen content of the water, resulting in undesirable odors. In the Phoenix area, stagnant, stratified lakes may also contribute to extensive fish kills during times of high productivity (spring, summer, fall).

The objectives of artificial circulation are to prevent stratification of the water column and improve aeration and chemical oxidation in the lake. Mixing also reduces algal production by diminishing the penetration of sunlight near the surface.

Tempe wind data and estimates of natural circulation suggest that wind mixing alone is inadequate to provide continuous lake circulation. One method of artificial circulation can be achieved through air-lifting, which is common in Phoenix area lakes. Air-lifting is accomplished by injecting compressed air into the deepest portion of the lake where it usually affords the greatest rate of mixing as air bubbles rise to the surface. Air injection in shallow water provides limited benefits.

Some degree of aeration is recommended for each of the Town Lake water supply options. The number of air diffusers, and the volume of air supplied to the lake will be determined during preliminary design, after the source water and intended uses of the lake have been determined. One concept for Town Lake was developed with the goal of mixing portions of the lake that exceed 10 feet in depth, or an area roughly bounded by Mill Avenue to the east and Grade Control Structure 4 to the west. The design consists of a grid of 21 air diffusers, each spaced approximately 300 feet apart. Roughly 7,000 feet of 2- to 4-inch flexible pipe is required to supply the air for this system.

At least two engineering options are available for installing the air piping network. Typically, low cost, flexible plastic pipes and in-line diffusers are anchored to the lake bottom. The installation is above-ground, and therefore relatively quick and inexpensive. A notable drawback is the system's susceptibility to damage from drawdown of Town Lake during storm events or major reservoir releases. High maintenance and repair costs may be attributed to the frequency of repair. One estimate of capital costs for a sacrificial air injection system in Town Lake is $50,000, but considerable refinement is necessary based on site-specific information.

Alternatively, pipes installed below the scour depth of the river will provide a permanent air distribution system. Initially, a permanent system is far more expensive, but requires less labor and expense for operations and maintenance.

Hypolimnetic Withdrawal

Hypolimnetic withdrawal removes deeper, nutrient-rich, and oxygen depleted water from the lake bottom. Removing the hypolimnetic water decreases the residence time of the hypolimnion, thereby increasing the oxygen content at the sediment-water interface, and decreasing the internal phosphorus loading. The technique has been applied successfully in Europe and the United States. Observed water quality improvements include reduced internal loading from sediments, increased oxygen concentrations, and increased transparency.

Benefits of this technique assume that the lake is deep enough to stratify and form a hypolimnion. The potential for success is greatest for stratified lakes with high internal loading of phosphorus. Although Town Lake is expected to stratify during the summer near the deepest part of the lake, artificial circulation by aeration supplemented by hypolimnetic withdrawal should effectively counter this tendency.

Hypolimnetic withdrawal is attractive because of the simplicity of design and operation. At Town Lake, the hypolimnetic withdrawals could supply water features below the dam, or serve as a source of water for landscape irrigation. An engineering concept for Town Lake consists of a transverse collection pipe anchored to the dam foundation, drawing water from behind the dam near the lake bottom. The pipes could penetrate the dam and provide water for downstream features, or deliver water to a sump for irrigation pumps.

Dilution and Flushing

Introducing a source of low-nutrient water to a eutrophic lake, whether on a continuous or periodic basis, acts to dilute the concentration of nutrients and flush out algal cells. The addition of low-nutrient water reduces nutrient concentrations and the potential for algal production. By increasing the fresh water input, a flushing action may occur, and at high rates may act to scour nutrient-laden or contaminated sediments from the lake bottom.

Observed benefits of dilution include a reduction in phosphorus and chlorophyll concentrations. The benefits of dilution and flushing are immediate and proven effective. Supply Alternative 5, involving SRP is the only realistic option for sufficient source capacity to provide a flushing action.

At Town Lake, high-quality surface water from the Salt River Watershed may be available for dilution and flushing. Salt River Water could be supplied to the lake in two ways: run-of-the river releases below Granite Reef Dam, or delivery of Salt River

Project (SRP) water via SRP's exiting irrigation distribution canals. Run-of-the-river releases are infrequent and undependable, but most often occur in February and March. Excess flows in the river could be used to dilute the lake during routine reservoir releases, and flush bottom sediments during major storm events. As the storm hydrograph recedes, low-nutrient water could be captured and impounded behind the inflatable west dam. One disadvantage of this scheme is that excess flow in the Salt River is rare during summer months when it may be most beneficial to the quality of Town Lake.

A highly dependable source of low-nutrient water may be available from SRP's Tempe Canal near University Road in east Tempe. One design concept for Town lake includes a new distribution pipe from the canal to the lake (see Water Supply Alternatives 5a and 5b).

Mechanical Harvesting

Harvesting of aquatic plants removes undesirable vegetation that either interferes with the lake's recreational and aesthetic benefits, or may be undesirable habitat for wildlife. Aquatic weed growth is a common lake management problem in the Tempe area.

The basic steps in harvesting aquatic vegetation are cutting, or separation of vegetation, collection of plant material, processing and storage, transportation to the shore, and disposal. Harvesting of the vegetation can occur either in a single-stage harvest by one machine or in multiple stages where cutting, collection, transport, and disposal are conducted by separate equipment. The factors affecting aquatic plant harvesting depend on site-specific characteristics; the type, density, and distribution of vegetation; public perception; and financial resources.

Some of the technologies available for mechanical control of submerged aquatic vegetation include aquatic plant fragment barriers, lake-bottom barriers, hydraulic dredging, diver-operated dredging, rototilling, and harvesting. The mechanical harvester is essentially a submerged mower, towed by boat or barge. Conveyer belts stockpile the weeds onboard for offsite disposal.

At Town Lake, the City will likely need a mechanical harvester, or subcontract this activity on a continuous basis. The primary benefits of mechanical harvesting consist of the removal of nuisance, and undesirable weeds, biomass, and nutrients. Drawbacks, however, include the potential spread of undesirable plant species, possible harm to fish and waterfowl populations, and labor and equipment costs. Lake features such as loading docks and truck access ramps are necessary to facilitate weed removal.

Capital and operations costs will fluctuate seasonally, and depend to a greater extent on source water quality. One estimate of annual expense for a similar size lake is $30,000 to $180,000 dollars.

Chemical Control

Chemical control of water features is commonly practiced in the Phoenix/Tempe area. With proper chemical applications, nuisance macrophytes can be killed, controlled, and maintained at acceptable population densities with minimal potential for human or wildlife toxicity. Herbicide treatments are a rapid, effective short-term management technique for temporarily reducing nuisance vegetation. Table 7-1 summarizes common aquatic weed species and responses to herbicides.

Algal growth can occur quickly and the appropriate response depends on species and the extent of algal blooms. Chelated copper compounds are most effective against free-floating and filamentous algae, whereas a variety of other organic herbicides are effective against specific aquatic weeds. Floating aquatic vegetation can be controlled with 2,4-D (2,4-dichlorophenoxyacetic acid), diquat (6,7-dihydrodipyrido[1,2-,:2,1-c] pyrazinediium ion), and endothall (7-oxabicyclo[2.2.1] heptane-2,3-dicarboxylic acid). Emergent broadleaf vegetation can be controlled with 2,4-D, dalapon (2.2-dichloropropionic acid), and glyphosate (N-(phosphonomethyl)glycine). Submerged aquatic vegetation can be controlled 2,4-D, copper sulfate, copper carbonate, organic compounds of copper, diquat, dichlobenil (2,6-dichlorobenzonitrile), and endothall. The effect of these herbicides on floating, emergent, and submerged vegetation can be species-specific in certain instances, and less effective on others.

Although herbicides and plant growth regulators are relatively non-persistent in natural environments, these chemicals do cause changes in aquatic ecosystems. Impacts from these chemicals must be considered for their toxicity to the target species, relative toxicity to non-target species, fate of residues and their significance to water, fish and public health, and conditions that affect toxicity, efficacy, and persistence. Synergistic and antagonistic activity of carriers, metabolites, and degradation products should also be considered. Public perception and environmental risks associated with chemical applications dictate that chemical control should be a last resort at Town Lake.

The Environmental Protection Agency (EPA) regulates the application of pesticides and establishes maximum contaminant levels (MCLs) for residual pesticide concentrations in drinking water. State agencies such as the ADEQ may impose more stringent standards than the federal regulations. All of the applicable laws should be reviewed before chemical treatment is initiated. At Town Lake, licensed professionals may be required to apply the chemicals.

Furthermore, chemical treatments of Town Lake must be compatible with intended use of the lake. Potable reuse of lake seepage losses, such as the proposal to deliver water to the Papago Water Treatment Plant, may not be compatible with chemical treatments. Town Lake as an in-line reservoir for SRP water may require conformance with SRP's treatment policies.

The cost of chemical treatments in Town Lake depends on the type of herbicide, the

Table 7-1
Common Aquatic Weed Species and Their Responses to Herbicides
(Adapted from Nichols, 1986)

	Diquat	Endothal	2,4-D	Glyphosate (Rodeo)	Fluridone (Sonar)
Emergent Species					
Alternanthera philoxeroides (alligatorweed)			C	C	C
Dianthera americana (water willow)			C		
Glyceria borealis (mannagrass)	C	NC	NC		
Phragmites spp (need)				C	
Ranunculus spp (buttercup)			C		
Sagittaria sp (arrowhead)	NC	NC	C		C
Scirpus spp (bulrush)	NC	NC	C		C
Typha spp (cattail)	C	NC	QC	C	QC
Floating Species					
Brasenia schreberi (watershield)	ND	NC	C		NC
Eichhornia crassipes (water hyacinth)	C[a]		C		NC
Lemna minor (duckweed)	C	NC	NC		NC
Nelumbo lutea (American lotus)	NC	NC	QC	NC	
Nuphar spp (spatterdock)	NC	NC	C	C	C
Nymphaea spp (waterlily)	NC	NC	QC	C	C
Submerged Species					
Ceratophyllum demersum (coontail)	C	C	C		C
Chara spp (stonewort)	NC[b]	NC[b]	NC[b]	NC[b]	NC[b]
Elodea spp (elodea)	C	QC	NC		C
Hydrilla verticillata (hydrilla)					C
Myriophyllum spicatum (milfoil)	C	QC		NC	C
Najas flexilis (naiad)	C	QC	NC	NC	C
Najas guadalupensis (southern naiad)		QC	NC		C
Potamogeton amplifolius (large-leaf pondweed)	QC	C	NC		
P. crispus (curly-leaf pondweed)	C	C	NC		
P. diversifolius (waterthread)	NC	C	NC		
P. natans (floating leaf pondweed)	C	C	C		
P. pectinatus (sago pondweed)	C		C	NC	C
P. illinoiensis (Illinois pondweed)					C

[a] Plus chelated copper sulfate
[b] Controlled by copper sulfate

Legend:

C = Controlled
NC = Not Controlled
BLANK = Information Unavailable
QC = Questionable Control

Source: From U.S. Environmental Protection Agency (1988) dosage, and the frequency of application. Each of these factors must be evaluated on a case-by-case basis. However, one chemical treatment of Town Lake might cost between $75,000 to $150,000 dollars.

Fish Populations

Herbivorous fish species in Town Lake may be beneficial for algae and aquatic plant management. Plant-eating *Tilapia* species frequent the Salt River drainage and are stocked in the Phoenix/Tempe area for algae and weed control. *Tilapia* should be stocked and managed in Town Lake if fisheries are consistent with desired lake uses. Mosquito fish may also be beneficial for insect control.

Sport fish may not be compatible with beneficial herbivorous fish. For example, largemouth bass should probably not be stocked as they often tend to eliminate other species. *Tilapia*, bluegill, sunfish, and catfish could all be sustained in Town Lake, as they are in other Tempe area lakes. Smaller forage fish will probably invade the system with the Salt River flows. A fisheries program in Town Lake should be consistent with the recommendations of the Arizona Game and Fish Department.

Town Lake Management Plan

Each of the lake management techniques described in the previous section is recommended for phased implementation, regardless of the source water. These primary management components will contribute to the following goals:

- Control the production of aquatic weeds and algae
- Maintain visual and recreational appeal
- Anticipate adverse water quality impacts
- Achieve the highest recreational and economic returns
- Avoid health concerns and negative public perception

In addition to these continuous management activities, a comprehensive management plan should include a combination of preventive measures, routine maintenance, and provisions for quick response to rapidly changing lake conditions.

Preventive Measures

Several components of the lake management program are meant to be preventive. Preventive activities include landscape design and maintenance that emphasizes erosion control, low fertilizer use, and minimal production of organic debris. Control of resident and migratory waterfowl, and a comprehensive water quality monitoring program are also preventive measures.

Irrigated landscaping is an integral part of the Rio Salado project. The landscape plans should enhance the aesthetic appeal of the project, while contributing to prudent water quality management. Strip parks and public use areas adjacent to the lake should be designed to retain localized stormwater runoff, thereby avoiding direct discharges to the lake. Seeding and maintenance of undeveloped properties north of the lake, and the construction of new retention basins may limit erosion potential and freeway runoff. Fertilizers are among the most significant sources of nutrient loading in receiving waters, so an emphasis on low-use or alternative soil supplements is desirable. Finally, landscape plans should avoid the use of species that may contribute organic debris such as leaves, branches, and lawn clippings to the lake. At a minimum, floating debris is unsightly.

Waterfowl populations, although an integral part of aquatic wildlife, can be detrimental to urban lakes. They muddy and destroy lakeside vegetation and lawns and contribute to the overfertilization of the lake. A program of public education and active management should be implemented to discourage the feeding of domesticated ducks and geese. The use of the lake by migratory waterfowl can be encouraged through the development of a shallow area with emergent aquatic vegetation, but extensive populations of resident birds should be discouraged. The Arizona Game and Fish is a resource for developing waterfowl management plans.

Water quality monitoring is integral to the lake management program and must be considered ongoing and preventive. Public health concerns such as waterborne pathogens (fecal coliform) and lake nutrient levels, as measured by water clarity and observations of algal growth, should be monitored weekly or as conditions warrant. The program will require trained personnel operating water quality sampling equipment and field meters from a boat. Results should be charted and reviewed in real time to be effectively used in lake management decisions.

Trash Accumulations

Floating debris of all kinds, man-made and plant materials, are a common problem of urban lakes. A management program of straining debris from the lake will prevent unsightly accumulations along windward shores. Removal may be by hand netting or mechanical screens towed from a boat. The trash cleanup program should be routine and continuous. Trash racks should be used on any stormwater inputs.

Lake Management Should be Minimally Intrusive

The management of Town Lake will need to be continuous and frequent, yet must not interfere with public use of the lake. Mechanical weed harvesting or aeration can be accomplished in locations away from most public recreation. Pumping systems should be designed for minimal public perception. Chemical control can be done in a manner to minimize disruption of normal lake activities. All management programs should be designed to minimize impacts to fish or wildlife as well. A program of public involvement through notices and newsletters can help ensure positive and informed attitudes towards lake management.

Maintain Flexibility

The Town Lake management program should be dynamic, and responsive to monitoring in an unpredictable, newly created environment. Although traditional water quality problems will be encountered, Town Lake is unique in morphometry, hydrology, and source water, and other site-specific characteristics. New reservoirs commonly undergo an evolution in species and system productivity in response to management and invasions of plants and animals over several years. Likewise, Town Lake will evolve and remain dynamic for several years. Variable conditions will persist due to its unique location, combination of source water, maintenance water, stormwater inputs, and flushing from river flows. As such, the management program must be continuously responsive to lake conditions and should have a number of components in place (e.g. aeration, weed control, harvesting) for use with any of the maintenance water options. Chemical Treatments and the unique option of lowering Town Lake to flush the system should be reserved for particularly intractable or severe water quality problems.

Cost

Annual costs for the management of Town Lake may fluctuate drastically depending upon the source water quality, season, temperature, stormwater discharges, public perception, and beneficial uses. The actual costs will not be apparent until the lake is created and maintained over a period of 5 to 10 years. A reasonable expectation for range of annual maintenance costs is from $200,000 to over per $500,000 per year.

Section 8
Implementation Plan

This section discusses implementation of the project beyond the feasibility study phase represented in this Engineering Report.

This report has been prepared and submitted to the City in draft form for review and comment prior to final printing. It is expected that direction received during these final review meetings will require modification and expansion of this section of the report.

Preferred Plan Selection

The information contained in this report will be used by the City in ongoing water resource management planning to select a preferred source of supply to the Rio Salado Town Lake. Among the most significant issues affecting the decision on source of supply is the City's level of continued participation and use of the 91st Avenue regional wastewater treatment system. This decision affects the expansion of the Kyrene WRF and construction of other wastewater reclamation facilities. Decisions on water reclamation facility construction is also conversely related to the question of how much water is required to sustain a lake. Over the life of this Engineering Report, this latter question (How much water is required to create a lake?), was resolved by TM8, the Town Lake Feasibility Study as modified by this Engineering Report. With the water demands for the lake established, the City is now in the position to make the related decisions regarding the quantity of reclaimed water that is (or will be made) available.

Thus, selection of the preferred supply option is the first step in preparing a specific project proposal for initiation of the environmental permitting process. Once a specific plan is selected, then geotechnical and predesign activities can be performed to support the technical requirements of the environmental permits.

Geotechnical investigations could be considered for immediate implementation to the extent that the geotechnical results might aid in further defining the preferred plan. This would be true, for example, in the case of further hydrogeotechnical investigations that would more conclusively determine the feasibility and cost associated with the alternative lake seepage control technologies.

Unresolved Issues

Key unresolved issues that must be addressed in the context of the City's overall water resource management planning for Rio Salado are:

- Current and future availability of reclaimed water for Rio Salado in relation to the City's continuing role in the 91st Avenue Regional Wastewater Treatment System.

- Salt River Project's interest in a defined role in the Rio Salado project. This role could vary from a limited role in operating the dams, to a larger role of SRP supply, ownership, maintenance, and operations of the lake for purposes of creating an SRP urban reservoir.

- There is a state agency issue (ADWR) that affects the cost of aquifer storage and recovery systems, and the water supply options that require a transmission pipeline to convey water to the lake. This issue involves the distance between the point(s) of aquifer recharge and the point(s) of aquifer recovery (wells). Lawsuits are pending and legislation is being considered by affected cities that would allow greater separation between the recharge and recovery locations. The significance can be shown by the example of potentially eliminating the need for approximately $5 to $6 million in pipeline costs associated with certain supply alternatives.

- Current state regulations and SRP's associated policies prohibit using the SRP canals for conveyance of reclaimed water. This prohibition is on a legal-administrative basis and has no bearing on the quality of the reclaimed water. Reclaimed water can often be of higher quality than SRP water. This prohibition affects water trades, and water rights trades for supply alternatives that involve indirect reuse of Kyrene WRF reclaimed water. At present, Kyrene WRF reclaimed water would have to be piped to a dedicated agricultural user rather than simply discharging to the nearest canal to affect an exchange.

- Use of the Southern Pacific Railroad right-of-way for the pipeline between the Kyrene WRF and the lake is a significant cost factor affecting the alternatives that need a piped route from the Kyrene WRF to the lake. The viability of this route could be established using the information presented in this report by City right-of-way staff in discussions with the railroad. If the railroad alignment is not permitted this report has estimated an alternative, but higher cost route.

Implementation Strategy

The major technical issue affecting implementation of Rio Salado relates to the technical basis for obtaining the required environmental permits, most importantly, the ADEQ APP. A successful permitting strategy should be based on "zero" impact on the hydrogeology of the project area. All planning to date has been performed with this approach in mind. This approach is intended to conserve water and to isolate the lake from the surrounding aquifer systems. Hazardous waste sites, both Superfund and non-Superfund sites exist in the vicinity of the project. Varying levels of data exist concerning these sites. In general however, it is widely accepted that owners of water projects should not adversely alter groundwater conditions in the vicinity of landfills, thereby exacerbating potential groundwater contamination problems. By maintaining a strict program of lake isolation from the groundwater the project would be viewed most favorably by the permitting agencies.

The financial plan for implementing the Rio Salado project is being addressed by City staff.

Project Delivery

The continuing phases of the project, from an engineering reference, are:

Preferred Plan Selection
Geotechnical Investigations
Predesign
Pilot Testing (Optional for Some Supply Alternatives)
Preliminary Operations Plan
Preliminary Safety Plan
Environmental Permitting
Design
Construction Permitting
Bid and Award of Construction Contracts
Construction
Final Operations Plan
Final Safety Plan
Startup and Operations

Each of these activities, in the context of Rio Salado are briefly described in the following pages.

Preferred Plan Selection

This Engineering Report describes five alternative water supply plans. Most of the plans have two variations, for a total of nine primary supply scenarios. Some of these nine scenarios have additional considerations of varying levels of treatment (for phosphorus removal for example) prior to lake supply. In addition, there are three viable technologies for controlling lake seepage losses. Among the possible combinations and permutations of these project components a "Preferred Plan" must be selected. The "Preferred Plan" will form the basis for all following technical phases of the project.

Geotechnical Investigations

Further geotechnical investigations are required to (1) provide documentation for the environmental permits (ADEQ APP and ADWR Reuse Permit); (2) establish foundation requirements for the dams; (3) establish design data for pipeline construction, (4) further define the cost-effectiveness of the alternative seepage control technologies; and (5) provide other geotechnical information supporting the design of the project.

The most critical geotechnical work is independent of the preferred water supply alternative selection and could be implemented at any time. The hydrogeotechnical work associated with seepage control will require about six months of exploration and analysis. Thus, when the project predesign-design schedule is set, this work should be programmed accordingly.

Predesign

Predesign of the lake seepage control system, the dams, and pipelines should be scheduled with the supporting geotechnical studies. Some predesign will be necessary to support the environmental permitting process. Most agencies require sufficient engineering drawings and specifications to adequately define the proposed project at the time of permit application. The permitting process cannot usually be completed without final engineered drawings and specifications.

Pilot Testing (Optional for Some Supply Alternatives)

Pilot testing will range from desirable (but optional) for some of the supply alternatives, to required for others as part of permitting requirements. More testing of phosphorus content of the Kyrene WRF reclaimed water could be performed immediately with modest cost. Testing of alum treatment schemes for phosphorus reduction could also be performed at modest cost. Other pilot testing at the Kyrene WRF may be desirable if Kyrene is selected as the preferred source of supply (on direct reuse basis). Pilot testing could also be applicable to supply alternatives involving well recharge and recovery systems.

If appropriate, pilot testing should be performed as part of the predesign phase activities.

Preliminary Operations Plan

After the preferred supply plan is selected a preliminary plan for operation of the dams and supply system would be useful for permitting, detailed coordinating and possible contractual arrangements with SRP, and further establishing design criteria for automated control systems if such systems are preferred.

Preliminary Safety Plan

A preliminary safety management plan for the lake could be developed in conjunction with the Operations Plan or as a separate document. The safety plan would address security for the inflatable dams, fencing, swimming prohibitions, search and rescue requirements, safety patrols, fishing prohibitions, boating rules and regulations, considerations for participant and spectator viewing of water sport events, evacuation procedures, "failsafe" dam deflation modes, and other security issues.

Environmental Permitting

Selection of the preferred plan will determine what regulatory agencies and permits will be required to implement the project. The process of environmental permitting should begin soon after the preferred plan is selected with pre-application meetings (with agencies that have the pre-application process). Following the pre-application meetings, information from the predesign phase will be necessary to complete the permit applications. The recommended approach to environmental permitting is to focus first on the Aquifer Protection Permit (ADEQ) followed by the Reuse Permit (ADWR), then all other permits.

The preferred plan will also determine the complexity of the permitting program. For example, a plan that incorporates Ranney well collectors for lake seepage control will require more documentation and permit negotiations than lake seepage control based on a constructed liner system. Also, any plan that incorporates ASR will require more permitting effort than a plan that does include ASR.

Once the permitting process is started it should continue aggressively through completion of the project. Most of the permits will not be issued in final form until after construction is complete. For this reason, funding for the defined elements of the preferred plan should be identified at the outset of the permitting process. Extraordinary delays during the predesign, design, construction phases, could result in a very frustrating and inefficient permitting experience.

Design

The elements of the preferred plan should be evaluated for appropriateness for separate design and construction scheduling. For example, the dams (upstream and downstream) could be separate projects or combined. Likewise, the seepage control system could either be included or separated from the construction contract for the dams. It may also be appropriate to consider two contracts for each dam, one for foundations and concrete structures, and the second contract for inflatable dam purchase, delivery, and installation. Separating the inflatable dam purchase could accommodate a long lead time in the manufacture of the dam plus eliminate general contractor markups and profit that could increase the overall cost of the dam(s). Other elements of the preferred plan such as pipelines, AWT processes at the water reclamation facilities, and ASR systems could be designed and implemented under separate contracts.

Construction Permitting

Pipelines associated with the preferred plan could require permits from the Southern Pacific Railroad, ADOT, and coordination with telephone, gas, and electric utilities. The dams will require a permit from the ADWR, and coordination and permits from Maricopa County and the Corps of Engineers. All facilities will be subject to construction permitting in one form or another. Definition of all the construction permits will follow selection of the preferred plan.

Bid and Award of Construction Contracts

All project elements can follow standard City of Tempe capital projects bidding and award policies and procedures. In considering sources of grant and loan funds from state and federal agencies, the City should consider implications of these programs on the design and construction phases. For example, some state and federal programs have had prohibitions on owner preferences for equipment selection and foreign equipment. Since manufacturers of air inflatable dams are limited, these types of restrictions could have significant impact on the materials that could be designed into the project.

Construction

Individual elements of the preferred plan could have construction durations ranging from 6 months to 18 months, depending on how the individual projects are defined for the bidding and construction phase. Overall, it is probable that the construction phase could be limited to an 18-month envelope, but 24 months is a more appropriate time frame for planning purposes until after the preferred plan is selected.

Final Operations Plan

The Final Operations Plan would be a refinement of the Preliminary Operations Plan and would include any changes that became necessary during the final phases of design, permitting, or dam operations agreements with SRP.

Final Safety Plan

Similar to the Final Operations Plan, the Final Safety Plan would incorporate any changes that followed the Preliminary Safety Plan. In actual practice, the Final Safety Plan would probably require periodic updating for some time after construction of the facilities are completed to accommodate adjustments for actual operations experience.

Startup and Operations

Startup of the individual elements of the preferred plan will be similar to the City's normal practice for the existing water and wastewater facilities. The equipment that operates the inflatable dams is within the range of mechanical equipment that City staff are familiar with as part of the existing water and wastewater facilities. The unusual aspect of startup and operations will be the timing and sequencing of operations that inflate and deflate the dams in conjunction with Salt River flows. Under any of the preferred plans, operation of the dams could be performed by Salt River Project.

Implementation Schedule

This section will be added based on City staff comments.

Section 9
Cost Opinions

The opinions of cost shown in this report, and any resulting conclusions on project feasibility or budget requirements, have been prepared for guidance in project evaluation and implementation from the information available at the time the opinion was prepared. The final costs of the project and resulting feasibility will depend on actual labor and materials costs, competitive market conditions, actual site conditions, final project scope, implementation schedule, continuity of personnel and engineering, and other variable factors. As a result, the final project costs will vary above and below the opinions of cost presented herein. Because of these factors, project feasibility, benefit/costs ratios, risks, and funding needs must be carefully reviewed by the City prior to making specific financial decision or establishing project financial budgets to help ensure adequate funding.

Order-of-Magnitude Cost Estimating Methodology

This is an estimate made without detailed engineering data. Some examples would be: an estimate from cost capacity curves, an estimate using scale up or down factors, and an estimate based on a ratio of cost comparing the cost of one facility to another.

Budget Level Cost Estimating Methodology

The budget here applies to the City's budget and not to the budget as a construction budget control document. Preparation of a budget estimate requires the use of flow sheets, layouts, and equipment details plus input from the City regarding allowances and contingencies that the City normally expects to include in projects of a given type or level of risk.

Definitive Level Cost Estimating Methodology

This is an estimate prepared from very defined engineering data. The engineering data includes as a minimum, 85- to 95-percent complete plot plans and elevations, piping and instrument diagrams, one line electrical diagrams, equipment data sheets and quotations, structural sketches, soil data and sketches of major foundations, building sketches and a complete set of specifications. Typically a definitive estimate would be made from "Approved for Construction" drawings and specifications.

Probable Cost Scenarios

Based on information available, and data that could be reasonably generated as part of this Engineering Report, the probable cost scenarios are based on Order-of-Magnitude and Budget Level estimating methodologies. Further, the Probable Cost Scenarios have been established to reflect engineering opinions regarding the likely cost for the component estimated. Where there is some expectation that a higher cost could result due to information not currently available this report includes Contingent Cost Scenarios.

Contingent Cost Scenarios

Some components of the project are sensitive to rock excavation, negotiated permit conditions that could require additional factors of safety or equipment redundancy, and other conditions that are not possible to fully define at this level of study. In situations where these circumstances are recognized, at least for planning purposes, a higher cost outcome has been presented. Alternatives and project elements that might be affected by these higher cost outcomes are discussed in the text with companion Probable and Contingent cost estimates. The Contingent Cost Scenarios reflect a high degree of engineering judgement and experience with representative similar projects, but do not guarantee a maximum cost based on the limitations of the Order-of-Magnitude and Budget Level estimating methodologies.

Allowances

All estimates include allowances for design and construction unknowns (contingency), bonds, insurance, administration, and engineering. Contingencies range between 20 and 30 percent depending on the type of facility estimated. The contingency is generally lower for pipelines and higher for ASR and treatment plant construction. A flat 15 percent has been included for engineering. Engineering will, of course, vary below and above the 15 percent level for separate elements of the project but the overall average is reasonable for the level of decisionmaking required to select among the various alternatives.

Glossary of Abbreviations

ac-ft	Acre feet
ADEQ	Arizona Department of Environmental Quality
APP	Aquifer protection permit
ASR	Aquifer storage and recovery
CAP	Central Arizona Project
CFM	Cubic feet per minute
cfs	Cubic feet per second
CMF	Continuous flow microfiltration
CSA	Cement Stabilizer Alluvium
DBPs	Disinfection by products
EPA	Environmental Protection Agency
FCDMC	Flood Control District of Maricopa County
GAC	Granular activated carbon
mg/l	Milligrams per liter
mgd	Million gallons per day
N	Nitrogen
NPDES	National Pollutant Discharge Elimination System
P	Phosphorus
PLC	Programmable logic controller
RO	Reverse osmosis
SCADA	Supervisory Control and Data Acquisition
SRP	Salt River Project
SRT	Solids retention time
TDS	Total dissolved solids
TM	Technical memorandum
TOC	Total organic carbon
TSS	Total suspended solids
USR	Underground Storage and Recovery
WAS	Waste activated sludge
WRF	Water (wastewater) reclamation facility
WTP	Water treatment plant