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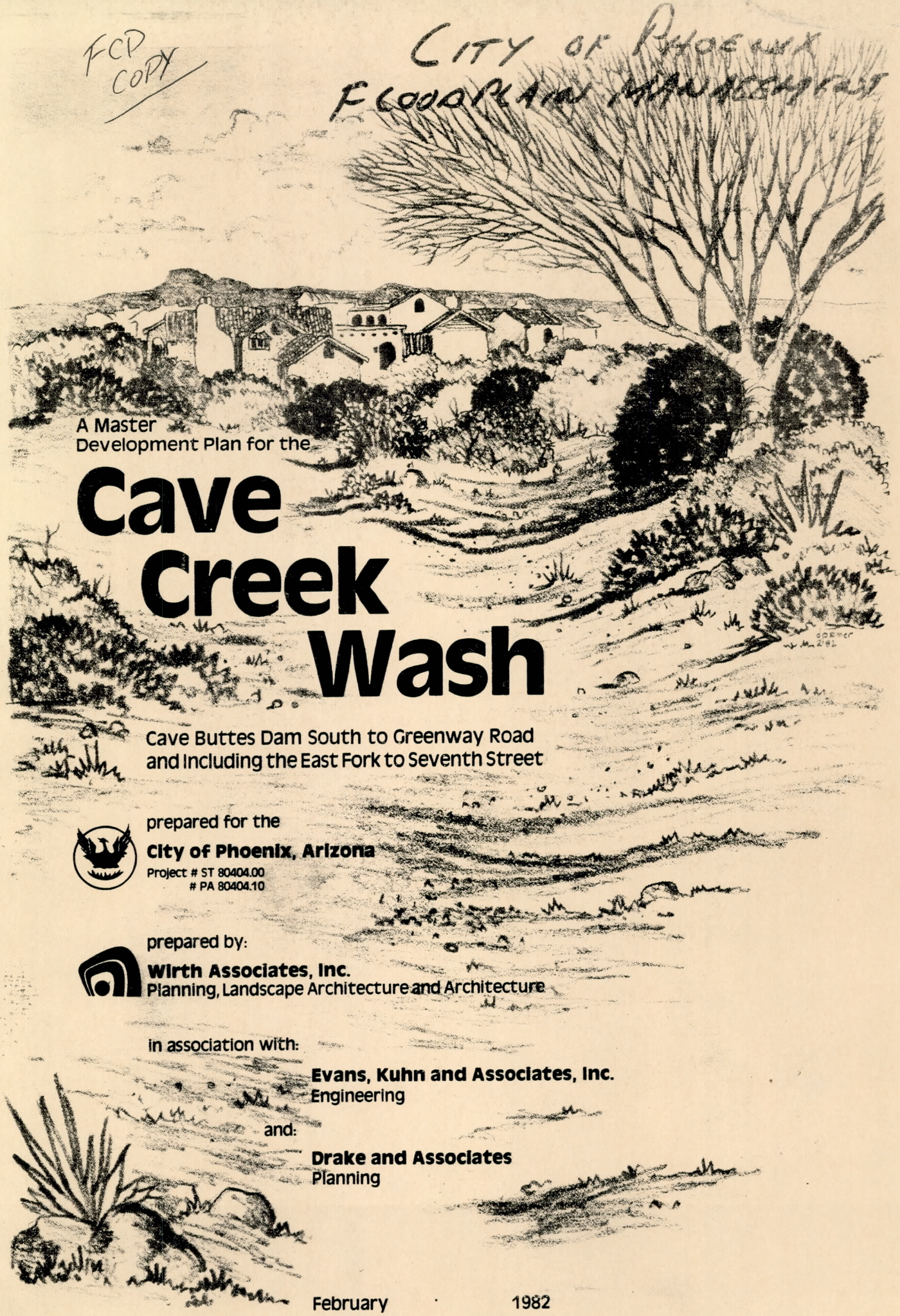
CITY OF PHOENIX FLOODPLAIN MANAGEMENT



A Master Development Plan for the

Cave Creek Wash

Cave Buttes Dam South to Greenway Road and Including the East Fork to Seventh Street

prepared for the

City of Phoenix, Arizona

Project # ST 80404.00
PA 80404.10

prepared by:

Wirth Associates, Inc.
Planning, Landscape Architecture and Architecture

in association with:

Evans, Kuhn and Associates, Inc.
Engineering

and:

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INTRODUCTION

OVERVIEW

The City of Phoenix retained the planning-engineering team of Wirth Associates, Inc. and Evans, Kuhn and Associates, supplemented by Drake & Associates and E.L. Smith & Associates to provide a comprehensive master plan for the Cave Creek Wash. A list of the study team and areas of responsibility is provided in Table I. The purpose of the Cave Creek Wash study is to inventory and evaluate the data necessary to determine opportunities and constraints leading towards the development of a phased master plan concept. The relationship of development interests, parks and open space, a trails system, and flood control all must interact to create a project of optimum benefit and opportunity, with limited costs to the City of Phoenix and the owners/developers of the area.

A combination of field study and secondary data review was used to collect information. Reports and updates on existing master plans, various city plans and village concepts, zoning requests and related permits, and uses were furnished by the city. Limited contact was made with the Corps of Engineers (COE), Flood Control District of Maricopa County (FCDMC) and the Bureau of Land Management (BLM).

A Technical Advisory Group (TAG), established by the city to assist in the study, included representatives from: the Planning Department; Development Coordination Office; Engineering; and Floodplain Management and Transportation Planning. Monthly meetings were held between the consultant and TAG as the plan developed. Although no direct public input was solicited or is expected to be requested, the plan will ultimately be reviewed by TAG and during the city's public meetings.

The general procedure for development of the plan follows:

1. Establish a study area based on the expected extent of impact surrounding the wash area, and potential recreation use and areas affected by the flood-control measures.

2. Identify the resource categories within the existing wash that would be affected by development. These resource categories were investigated and analyzed in text and map form.

3. The various resources evaluated were synthesized into an opportunities and constraints format. Those resources or combination of resources which could provide an opportunity for development, preservation, interpretation, flood control and so on, and resources that constrain development, etc. were identified and mapped.

4. Alternative approaches to development of the wash area were derived from the opportunities and constraints identified. These alternatives are based upon a multitude of cause and effect issues as well as natural resources potentially impacted. Such concerns included existing and proposed real estate markets, existing land ownership and development patterns, existing zoning change and development requests, public space implementation (e.g., parks, trails, etc.), as well as operation and maintenance, and other identifiable factors within the study objectives.

The primary objective of the study was to establish a method by which the city can permit development of vacant lands within the study area while accomplishing two basic tasks: (1) orderly planning and zoning, and resultant development of the area along Cave Creek Wash (development will relate to the various established city plans and projections such as the 1985 Interim Plan) as well as responding to existing development patterns; and (2) private development surrounding the wash will be involved in the master plan implementation, operation and maintenance whenever possible (the financial responsibility will be removed from the city whenever possible and placed upon the owner/developer through such creative planning tools as density trade-offs and strong homeowner associations).

Development shall respond to the engineering criteria necessary to provide safe and adequate flood-control measures now and in the future. Problems such as gravel and sand extraction, and landfills are considered in terms of existing use and rehabilitation potential. Vegetation restoration or enhancement providing increased wildlife habitat and added aesthetic resources, and vehicular circulation routes were also considered.

The final plan is a functional document which guides the development of Cave Creek from Cave Buttes Dam to Greenway Road and East Fork from the confluence of Cave Creek to 7th Street. The report gives the city a tool to effect a controlled-growth pattern and provision of public recreation and open space along the wash, especially a continuation and enhancement of the hiking and riding trails system, both existing and planned, while assuring flood control along the wash. The report also includes measures for the relief of initial and continued costs to the city while still maintaining control of the wash area.

The following sections, after a brief description of the project, describe the inventory, implementation and results of each resource study, discuss opportunities and constraints for study area development, and present alternative developments considered (including implementation, funding and maintenance implications).

PROJECT DESCRIPTION

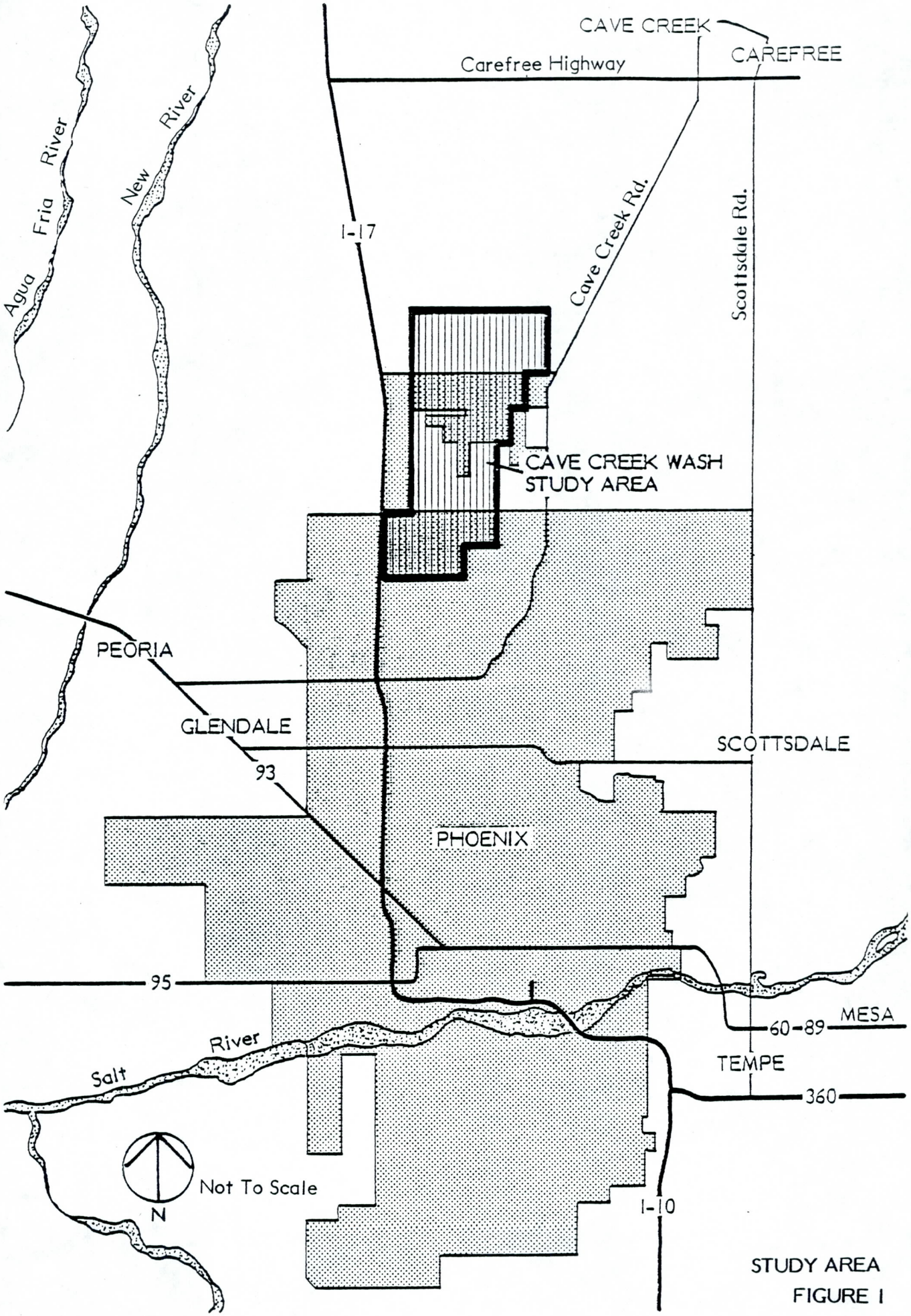
Cave Creek Wash study area includes the floodplain and surrounding developed and undeveloped areas of Cave Creek Wash and a tributary, the East Fork

(Figure 1, Study Area). The wash area studied extends approximately seven miles downstream from Cave Buttes Dam to below Greenway Road where the wash passes under 19th Avenue. The East Fork study area is approximately two miles long beginning at 7th Street and ending at its confluence with Cave Creek Wash.

Cave Creek Wash is a natural earth channel except for one mile of channelization between Greenway Road and Bell Road, and numerous gravel extraction pits. The entire wash has been extensively disturbed by off-road vehicles and trash dumping. Residential development has encroached against portions of the East Fork and industrial use abuts the main channel wash in some areas.

The channel road crossings are of various complexity and flood-level rating at one-mile intervals with intermediate roadways interspersed. These roadways provide access to the channel for the various users as well as preventing a continuous trail along the wash.

Vegetation is sparse along the wash except in three areas: (1) East Fork immediately past the confluence; (2) a portion of the main wash between Union Hills Drive and Beardsley Road; and (3) a section north of the Central Arizona Project (CAP) to the gravel pit excavations. Much of the existing plant material is volunteer establishing itself after some sort of disturbance of the channel bottom or edges.



STUDY AREA
FIGURE 1

RESOURCE STUDIES

EXISTING LAND USE

Inventory

To develop opportunities and constraints, it is essential to have an accurate inventory of what the existing land uses are and where developed and undeveloped land occur. Existing land use data were collected in a field inventory during May 1981. An aerial photograph (March 31, 1981), zoning maps and previously published inventories were initially reviewed and mapped. Field maps were prepared showing detailed, parcel-specific land use information. A summary land use map was prepared for use in the planning and design phases of this project (Figure C-1, Existing Land Use).

Aside from extractive uses (e.g., gravel mining), there is no definite encroachment upon the 100-year floodplain of Cave Creek Wash currently exists. The floodplain north of Rose Garden Lane and Beardsley Road, however, is only partially defined, with a north floodplain boundary branching west from the main channel and ending at 7th Avenue. Although the southern floodplain boundary has not been defined for the west branch, some single-family development is occurring and a cemetery exists within what may be floodplain. Near Turf Paradise the wash has been channelized, thereby altering the floodplain boundary shown on FCDMC maps.

The East Fork of Cave Creek Wash is largely undeveloped along its north bank. A church, school and 40-acre mobile home park at the southwest corner of Central Avenue and Bell Road are the only existing uses. Single-family detached dwelling unit subdivisions are found along the south side of the wash, with residential densities ranging from 1.35 to 5.30 dwelling units per acre.

South of Bell Road, the main channel of Cave Creek Wash is bounded by vacant land on the east and by Turf Paradise and a mobile home park (80 acres+) on the west. The wash has been channelized adjacent to Turf Paradise.

Between Bell Road and Union Hills Drive are subdivisions of single-family dwelling units west of the channel. Land on both sides of the wash is undeveloped at the Bell Road and Union Hills Drive frontages. A large mobile home subdivison and a single-family unit residential subdivision extend east from Central Avenue (one-eighth to one-quarter mile east of the floodplain). All land from Bell Road to Union Hills Drive (between Central Avenue and 7th Avenue) and from Campo Bello Drive (extended) to Bell Road (between 7th Street and the west floodplain boundary) is undeveloped.

Land immediately adjacent to the wash from Union Hills Drive to Beardsley Road is largely undeveloped. Gravel is being extracted in and adjacent to the

wash from Beardsley Road to approximately three-quarters of a mile south. Two horse stables and training facilities and two single-family residences are located east of the wash. Other nearby uses include the City of Phoenix police facility and service yard at Union Hills Drive and Central Avenue, a 40-acre single-family subdivision at Union Hills Drive and 7th Street, and a 40-acre mobile home park one-quarter mile north of Union Hills Drive on 7th Street.

The wash channel is used for gravel mining from Beardsley Road north to the wash's crossing at 7th Street, about one-quarter mile south of Deer Valley Road. A batch plant is located immediately south of this crossing, on 7th Street. Other land adjacent to the wash is undeveloped. West of the channel, a cemetery and single-family subdivision are located within what may be floodplain. Single-family detached housing is under construction west of 7th Avenue.

North of Deer Valley Road, aside from gravel mining in the wash, the land within and adjacent to the wash is undeveloped. Deer Valley Airport's clear zone, extending across the wash to 16th Street, restricts potential land uses to those involving minimum human occupation.

Implications

Obtaining cooperation of extractive users of the wash should be explored, as they may be able to shape mining operations to facilitate construction of flood control and recreation improvements. The presence of large undeveloped tracts of land adjacent to the wash presents a major opportunity to guide future development in directions compatible with recreation and flood control while providing a base of economic support for the objectives of this plan.

ZONING

Inventory

The zoning element of this project provided the basis for determining potential land development under the present zoning regulations. Zoning information, including classifications and regulations, was collected from the City of Phoenix and Maricopa County Planning and Zoning Department and transferred to the project base maps.

The following is a brief description of zoning classifications along Cave Creek Wash. Except for land north of Pinnacle Peak Road, which is in an unincorporated area of Maricopa County, all zoning indicated is that of the City of Phoenix. Refer to Figure C-2 (Zoning) for location of specific zoning district boundaries.

East Fork of Cave Creek Wash

South of the wash, land is presently zoned for single-family residential development with zoning districts ranging from R1-6 (5.30 dwelling units per gross acre), R1-10 (3.50 dwelling units per gross acre) and PAD-3 (Planned Area Development, 1.35 dwelling units per gross acre maximum). The PAD-3 District area is located on the slopes of Moon Mountain, with a developed R1-10 subdivision immediately to the east. An area of PAD-6 (Planned Area Development, 2.75 dwelling units per gross acre, maximum) is located at the southeast corner of 7th Avenue and Greenway Road and is developed with single-family attached homes. Large, undeveloped areas of R-3 (Multi-Family Residence/Restricted District, 14.5 maximum dwelling units per gross acre), and R-5 (Multi-Family Residence, General, 43.5 maximum dwelling units per gross acre) are located at 7th Street/Bell Road and are proposed for development with a mix of patio homes, condominiums and apartments. Other land along the East Fork of Cave Creek Wash is zoned S-1, Suburban District - Ranch or Farm Residence. This district is designed to "provide for very low density farm or residential uses to protect and preserve low density areas in their present or desired character..." (Section 413, Phoenix Zoning Ordinance). In a rapidly urbanizing area, S-1 can be seen as a holding district, to be zoned to a more appropriate district as development patterns emerge.

Main Channel of Cave Creek Wash

Greenway Road to Bell Road: At 19th Avenue, north of the wash, is a mobile home park zoned R1-6 (Single-Family Residence) and C-2 (Intermediate Commercial). A large area of R1-10 (Single-Family Residence District) is located between the main wash and the East Fork. All other property in the vicinity of the wash between Greenway Road and Bell Road is zoned S-1, Suburban District - Ranch or Farm Residence.

Bell Road to Union Hills Drive: The entire wash is zoned R1-8, Single-Family Residence District, allowing a maximum of 4.30 dwelling units per gross acre. It should be noted that churches, schools, public utility buildings and facilities and governmental uses are allowed in any residential district. Land immediately to the west of the wash is zoned R1-8 and R1-6, with a C-2 commercial corner at 7th Avenue and Union Hills Drive. Undeveloped R-4-A (Multi-Family Residence, General District) is found along the Bell Road frontage west of the wash. East of the wash, the south half-mile is zoned R1-8, Single-Family Residence District, and the north half-mile is zoned PAD-8 (Planned Area Development, maximum of 4.75 dwelling units per gross acre). The PAD-8 area is developed as a mobile home park.

Union Hills Drive to Beardsley Road: Cave Creek Wash and land immediately adjacent to it is zoned R1-8, Single-Family Residence. Some higher density

single-family zoning (R1-6) is located to the west, on 7th Avenue. Mobile home parks along 7th Street are zoned R-3 (Multi-Family Residence/Restricted) and PAD-10 (Planned Area Development, maximum of 8.00 dwelling units per gross acre).

Beardsley Road to Deer Valley Road: South of Rose Garden Lane, land within and adjacent to the wash is zoned R1-8, Single-Family Residence. Between Rose Garden Lane and 7th Street, the wash turns to the east through an area of A-1, Light Industrial District. This district is "a district of industrial uses designed to serve the needs of the community for industrial activity not offensive to nearby commercial and residential uses" (Phoenix Zoning Ordinance, Section 420). A broad range of permitted industrial uses is defined in the Zoning Ordinance. From 7th Street to Deer Valley Road, the wash and adjacent lands are zoned RE-43, Residential Estate District - One Family Residence. This district is "a district of single family homes designed to maintain, protect and preserve a character of development on lots with a minimum area of 43,560 square feet and with not more than one dwelling unit and customary accessory buildings upon one lot" (Phoenix Zoning Ordinance, Section 401).

Deer Valley Road to Pinnacle Peak Road: Between Deer Valley Road and Williams Drive, the wash passes through land zoned as Industrial Park District. This district "shall provide sufficient space in appropriate locations for certain types of business and manufacturing which shall be free from offense in modern landscaped buildings, to make available more attractive locations for these businesses and factories" (Phoenix Zoning Ordinance, Section 419). North of Williams Drive to Pinnacle Peak Road, the wash and adjacent lands are zoned Industrial Park District to the east and A-1, Light Industrial District, to the west.

North of Pinnacle Peak Road: All land from Pinnacle Peak Road to the north study area boundary in and near the wash is zoned Rural-43, a Maricopa County Zoning District (Rural Zoning District). The purpose of this district is "to conserve and to protect farms and other open land uses, foster orderly growth in rural and agricultural areas and prevent urban and agricultural land use conflicts; but when governmental facilities and services, public utilities and street access are available, or can reasonably be made available, applications for change of this zoning district to any single-family residential zoning district will be given favorable consideration. Principal uses permitted in this zoning district include both farm and nonfarm residential uses, farms and recreational and institutional uses" (Section 601, The 1969 Amended Zoning Ordinance for the Unincorporated Area of Maricopa County.)

Implications

Zoning classifications describe general types of land uses presently allowed on specific parcels. Although the plan for Cave Creek Wash may propose land uses that differ from those allowable under present zoning, plan proposals must be made with an awareness of their "real world" relationship to present zoning. If the plan proposes land uses only allowable with rezoning to more intensive classifications, it is likely that the land owners will support the plan. If downzoning is recommended, the owners may not support the plan and have the right to proceed with development under present zoning. Some development incentives must be built into the plan to encourage effective implementation.

LAND OWNERSHIP

Inventory

Land ownership information was collected as a necessary component of the base data used to develop various Cave Creek master-plan scenarios. Land ownership data were collected during June 1981.

The inventory of land ownership data within the Cave Creek study area was accomplished through discussions with various Federal, state and local agencies, and the use of maps provided by these agencies. The following agencies were contacted during the inventory:

U.S. Bureau of Land Management
Arizona State Land Department
Maricopa County Assessors Office
Maricopa County Flood Control District
City of Phoenix, Department of Parks and Recreation

In addition to identifying public land ownership within the study area, private ownership and leased-lands information was also collected. Identification of private-sector owners was restricted to parcels larger than one-sixteenth of a section or 40 acres. This information was obtained from the Maricopa County Assessors Office. Leases on public lands were identified through discussions with the BLM and the Arizona State Lands Department.

Land ownership within the Cave Creek study area is roughly divided between public and private owners. The southern half of the study area is dominated by private-land holdings. Approximately one-half of these lands are currently developed as residential areas (Figure C-3, Land Ownership).

The northern half of the study area has less development with a majority of the land in public ownership. The Bureau of Reclamation (BuRec) and the BLM

are the only Federal agencies with land holdings in the study area. The BuRec has jurisdictional authority over the Granite Reef Aqueduct right-of-way which crosses the study area from northwest to southeast. The BLM oversees two large tracts of land in the study area equalling approximately two sections or 1,280 acres. Over half of the BLM lands are currently being leased by the FCDMC.

The Arizona State Lands Department has significant land holdings within the Cave Creek study area and has leased a large portion of these holdings to the FCDMC, the City of Phoenix and private parties. One small parcel of state land has been accorded special protection through an agreement between the State Land Department and the State Historic Preservation Officer. This parcel is located within the Cave Creek Dam Archaeological District.

The FCDMC and the City of Phoenix both own and lease land in the Cave Creek study area. The FCDMC owns and leases land in the northern portion of the study area near Cave Buttes Dam. The City of Phoenix land holdings include a gravel operation and the Deer Valley Airport.

Implications

The implications of land ownership are primarily that a direction for development of the property may be surmised from the type and background of the existing owner. This information is dependent upon many other outside influencing factors such as existing market for real estate, socioeconomic status of the proposed user and nature of existing surrounding development. While no predictions are infallible, certain assumptions may be made concerning the land in relation to its present owners. The land ownership in the study area is divided into two basic categories: public and private. Theoretically, uses of either public or private land will concur with the city's village plans, interim plans and long-range concept plans. The uses should also be compatible to existing neighborhood community plans such as the Deer Valley plan for adjacent development.

Consideration of land ownership is basically a tool for support and prediction of land use relating to the known and/or historical goals of the owner. Use and development potential and the sequencing of such objectives often relate more directly to the interest rate, inflation and the economy than to the actual ownership; however, certain general implications can be established.

Public Land

The public lands owned by the Federal Government are not expected to be developed by any of the ownership agencies for any purpose other than stewardship. It is possible that the land may be sold or leased to other public

agencies but only for non-developer uses, specifically flood control and recreation. The City of Phoenix has already expressed an interest in (the Federal agencies have responded postively) several areas for recreation and open-space use.

State government lands (excepting Arizona Department of Transportation) are projected for private development either through lease or sale within the next few years. This use is expected to be initially industrial, followed by residential. The prohibitive cost of lease for recreational purposes precludes the use of these lands for parks or open space. An area of state land is earmarked as a significant historical resource by the State Historic Preservation Officer and a Historic District is located in the north portion of the study area.

Flood Control District of Maricopa County is solely concerned with the function of the Cave Creek Wash as a flood control measure complementing Cave Buttes Dam and will remain responsible for its maintenance to Corps of Engineer satisfaction. The City of Phoenix has proposed assuming the FCDMC lease on BLM land to be used as recreation - open space.

The City of Phoenix lands are utilized for park sites or other city related uses. A portion of these lands may be traded or sold to developers if such a move is considered beneficial to the implementation of a master plan concept.

Private Land

By establishing the basic ownership pattern of private land within the study area, support of the direction suggested in the master plan can be established. As example, the need for medium density development is going to be supported by an owner/developer with a history of such development versus an owner/developer with a penchant to develop shopping centers. It gives the impetus to the owner/developer holding the property for speculation to direct their efforts to the type of development favored on the final master plan. The land ownership also establishes blocks of property which can be expected to develop in contiguous patterns and general areas. This is valuable in relation to wash frontage and width assigned to a specific type of desired development.

Land ownership, therefore, becomes a valuable tool assisting in creative land use and the meeting of the city's goals for the Cave Creek area. It also allows the plan to be pragmatic in certain cases and develop a land-use pattern based on ownership which has a better chance of being implemented in an expedient manner, giving full value to the opportunities presented the city, such as implementation and maintenance of the wash. An example of this would be the extractive uses. It could be reasonably expected that the companies involved will continue to mine the resource until it is depleted. At its point of abandonment, the area is predictable as to landform, general character and potential new use to either private or public sector.

Existing land ownership enhances or restricts certain potentials for development along the wash as well as giving a starting point for expected development relating to the owner/developer. It is a minor tool in the overall development of the master plan but does have a discernible and interlocked relationship to all other planning and engineering aspects of the plan and assists in determining the direction of the master plan. Of further use to the master plan implementation, is the fact that the secondary research has been completed and mapped to determine owner/developer.

TRANSPORTATION

Inventory

Transportation facilities covered include major (four, five or six lanes) and collector (two lanes) streets, wash/street crossings, bicycle paths and trails. The information is used in evaluating the location and level of service for wash crossings and for land-planning considerations. The principal sources of information were the City of Phoenix's Minimum Right-of-Way Standards Map and the Existing Street Classification Map, both as amended August 14, 1979.

Major street crossings are located at Bell Road and on one-mile increments to the north (Figure C-4, Transportation). In addition, 7th Street crosses the main channel of the wash, south of Deer Valley Road and; 7th Street also crosses the East Fork, south of Bell. Crossings of the main channel also occur on a street acting as an extension of Greenway Road and for the main channel at 7th Avenue north of Greenway Road on the East Fork. The 7th Avenue crossing on East Fork is being evaluated with respect to eliminating the road access.

Deer Valley Road is a proposed parkway. Two streets (Bell Road and 7th Street south of Deer Valley Road) have major drainage structures in place. The wash will be used as a backbone for a major pathway system.

Implications

A number of general implications can be derived from the data relating primarily to the street/wash crossings. With the high cost of crossings, it is desirable to minimize the number by proper site planning. Crossings to be installed should consider various levels of service (i.e., 100-year/dry, 10-year/dry, etc.). It is possible that one of the wash crossings (7th Avenue north of Greenway on the East Fork) may be eliminated. Interior collector streets serving developments adjacent to the wash should, where possible, run parallel and adjacent to the wash to serve as a security buffer from vandalism between the wash and adjacent residential property.

All at-grade crossings should be considered temporary until traffic volume and funds are available to upgrade these crossings. A high level of service should be considered for wash crossings on the four parkways: Greenway Road, Bell Road, 7th Street and Deer Valley Road. A major emergency service site is located on Union Hills Drive just east of the main fork of Cave Creek Wash, making this crossing a desirable one for a higher level of service. Beardsley Road is also proposed for a major crossing (based upon a one-mile emergency access grid).

Crossings can be designed to perform a dual function, acting both as bridges for street traffic and as pedestrian underpasses for the bicycle and trail system (Figure 2, Continuous Trail System Concept (Plan View)). Grades should be set to result in a minimum clearance of 8 feet (10 feet for equestrian) on the underpass/bridge with the deck set at grade (avoiding the expense of approaches if a raised deck were used). The deeper bridge section will also reduce the required span for a more economical structure. Existing bridge inverts may have to be modified before being utilized as equestrian undercrossings (Figure 3, Typical Roadway and Below Grade Trail Crossing). Seventh Avenue, north of Bell Road, is proposed for realignment to the west eliminating the necessity for a crossing. Refer to the recommended Master Plan (Cave Creek Wash Master Development Plan Executive Summary) for the proposed alignment.

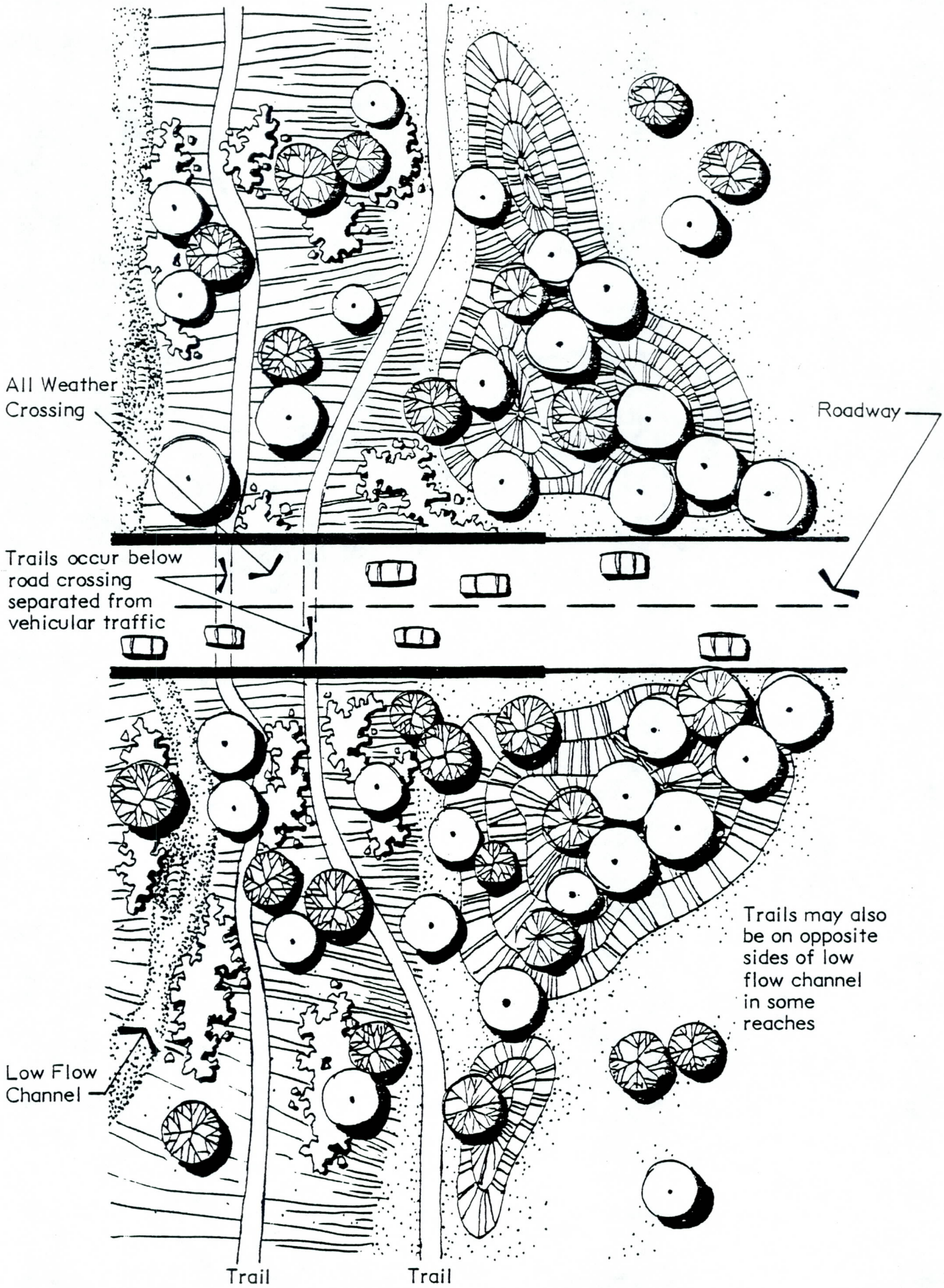
Greenway Road is proposed as a six-lane interim transportation loop that connects Greenway Road, at 19th Avenue, with 7th Street at the south boundary of the East Fork floodplain. Its alignment between these points is shown on the master plan as a corridor with the exact alignment within the corridor to be determined by the city. Two bridge crossings are anticipated within the corridor.

INFRASTRUCTURE (UTILITIES)

Inventory

Utility lines of interest in the area are located both above and below ground, and consist of service facilities for telephone (Mountain Bell), electric (Arizona Public Service), water (City of Phoenix), sanitary sewers (City of Phoenix) and storm drains (City of Phoenix). These service facilities are reviewed primarily with respect to cost and feasibility for relocation or protection at interfaces with the channel. Information was obtained from the utility companies and City of Phoenix, and summarized by utility and location (Table II and Figure C-5, Infrastructure).

In addition to the data listed, there are a number of developed, open channels draining into the wash that will be considered with the impacts of the proposed storm drains. There is also a methane-gas removal system in the Greenway



CONTINUOUS TRAIL SYSTEM CONCEPT (PLAN VIEW) FIGURE 2

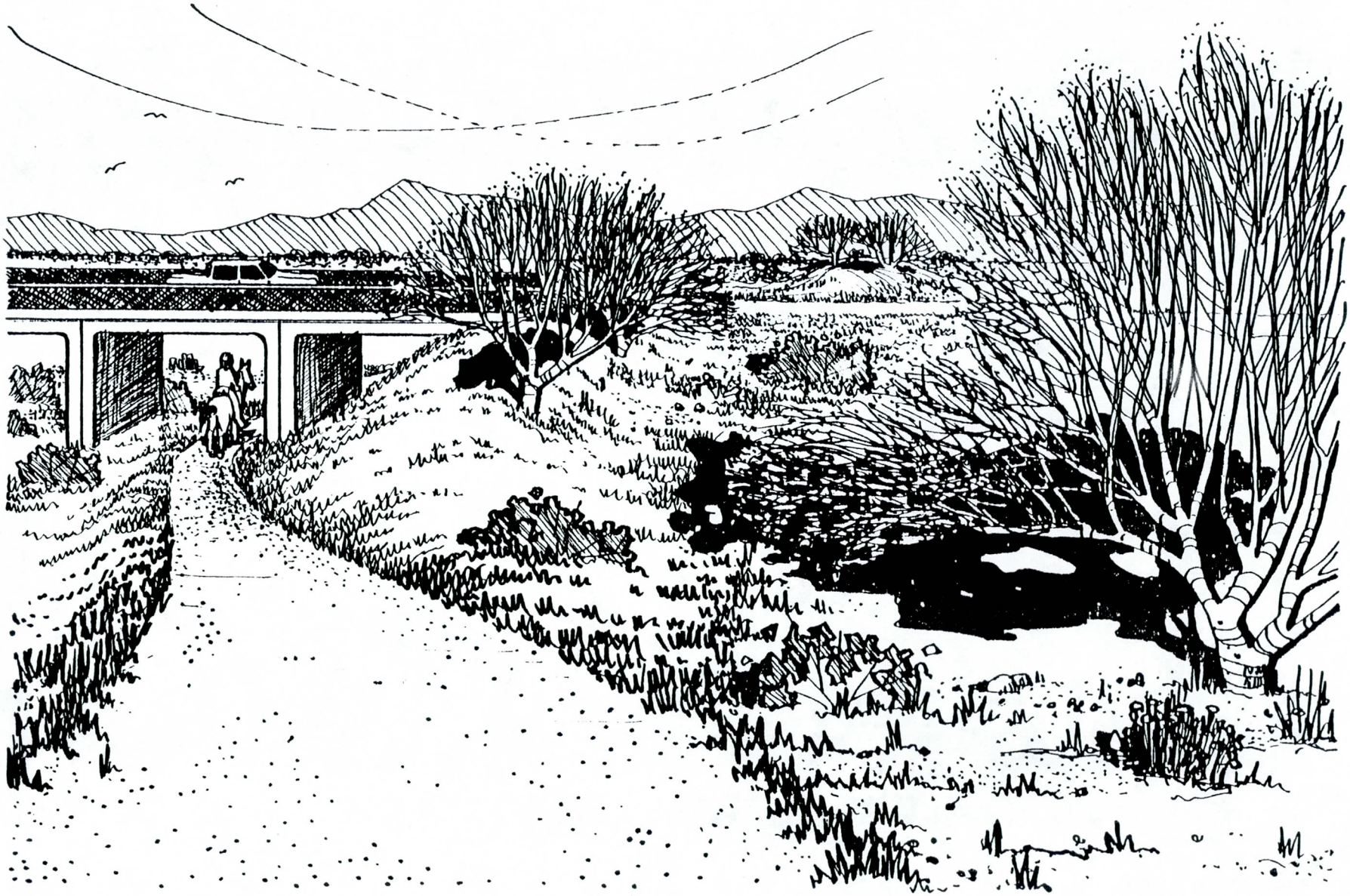


FIGURE 3

TYPICAL ROADWAY AND BELOW GRADE TRAIL CROSSING

and 19th Avenue area for the old landfill southeast of Greenway and 19th Avenue.

There were no irrigation or cable TV lines found in the study area, however, it can be anticipated that cable TV lines may be installed in the near future.

Implications

Of the data collected, the sewer lines are of primary interest with respect to potential conflicts with the channel work proposed. There will be a number of relocations necessary for the road crossings. Sewer lines in conflict may have to be rerouted to the upstream side of any drops necessary for road crossings. Water, electric and gas lines may, in addition to the sewer lines, have to be relocated for channelization or wash/street crossings.

Proposed storm drains and open-channel outlets are of interest with respect to the nuisance water and low-flow problems created. Alternative plans will treat these areas as resources; in that the nuisance water can be used to support a wider choice of vegetation than would otherwise be possible.

PLANNED LAND USE

Inventory

The 1985 Interim Plan, prepared by the City of Phoenix in 1979, is the adopted document that provides guidelines for consideration in land use and zoning changes. The plan was reviewed to determine City of Phoenix objectives and policy relative to land use within the study area. Applicable data were transferred to the project base map and policy statements were reviewed for relevancy as shown in the Implications section. The City of Phoenix Planning Department Development Coordination Office was contacted for information about major development plans in the study area.

The 1985 Interim Plan provides a general, conceptual planning framework for the City of Phoenix. Most of the Cave Creek Wash study area is in Village 1, as defined in the Plan. Part of the East Fork of the wash is in Village 3. Figure C-6, Planned Land Use, shows village boundaries and land use intensity designations.

As shown in Figure C-6 (Planned Land Use), north and south ends of Cave Creek Wash, within the study area, are in low intensity areas. From Turf Paradise to 7th Street, the wash is included in a medium intensity area. The village core (not shown on the map) is near Beardsley Road and Interstate 17 (I-17). The "intensity" of an area is defined by the plan as the "overall mix of land uses within a given area." In Village 1, this mix has not yet been defined in terms of specific uses or densities.

From 12th Street, downstream, the wash is within the plan's prime development area. No development is to be encouraged beyond this area in the 1980-85 period. No development is to be encouraged north of the CAP prior to the Year 2000.

Two major development proposals have been put forward that affect Cave Creek Wash within the study area. These are:

- ANO-ZIRA, approximately 150 acres at the southwest corner of Bell Road and 7th Street. Proposed is a mix of commercial, office, medium- and high-density apartments, condominiums and patio homes. A green belt concept and a "water feature" for the wash are being considered. About 24 acres of land will be left as open space within the wash. A total of 1,500 dwelling units is proposed.

- A 365-acre project is proposed between Union Hills Drive and Bell Road. Approximately 868 residential units, mostly in single-family (R1-8) subdivisions are planned along Cave Creek Wash. Zoning for offices and apartments (PAD-14) is proposed on Union Hills Drive. Commercial and apartment zoning (R-4-A) existing are planned for the entire Bell Road frontage. A school site is reserved. Preliminary Plan concepts show relocation of the wash west of its present location and channelization (see Figure C-7, Land Use Summary).

Implications

The 1985 Interim Plan specifies both citywide and village policies and standards. The three citywide policies most relevant to the Cave Creek Wash planning study are:

6. Strip commercial zoning should be discouraged throughout all villages.

9. Undeveloped areas not shown with a specific land use recommendation on the village map should be developed with uses that reflect the intensity level in the zone in which they lie and their impact on adjacent uses.

10. Service facility needs should be assessed using the development standards as a guide and should be provided as the need becomes apparent.

Relevant village policies include:

Village I

2. New basic land uses (of a garden or light industrial type) should be encouraged to locate in and around Deer Valley Airport. Additional

basic land use activity along the freeway (except in the village core) should be discouraged.

3. Development of the Cave Creek Park and Skunk Creek areas for regional parks, open space, recreation and related uses should be encouraged.

4. This village should maintain an overall density lower than the city average. Large areas of low intensity uses should be developed and preserved.

5. Shopping facilities should be encouraged to develop in the center of a square mile at the neighborhood level with other facilities being spaced at two-mile intervals on major intersections in the newly developed portions of the village.

6. People-intensive activities should be discouraged from locating within the area affected by the Deer Valley Airport approach and take-off patterns.

Village 3

1. Development of the Cave Creek Wash area as a regional park should be encouraged.

2. Development within the Mountain Preserve area is to be discouraged.

The Plan cites the following standards for park development.

Neighborhood Parks

Serve 4-7,000 population, one-half mile service radius, 8-15 acre site, 2.7 acres per 1,000 pouplation.

Community Parks

Serve 15-30,000 population, one and one-half to two mile service radius, 20-40 acre site, 2 acres per 1,000 population.

Implementation efforts should be first concentrated within the Prime Development Area (from 12th Street downstream) where development and private sector support is most likely to occur within the next four years.

RECREATION

Inventory

An assessment of recreation, both organized (parks) and unofficial (off-road vehicles) for the Cave Creek Wash Master Plan study area was undertaken to develop an understanding of: (1) existing recreation use; (2) planned recreation facilities and programs; (3) opportunities and constraints of existing recreation and planned activities; and (4) implications of potential long-range activities and the implementation, operation and management of such facilities. Finally, evaluation of general recreation trends and activities in the wash resulted in management recommendations for future recreation.

The recreation inventory was accomplished in three steps: (1) review of city plans and programs, county intentions, Federal land ownership and perceived use, private recreational activities and recordation of all existing recreation sites; (2) on-site examination and observation of recreation activities within the study area over several time periods; and (3) interviews with city parks personnel, other city staff whose functions relate to the furnishing of parks and recreation services, and on-site interviews of persons using the wash area for recreation purposes.

Material (written and maps) from the following agencies and organizations were reviewed:

- City of Phoenix Parks and Recreation Department
- Maricopa County Parks and Recreation Department
- Corps of Engineers, Los Angeles District, Recreation Development Plan for Cave Buttes Dam and Cave Creek Wash
- Arizona Outdoor Recreation Coordinating Commission, State Comprehensive Outdoor Recreation Plan (SCORP)
- Bureau of Land Management for Areas Desirable to the City
- Arizona State Land Department for Areas Potentially Desirable to the City
- Arizona State University, Department of Leisure Services
- Central Arizona Project, Trails and Parks Potential
- Arizona State Parks Hiking and Riding Trails Program and the Natural Areas Program
- Relevant School District Plans for School Sites Within the Study Area.

Organized recreation areas were plotted on the various resource base maps (land ownership, land use). Those city parks existing under ownership by the city (but not developed) or in process of acquisition, are identified in Figure C-1 (Existing Land Use). Unofficial recreation uses are not shown on the maps (except in the obvious relationship of wildlife habitat as it relates to bird watching, etc.).

To determine recreation implications for the Cave Creek Master Plan a relationship was established between existing recreation and land use, and potential recreation and land use. The possibility of including cultural and archaeological resources as an interpretive recreation experience was also identified. The projected needs for recreation (SCORP) and the ability to financially support a recreation system in the wash was considered, as well as the potential to compliment and enhance existing recreation facilities outside of the study area, such as a trails system.

Formal recreation associated with the Cave Creek Wash area is very limited at this time. There is a city park site on the East Fork which is undeveloped, a golf course (under construction) west of I-17, and a COE designated recreation area upstream of the new Cave Buttes Dam, also undeveloped.

The stretch of wash between Cave Buttes Dam (north) and bordering I-17 (southwest) has no public recreation space provided. There is the private provision of a bicycle moto-cross track by the gravel quarry immediately south of the dam, and the potential cultural/archaeological interpretive areas north of the CAP canal.

Proposed recreational development of the wash area include the development of the park area (existing) in the middle of the East Fork; the provision of a neighborhood park between Beardsley Road and Bell Road (approximately 15 acres desired); acquisition of the BLM land now comprising Union Hills (see land ownership map) for a rural city park devoted to hiking and horse riding; the assignment of all BLM leases now held by FCDMC above the CAP; and control of the COE designated recreation area above the dam.

The city has no plans at this time to assume leases for State of Arizona land, but may be interested in purchasing land between Bell Road and Union Hills Drive. There is a portion of city-owned land between Beardsley Road and Union Hills Drive which may be used for recreation purposes. It coincides with the desired location of the planned neighborhood park and is presently used for a police substation, city vehicle maintenance yard and gravel and boulder extraction pit.

Informal recreation takes place throughout the wash by off-road vehicles and motorcycles. Evidence is present throughout the drainage way and on surrounding hills to document the presence of motorized vehicles. It is also evident that horse riders use the entire wash south of the CAP and along East Fork. The CAP presents an obstacle to movement north except for the two bridges at 7th Avenue and 7th Street. The wash is a natural trail system and connects north into Carefree. The heaviest use occurs from the horse estate residences north of Union Hills Drive to the connection of Cave Creek Wash to the Sun Circle trail system. Some sign of walking for recreation is present; however, it appears that neither the East Fork nor the main drainage way are used for hiking as a direct activity. This is probably due to the general lack of aesthetics and specific trail destination within the wash study area.

Although unofficial, but somewhat organized, motorcycle enthusiasts use the clear zone east of the runways at Deer Valley Airport. The use extends beyond the actual clear zone to surrounding public land, mainly to the north. At one time, the City of Phoenix leased state land in this area specifically to provide a "motorcycle park" in hopes of controlling the spread of use to adjacent areas as well as improving access and safety for the users. This was unsuccessful due to the city's inability to staff the facility and the attempt to charge a user fee. Since there was a general lack of public interest, the lease has not been renewed.

Some target shooting takes place on the north end of the study area using the hills north of the CAP as a backdrop. This also appears to be a good "boondocker" area, with numerous fire pits and many years accumulation of broken bottles on the hillside slopes. Another area with liquor bottles and related trash is the East Fork adjacent to 7th Street prior to the wash starting to head-cut the desert, making access difficult. Small game hunting takes place almost exclusively north of the airport clear zone, and particularly north of the CAP canal.

The CAP canal bisects the wash and floodway to the north of the Deer Valley Airport clear zone and proposed alignment of the Deer Valley Parkway. There are three crossings over the CAP canal in this area, otherwise the entire canal reach is fenced from any public access. There are bridges on 7th Avenue and the approximate location of 7th Street and a floodway in alignment with the wash that passes over the canal and continues south. The two bridges were not designed with sufficient pedestrian/equestrian space and will be a bottleneck to a trails system seeking to cross there. As traffic volume increases, residential and commercial development to the north of the CAP will be of concern. The floodway crossing on the CAP is unusable for any pedestrian/equestrian access due to its design.

Existing bridges at Bell Road, 7th Street and 19th Avenue may provide access underneath for trails. Some modification may be necessary to insure headroom is maintained. All other roadway crossings using box culverts are not of sufficient size to allow passage under the road. This may present a problem in providing trails at unsignaled portions of roadways which carry a sufficient traffic volume at high speed. Box culverts and dip-crossings may become hazardous for non-vehicular traffic until these crossings are improved by new bridge construction. Presently no established or identified trails exist on any stretch of the wash within the study area excepting the proposed CAP trails system which will intersect Cave Creek.

Implications

Constraints

The area adjacent to the wash is becoming more valuable to developers as land in the northwest expansion of Phoenix becomes scarce and increases in value. This will result in the goal to construct as close to the floodway as possible (to produce as many lots per zoned acre as practical). Coupled to the problem of showing a tangible benefit of having a recreational facility adjacent to or interacting with the development, it is difficult to convince a developer to become a part of the recreational facilities development.

The cost of recreation must be in proportion to the benefit received by the developer, and in proportion to the cost of maintenance to be borne by the city or the homeowner associations responsible for upkeep. Thus, division of responsibility for implementation, maintenance and operation between the private developer/owner and the public sector will depend upon density and type of dwellings adjacent to the recreational facility.

Single-family detached housing has not historically supported common space for recreation or open space. The ability of high-density, multi-family dwelling areas to establish and maintain common areas and recreation facilities has been far more successful. Also of concern is the continuation of maintenance past the original owner/developer. Any facilities abandoned by the original maintaining group may become the responsibility of the city parks. To avoid this situation, careful evaluation of the homeowner's association should be conducted to insure continued private maintenance of the facilities.

Phasing of the various stages of recreation development and open space will be necessary. The wash will most likely develop in a piecemeal fashion rather than a linear progression due to the nature of the real estate/development market. Therefore, development of a park in the floodplain may rely upon channel modification upstream or downstream from the park in order to construct and maintain certain areas or facilities within the park. If this modification is not possible because of lack of a developer, the complete park program may be impossible to provide until such a developer is found. The city has made it very clear that there is no possibility of channel and bridge modification without contribution from the surrounding developer. Timing of development and the interlocking of parts of trails and open space acquired and constructed at different times in different locations will be a key consideration. At present, the final product desired by the city is a contiguous trails and open-space system throughout the wash area from Cave Buttes Dam to I-17 and along East Fork from the confluence to 7th Street. The overall responsibility for control of the floodway and wash from Cave Buttes Dam to Peoria Avenue rests with the COE. The COE delegates the responsibility to the FCDMC to ensure the use and maintenance of the wash to meet COE criteria for maximum flood projections. Any development for recreation

within the Cave Creek study area will have to interface with the COE/FCDMC needs and regulations (these guidelines do not agree with the Federal Emergency Management Administration (FEMA) floodplain delineations used by the city--see Hydrology section).

There are other minor controversies in the wash development: The existence of abandoned mine shafts in the area; conflicts of use such as a field dog trial area above the dam and the riding trails which may cross it; a hot-air balloon land pad near the Deer Valley Airport traffic pattern; reconstruction/ modification of the CAP crossover spillway to allow crossing by trail users; and law enforcement along the trails and park area not visible from the major vehicular crossings.

Inundation of lands and facilities along the wash during a flood period would present problems of repair and cleanup. The arrangement between the city parks system and the adjacent owners/developers will have to consider "special" maintenance cases and responsibility for necessary action over and above normal requirements. Also of concern is the allocation of area to the various surrounding developments.

Certain parks are seen as joint conglomerations of private-public maintenance, areas of trails and open space/flood channel will be shared responsibility (i.e., one side flanked by single-family residence, therefore city maintained; one side flanked by high-density multi-family residence, maintained by numerous associations) and the limitations of responsibility upstream and downstream from the actual property boundaries within the wash. This also applies to the width of the wash for which the owner/developer is held responsible. For example, in some cases, where the wash was flanked by single-family one side, multi-family the other side, the single-family side could be separated from the wash by a parkway road, the open space plan integrated into the multi-family development and the total operation and maintenance paid by the multi-family owner/developer. This would also be in conjunction with density trade-offs, discussed elsewhere in this study.

Opportunities

There are numerous recreation opportunities available within the wash study area. The major opportunity is that, in an era where funding for all phases of public recreation is very scarce, a plan may be developed whereby the service is supported by the private sector either as supplemental to the public offering or in total for parts of the open space and trails.

Also of interest would be a joint operation and maintenance program, or even division of total responsibility for the recreation areas between the City of Phoenix, Maricopa County Parks and Recreation (trails and trailside rests seen as a complementary extension of the comprehensive county trails system),

Arizona State Parks (the provision of park areas to serve urban population is still a concern; state parks is also responsible for historic preservation within the state and therefore may be interested in the historic/archaeological ruins within the study area; and the state hiking and riding trails coordinator resides under the state parks umbrella) and the various Federal agencies known to indulge in provision of recreation (BLM, BuRec, National Parks Service and the COE). Assistance may also be available through Arizona Game and Fish for revegetation designed as wildlife habitat. (The Arizona Game and Fish does not presently consider the study area as significant wildlife habitat.)

The opportunities in terms of recreation facilities are initially only limited by the imagination. Pragmatically, however, the list is narrowed considerably by the ability and/or desire of the city or the owners/developers to pay the cost resulting from extensive or exotic types of recreation. The more complex facilities should be left entirely to private developers established to provide the specific service (water slides, sports arenas, pistol and archery ranges, equestrian facilities such as polo fields, hot-air balloon launch pads, field-dog trial areas, and bicycle moto-cross racing, recreational vehicle campgrounds, golf courses and other non-standard forms of recreation facilities).

The services provided by the owner/developer organization should be limited in scope to keep the operation and maintenance within a range the group will continue to support. City services should be limited to trails, picnic areas, vehicular parkways, group picnic areas (such as in Squaw Peak Park), related parking, multi-use fields and play apparatus as appropriate within the neighborhood parks.

Revegetation, vegetation enhancement and earthform work will be the responsibility of the city within its controlled areas of the wash. The city parks department will also be in an advantageous position to monitor and advise on construction of recreation facilities to the city's standards throughout the wash development. Further considerations could be given to the continued monitoring of the maintenance throughout the wash by private owners/developers to insure continuation of the city park's standards.

The city may wish to consider an urban campground concept, in which organized camping is developed in close proximity to the city. This program could be established and operated by the city in conjunction with another agency, such as state parks or Maricopa County or by concession agreement. The feasibility of such an offering would require a cost-effectiveness management study on its own; however, the area for such a project is presently north of the CAP.

Other events not needing extensive or special facilities should be considered such as a Cave Creek 10K run, regional or national dog trials, radio-control aircraft flying events, community craft markets and so on. The cost of cleanup and repair after such events is a concern and a special-use permit and enforcement would be necessary to continue such services.

Recommendations

The recommendation for recreation opportunities in the overall master plan for the wash development is based on the following:

1. Identification of existing and potential compatible recreation activities within the wash.

2. Determination of the size of site(s) needed for the desired recreation activities and the utilization of the entire site. All parts of the property should have a definite function and contribution to aesthetics and utility.

3. Provision of priority areas and facilities. Activities in greatest demand should be planned for early installation; incidental features receive secondary consideration in allocation of space and funding.

4. Multiple use. Features should be identified which provide varied forms of recreation, either through seasonal or time-schedule changes and different age and occupational groups.

5. Ease of operation and maintenance. The facilities should be established as vandal-resistant, non-irrigated, easily accessible and at a basic level of sophistication. This includes the amount of supervision necessary to maintain the facility and its activities.

6. Circulation and access. It should be convenient for the people engaging in the types of activities taking place in the wash to reach them. At the same time, security must be maintained for those people residing on or near the wash area. Constant trail access should be possible without interfering with other activities.

7. Safety. Proper location of trails and roads as well as any ancillary items placed in the wash must be evaluated for potential liability.

8. Utilization of natural features. Any natural feature within the wash area which is available for recreation use will be incorporated in the plan. This is buffered by the features relation to flood control, existing or desired recreation activity and the ability to control and maintain the feature.

Recreation development of the wash naturally divides into three distinct sections based upon the resource studies completed:

1. The area north of Deer Valley Road. This includes those areas desired by the City Parks through assumption of BLM lease now held by FCDMC and, the Union Hills lease desired from BLM, as well as

portions of the Deer Valley Airport clear zone to the east of the runways. This area is more natural in character, despite the gravel extraction area and contains the second best vegetation (East Fork is the best, see Biology) and the outstanding cultural/archaeological material within the study area. Development has not encroached into the area and there are expansive flat reaches both above and below the Cave Buttes Dam. The steepest hills within the study area also exist herein but are of limited coverage over the entire portion of the site. This area is accessible to the study area south of the CAP only by bridges on 7th Street and 7th Avenue. A portion of the site is in the Deer Valley Airport clear zone and is presently used for off-road vehicle recreation.

2. The study area south of the CAP to east of I-17. This area is scarred, excavated and generally stripped of its natural character. There is an area of vegetation between Beardsley Road and Union Hills Drive. This area would correspond with a suggested park area along the wash (Figure C-10, Opportunities and Constraints) and the lower one-mile from Beardsley Road to the Interstate is channelized and regraded, completely disrupting the natural channel and habitat. The basic recreation use of this stretch between CAP and I-17 is horse riding between the horse-oriented development to the north and the Sun Circle Trail. The area is broken by erosion and side drainage with limited open, flat areas to develop large-scale recreation facilities. These open areas are also prime development areas for expansion of residential, commercial and industrial use.

3. The East Fork (confluence of Cave Creek near Greenway Road to 7th Street). This area presently encompasses a proposed city park and contains some of the best vegetation within the study area. There are limited open areas excepting the city park and development has moved against the channel in areas.

Basic recreation facilities for the Cave Creek study area will be discussed in relation to the three basic reaches. The first area (north of Deer Valley Road) lends itself to larger-scale recreation: campgrounds, field-dog areas, archery-pistol ranges, equestrian facilities, balloon launching sites and other activities requiring considerable space for participant and spectator.

Concession-run recreational vehicle campgrounds, bicycle race tracks and any other consideration of a lagoon within the existing gravel pit should also be located in this area. The existing use by motorcycles should be continued but carefully confined to the existing areas of use for the following reasons: the area is already greatly disturbed, the area is known and frequented by the motorcycle users, it is in a basic undevelopment zone (airport clear zone) and, if closed to off-road use, would simply result in the users going elsewhere, perhaps to a less environmentally desirable area. While the off-road use is

basically incompatible with all other forms of recreation noted, the confinement to the existing area should resolve the problem of overlap.

The Union Hills-BLM lease would be left in natural state except for trails and minimal development for the safety and comfort of hikers and equestrian users (Figure 4, Landscape Rehabilitation Area with Trail). An improved connection between the north and south side of the CAP is needed to implement the flow of users along the wash area. This would be either bridge improvement to give an equestrian pathway along the existing bridges at 7th Avenue or 7th Street, a rebuild/modification of the spillway, or a new crossing strictly for hiker-equestrian trail use, preferably adjacent to the existing spillway to assure a contiguous trail pattern.

The second area, south of Deer Valley Road to the Interstate should be an area of limited recreation relating mainly to surrounding development and serving as a medium for trails continuation and neighborhood park facilities (Figure 5, Typical Continuous Trail System (Perspective)). This stretch of Cave Creek is the most adaptable to modification including recreational facilities. Limited facilities are suggested such as picnicking, trail rest sites and neighborhood parks as appropriate (Figure 6, Neighborhood Parks and Trails). Trails access points from surrounding areas or trailheads are also present. This area is the city's major opportunity to acquire private maintenance through density trade-offs and joint open-space use.

The third area, East Fork, contains the best vegetation in the study area and should be left, as much as possible in relation to the hydraulics, in its natural state. A method of accomplishing this may be to limit the width of the channel work to no less than 300-feet wide, of which one-third of that width must be left within the channel containing that section of the channel's best vegetation. The linear strip containing the best vegetation does not have to be continuous and may undulate within the confines of the channel limits (Figure 7, Floodplain Channel Retaining Natural Vegetation). The existing city park is on the East Fork and should be tied into the natural channel (no channelization at all within the confines of the park) to provide a continuous vegetation belt from the confluence with Cave Creek to 7th Street. Along with the natural strip would be the trails system with a trailhead at 7th Street. No recreation features other than the park and the trails would be furnished along East Fork.

General site planning for the study area calls for a contiguous trail system for hiking, biking and equestrian for the entire length of the wash and tributary (Figure 8, Typical Trail Picnic or Rest Area (Plan View)). Trailheads would be placed at the start of the system near I-17, on 7th Street, intermittent along the main wash at park sites, at the CAP trail interconnect and at Cave Buttes Dam.

The trails opportunities are to connect southward with the Sun Circle system, the Arizona Canal Diversion Channel system and on to the potential Rio

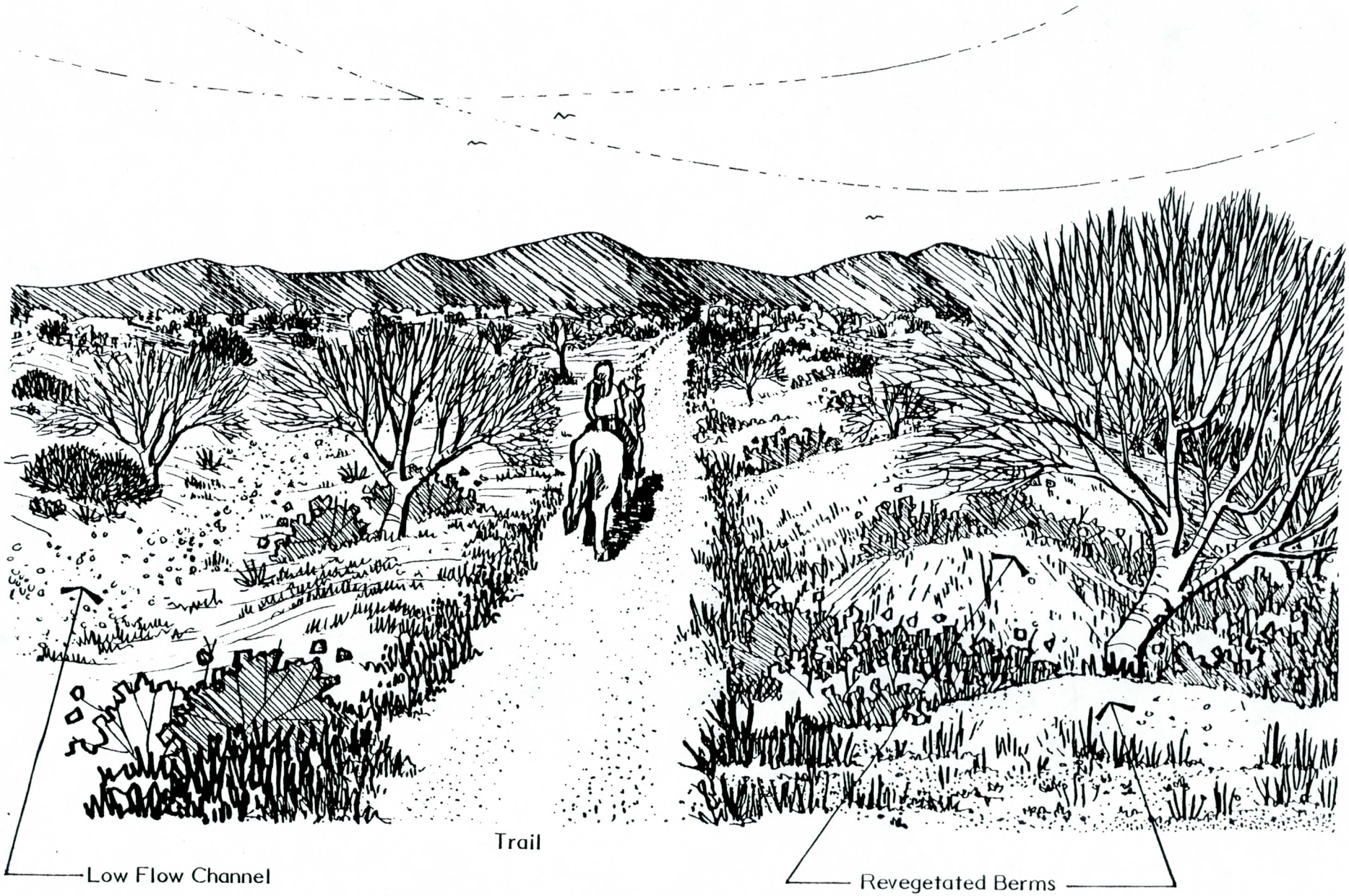


FIGURE 4

LANDSCAPE REHABILITATION AREA WITH TRAIL

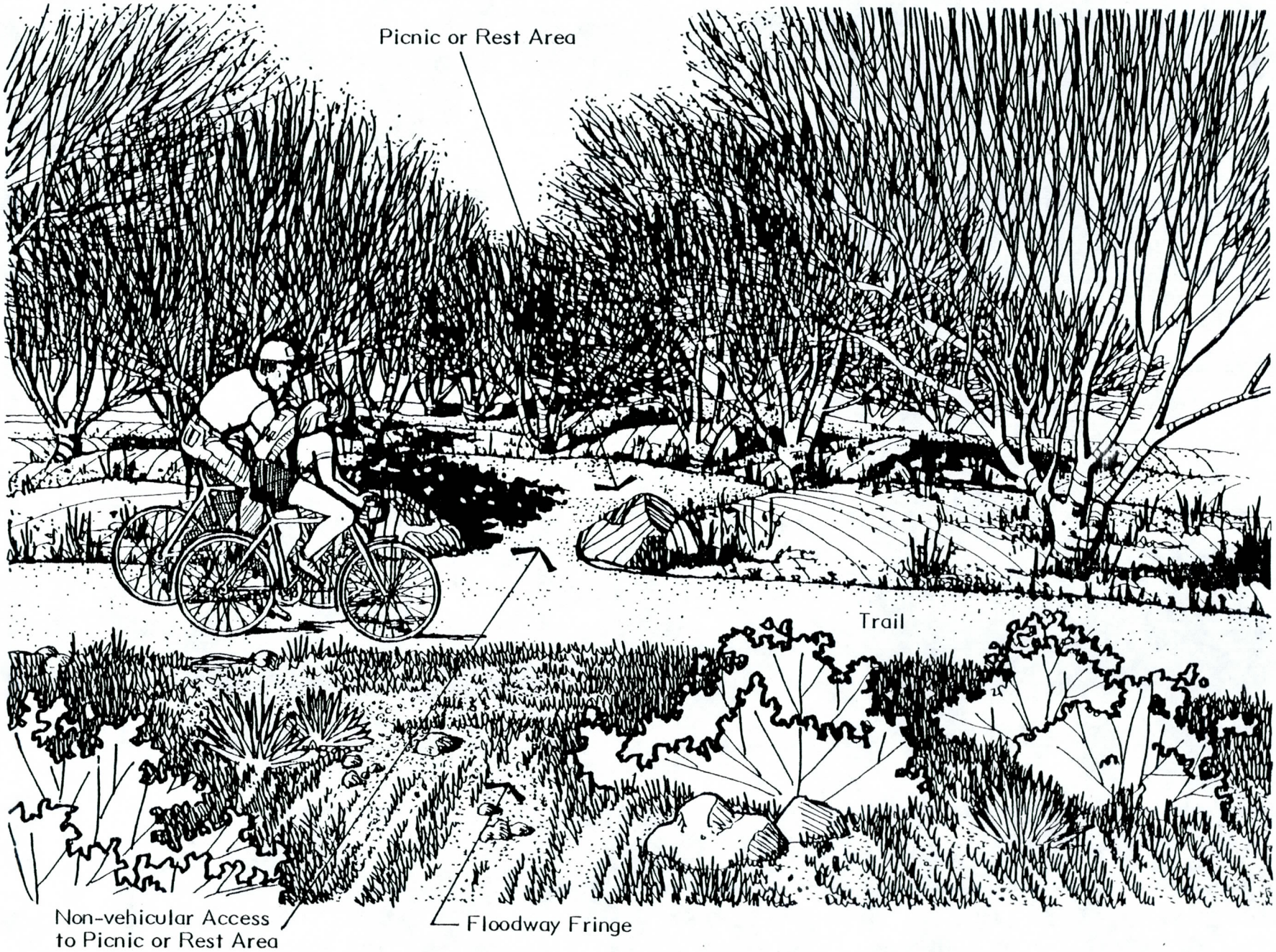


FIGURE 5

TYPICAL CONTINUOUS TRAIL SYSTEM (PERSPECTIVE)

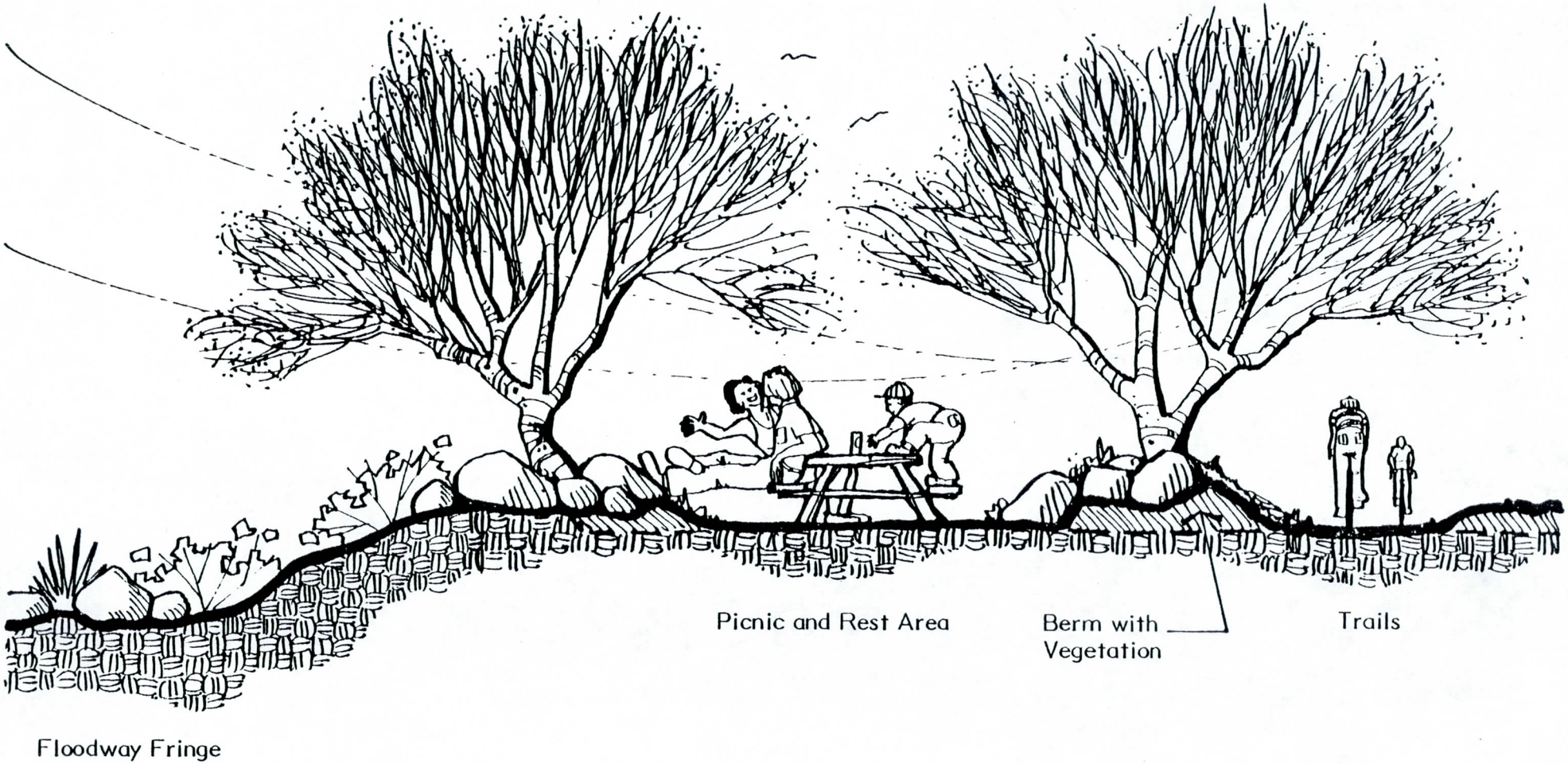


FIGURE 6

NEIGHBORHOOD PARKS AND TRAILS

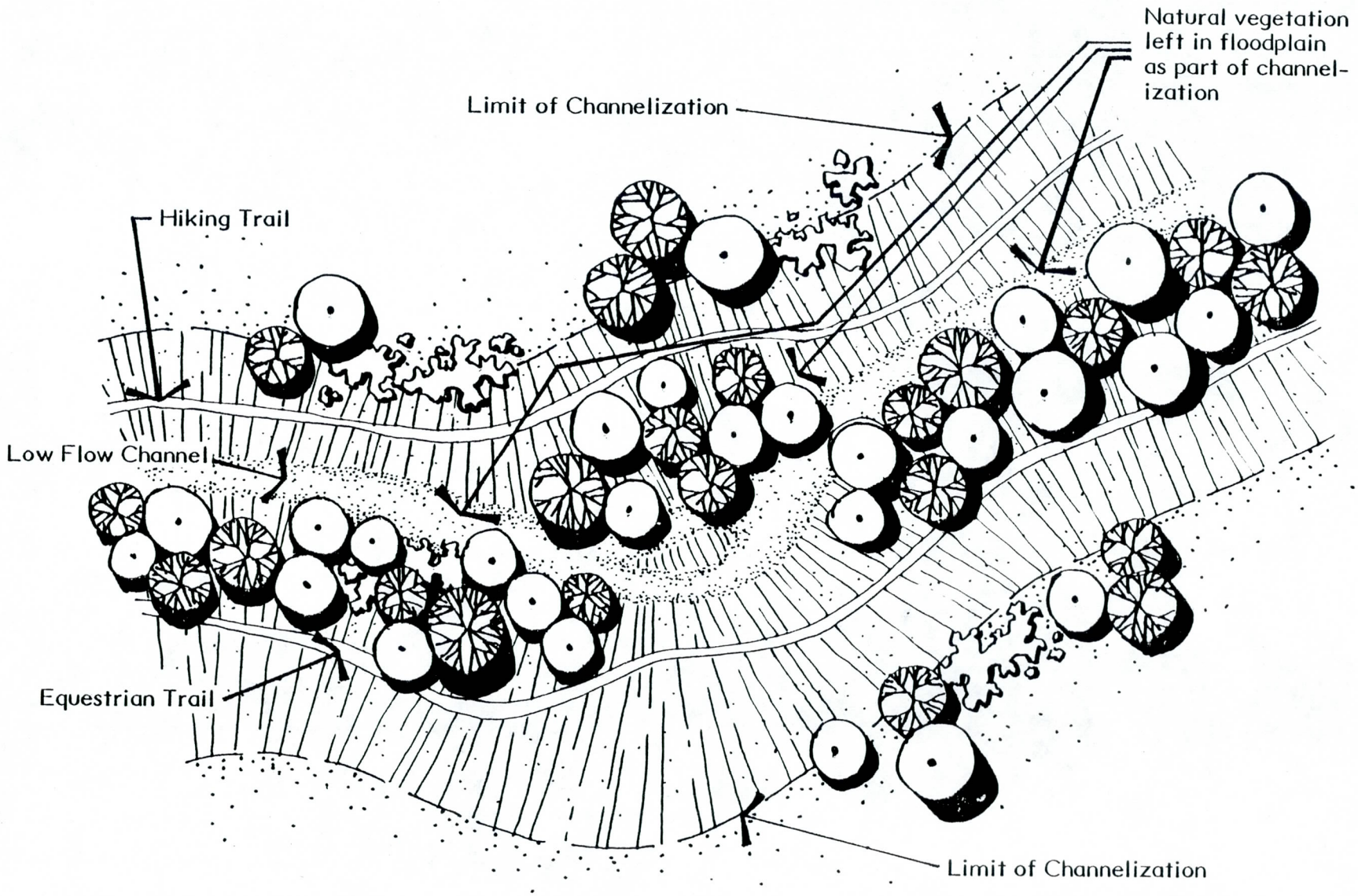


FIGURE 7

FLOODPLAIN CHANNEL RETAINING NATURAL VEGETATION

TYPICAL TRAIL PICNIC OR REST AREA (PLAN VIEW)

FIGURE 8

Salado system. Trails north to Cave Creek and the Agua Fria River could be established and the interconnect with the CAP trails adds access to Skunk Creek west and Indian Bend Wash east. An eventual tie is possible to the Roosevelt Water Conservation District trail from Apache Junction to Gila Butte.

Development of cultural resources in the designated areas could add considerable interest to the recreation plans, providing a trail destination for users. Interpretation could be very simple without architectural enhancement. The major problem perceived is management and protection of the resource.

Special users should be supported in every manner possible including development of facilities relating to elderly and handicapped. The area is within range of Sun City, for example, and group-use facilities might be appropriate. Use by various handicapped groups could be carried into the interpretive and trails program with special signage and displays available.

VISUAL RESOURCES

Inventory

The purpose of the visual resource study was to analyze and describe the visual attributes and aspects of the study area. The study was conducted in June and July 1981.

The study approach was to determine the dominant visual elements of vegetation and/or landform interest and major vistas dependent on number of viewers (duration of view). This information assisted in the designation of areas which could be retained, screened, enhanced or areas of linkage opportunity.

The visual study included the analysis of topographic and aerial photographs, combined with land use and cultural information. Areas were field-checked to note views and landscape conditions. Visual characteristics subsequently identified included natural areas, potential vistas, disrupted areas, possible on-site and off-site linkages, and ultimately areas of primary concern.

The visual landscape is typical of alluvial desert deposition. The wash area has been cut by a braided stream network and has some deeper main channels in some stretches. The natural edge quality of most of the channel is mostly disrupted and eroded. The vegetation consists of some clumped riparian growth, but mostly consists of disrupted creosote-bursage communities typified by ephemeral and phraetophyte invader species. The wash bottom, in many cases, has been dredged, bladed and used as a refuse dump. There are many disrupted areas around residential developed areas (which surround the wash area), and in and around several gravel pits operating in the wash area.

Several of the surrounding hillsides show signs and scars from past and present mining tunnels, tailings and road cuts. Much of the wash area shows degradation from off-road vehicles.

Four major accessible vistas were identified for site viewing: (1) Cave Creek Buttes Dam; (2) top of a hill north of Pinnacle Peak Road and west of Cave Creek; (3) top of hill north of Pinnacle Peak Road and east of Cave Creek; and (4) hills surrounding Deer Valley Road at Cave Creek. In addition, because of informal recreation activities and adjacent residences, the entire site is visible and, consequently, visually sensitive.

Implications

Vistas identified throughout the study area (including travel routes, residences and use areas) provide an opportunity for technical interpretation of the project environs (e.g., the cultural resources). Identified sand and gravel operations should be screened from users of existing or proposed roads and/or trails within the study area through vegetation and landform manipulation. In addition, after abandonment of sand and gravel operations, rehabilitation of excavated areas would be desirable through vegetation and landform manipulation. Although a few opportunities exist for exterior views (e.g., viewing Union Hills from Cave Creek), the majority of views within the Cave Creek Wash area including East Fork, will be interior (e.g., views within the wash) in orientation since the surrounding landscape is presently or will be developed.

CULTURAL RESOURCES

Inventory

The purpose of the cultural resource study is to evaluate the cultural resource base in the study area and gain an understanding of the opportunities for, and constraints to, the development of the Cave Creek Wash area. Based on the results of the study, implications for the management of the identified cultural resources are provided. The study was conducted in June and July 1981.

The resource inventory was accomplished by records searches at the following institutions and agencies:

Arizona State Museum, Tucson
Arizona State University, Tempe
Museum of Northern Arizona, Flagstaff
State Historic Preservation Office, Phoenix
Bureau of Land Management, Phoenix

Site locations were plotted on 7.5' U.S. Geological Survey (USGS) topographic quadrangles and the 1:600 scale project base map. Site information was obtained from the institutions and compiled. Brief field reconnaissance was conducted in the Fort Mountain vicinity July 8, 1981 in order to determine the present condition of some of the sites within the study area.

The assessment of resource significance was necessarily limited by the nature of existing information. For the most part, significance evaluations would require more data than are currently available. The exception to this is the Cave Creek Dam Archaeological District (see below), for which detailed significance evaluations have been compiled (Fryman 1976).

As a seasonal water source in an arid environment, Cave Creek was expected to have a high potential for containing significant archaeological materials. These expectations were fully borne out and the results of the investigation revealed 25 recorded archaeological sites (Table III) and several historic structures and mines in the study area (Table IV) although they have no official site numbers.

Prehistoric Sites

The northern portion of the study area overlaps the Cave Creek Dam Archaeological District, nominated to the National Register of Historic Places in 1976 (Figure C-8, Cultural/Biological Resources). This portion of the district encompasses 12 prehistoric sites representing use of this upper Sonoran Desert environment during a period from A.D. 700 to 1350 by Hohokam or a Hohokam-like culture. The sites reflect functionally interrelated activities including irrigation canals, water control structures, agricultural terraces, garden plots, field houses and habitation units. Also included in the complex are petroglyph panels and a rock wall-enclosed butte top known as Fort Mountain. The majority of the sites surround Fort Mountain of the Cave Buttes (the two buttes which dominate the area). The agricultural terraces and gardens were located along the lower terraces to catch water runoff from slopes above. A canal system diverted water flow from Cave Creek to irrigate alluvial terraces and floodplain areas adjacent to Fort Mountain.

Previous archaeological research in this area includes Midvale n.d.; Rosnek 1950; Dittert, Fish and Simonis 1969; Kemper, Schultz and Dodge 1972; Holiday 1974a, 1974b; Rodgers 1974, 1976a, 1976b; Smith 1974, 1976; Burton 1977.

In general, the sites suggest that the inhabitants were involved in extensive and intensive agricultural use indicating a particular settlement adaptation to the desert upland environment of Cave Creek.

The remaining 13 sites within the study area (south of the archaeological district) consist primarily of sherd and lithic scatters. Prior to the development of housing subdivisions in the area, two of the sites (T:8:87 and T:8:100) have been excavated and documented (Rosenberg 1976, Woodward 1979). Site information for the remainder is unfortunately minimal or nonexistent.

Historic Sites

Within the study area, the historic sites identified are in the immediate area of the Cave Creek Dam Archaeological District. Two of the sites considered particularly significant include the Rio Verde Canal and the Cave Creek Dam, resulting from a need to manage water; this theme continues from the prehistoric period of the area.

The Rio Verde Canal (1890s) was part of a proposed system of dams and irrigation canals to deliver water to the valley between the Verde River and the New River for agriculture. Only the canal segment from the headgate on the Verde River to Cave Creek was completed before the project was abandoned. A similar project later intended (1918) to use the completed portion of the canal, but this project was also abandoned.

The Cave Creek Dam, constructed in 1922-23 and still in use, was built to control flooding. The dam, a multiple arch reinforced concrete structure designed by a noted engineer, was one of the first of its kind in the United States.

Among other historic resources are a ditch (which basically parallels one of the prehistoric canals) and associated laterals, Union Mine of the late 1800s, a water pipeline (plotted on an 1895 General Land Office map) from Union Mine to a mill and early Cave Creek Road from Phoenix to Cave Creek.

Implications

Constraints

Archaeological and historical sites are nonrenewable resources with scientific, public, educational, aesthetic and commemorative values. They potentially provide information which is useful in the study and reconstruction of past lifeways; they can be used in interpretive programs that enhance public understanding and enjoyment of their cultural heritage; and, they serve as a bridge between the present and past.

The presence of significant cultural resources should constrain development so that disturbance to these resources can be avoided, if possible. This is especially the case on public lands, where cultural resources receive legal protection.

The Arizona State Historic Preservation Office has determined that the Cave Creek Dam Archaeological District is a significant resource and has nominated it to the National Register of Historic Places (Fryman 1976). Development in this area should be required to avoid impacts to cultural resources. Currently, sand and gravel mining operations on state lands in the district are required to avoid such impacts. In addition, the COE avoided impacts to old Cave Creek Dam through a redesign of the spillway for the new dam.

The Fort Mountain complex demonstrates the high archaeological potential of Cave Creek. Known cultural resources outside the district may also constrain development. Specific planning requirements should be included in the master plan to ensure adequate protection of cultural resources. It is recommended that the State Historic Preservation Office be contacted in the early planning stage of any specific proposal that would involve grading or other significant forms of ground disturbance. This stipulation should apply equally to private developers as well as to public agencies.

Opportunities

In addition to constraining development, cultural resources may also present the planner with the opportunity to enhance open space and recreation goals. Both public (state and Federal) and private funds are available for the protection, preservation, interpretation and enhancement of cultural resources. While Federal funds can be expected to be reduced in the near term, long-range planning must take into account the long history of public and private involvement in historical and archaeological preservation. The likelihood is that this interest will be carried into the future.

The Cave Creek Dam Archaeological District provides an excellent opportunity for historic preservation and interpretation. It contains many cultural resources (both prehistoric and historic) that are visible on the ground surface. These include prehistoric petroglyphs (rock paintings) and pit houses, prehistoric and historic irrigation canals, historic engineering structures, and a prehistoric fortified hilltop. There already exists a graded road to the hilltop which could be developed into an interpretive trail. Overlooks include views of prehistoric canals, an early historic canal, a nineteenth century pipeline associated with the Union Mine, Old Cave Creek Dam, Cave Creek Buttes Dam and the Granite Reef Aqueduct. Thus, a thematic interpretive program emphasizing the prehistory and history of water control in the region could be developed. The fortified summit of Fort Mountain contains impressive prehistoric dry masonry and commands excellent views of the Cave Creek area. The petroglyphs at the eastern foot of Fort Mountain are immediately adjacent to the Cave Creek floodplain and could be easily linked to any recreational trail system that were to follow the stream.

For the most part, the resources of the Cave Creek Dam Archaeological District are in an excellent state of preservation, although recent refuse,

including broken glass, skeet and other shooting targets, litter much of the lower areas. The fortified area is largely undisturbed, despite the road to the summit (which requires a four-wheel-drive vehicle). From an interpretive perspective, the major challenge would be the treatment of the modern grafitti which mars several of the petroglyphs at the foot of the mountain.

BIOLOGICAL RESOURCES

Inventory

The following summarizes the biological study undertaken to determine the nature and quality of naturally occurring biological resources present in the Cave Creek study area. In particular, the presence of highly sensitive biotic resources (e.g., threatened or endangered plants or animals) was determined so that such features could be taken into consideration in future planning and implementation.

Field reconnaissance of the study area was conducted on foot and by vehicle. The information collected during on-site studies was combined with a brief review of pertinent literature and a discussion with the Arizona Game and Fish Department (Robert K. Weaver) regarding the area to form the foundation of this report.

Vegetation

Cave Creek Wash between Greenway Road and Cave Creek Dam and along the East Fork tributary (to 7th Street) is floristically dominated by species that are charcteristic of desert riparian plant communities. Blue paloverde (Cercidium floridum) is the most common tree species. Blue paloverde is commonly associated with mesquite (Prosopis velutina), ironwood (Olneya tesota), desert willow (Chilopsis linearis), foothill paloverde (Cercidium microphyllum), and, in areas where water collects, salt cedar (Tamarix pentandra). These tree species form a rather sparse woodland along most of the wash. Only in a few areas is the density of these species adequate to form a true woodland community - generally there is a separation between individual trees of 10 meters or more. The most abundant perennial plants along the wash are shrubs of various species: wolfberry (Lycium andersoni), catclaw (Acacia greggii), desert broom (Baccharis sarothroides), burro brush (Hymenoclea sp.), desert lavender (Hyptis emoryi), and canyon ragweed (Ambrosia ambrosioides). Burro brush and desert broom are the most abundant plants.

Upland areas adjacent to the wash are dominated by creosotebush (Larrea tridentata) in association with triangle-leaf bursage (Ambrosia deltoidea), with bursage (A. dumosa), foothill paloverde, and ironwood also present. Rocky

sites near the wash support the best stands of cactus in the area with saguaro (Cereus giganteus), teddy bear cholla (Opuntia bigelovii), staghorn (O. versicolor), and barrel cactus (Ferocactus wislizeni) all occurring in such areas. Staghorn and christmas cactus (Opuntia leptocaulis) also occur locally in Cave Creek Wash itself.

No threatened or endangered plant species are known to occur in Cave Creek Wash (U.S. Fish and Wildlife Service 1980). There are a number of species, however, that occur in and near Cave Creek Wash, protected by the Arizona Native Plant Law (e.g., paloverdes, mesquite, ironwood, and all cacti). Any clearing of land supporting such species must be preceded by notification of the Arizona Commission of Agriculture and Horticulture at least 30 days before such clearing is to take place.

Wildlife

The majority of wildlife species likely to occur along this stretch of Cave Creek Wash are nongame species. Game animals that are present along the wash include gambel's quail (Lophortyx gambeli), mourning dove (Zenaida macroura), white-winged dove (Z. asiatica), and desert cottontail (Sylvilagus auduboni). Mule deer (Odocoileus hemionus) probably occurred along the wash prior to the human development presently existing in and along it (R.K. Weaver, Arizona Game and Fish Department, personal communication, July 1981). Other protected or regulated species that may occur in Cave Creek Wash are gila monster (Heloderma suspectum) and horned lizards (Phrynosoma sp.). Gila monsters are probably uncommon-to-rare in the wash and horned lizards may be locally common.

The best areas of wildlife habitat along the wash occur between the CAP aqueduct crossing of Cave Creek Wash and the gravel excavation area south of Cave Creek Dam, and in the area between Union Hills Drive and Bell Road. Also of value to the study area's wildlife is the existing vegetation between the confluence of the East Fork and Cave Creek and the start of the head-cutting erosion approximately one-quarter mile downstream from 7th Street. The area north of the CAP crossing contains some dense riparian (desert riparian) habitat that is not too badly disturbed. There is also an area just below Cave Creek Dam that holds water for long periods, attracting waterfowl in the fall and winter months (R.K. Weaver, Arizona Game and Fish Department, personal communication, July 1981). This same area supports a small stand of cottonwood and willow trees along with many salt cedars, all of which are just beginning to take hold following flooding of the area in recent winters.

The area between Union Hills Drive and Bell Road, and including the East Fork, contains some reasonably good small game and nongame habitat. The area is badly disturbed from off-road vehicle use, trash-dumping and sand extraction (small scale) but still maintains a major percentage of its natural

integrity. Other pockets of fairly good wildlife habitat occur throughout the length of the wash but, generally, major disturbance and total habitat destruction are the predominant features of Cave Creek Wash.

Implications

Maintaining the riparian habitats north of the CAP crossing in their present state would be beneficial to many wildlife species and provide a site for area residents to enjoy some natural open space. The area between Union Hills Drive and Bell Road could be greatly enhanced from the standpoint of natural biotic resources if trash dumping and excessive off-road vehicle use were eliminated. This area could also provide some attractive open space for area residents as well as providing habitat for some wildlife species. The East Fork is in good enough condition that a cessation of off-road vehicles and dumping and a detailed clean-up of existing trash would result in continued plant cover growth and an attractive corridor for potential trails use. The various trail uses have not historically interfered with the existence of the nongame species now present. Introduction of arid-plant material such as atriplex to enhance the wildlife habitat could prove very beneficial, both to wildlife and erosion problems.

In terms of priority of the existing wildlife habitat and diversity of plant species, the ranking of importance of the three remaining areas are: (1) the riparian growth below Fort Mountain, north of the CAP to the gravel extraction area; (2) the East Fork from approximately one-quarter mile west of 7th Street to the confluence with Cave Creek Wash; and (3) the areas between Union Hills Drive and Bell Road.

The effect of Cave Buttes Dam on the flora and fauna of Cave Creek Wash remains to be seen. The animal life is dependent upon the vegetation, and the vegetation is dependent upon the limited water supply available in this area. Several areas will probably benefit from the dam, specifically the immediate downstream area due to seepage should the dam ever hold a large quantity of water for a period of time. The entire Cave Creek Wash may benefit since the water will now be held and released at a given rate, probably over a longer period of time than the same amount of water would take to pass through Cave Creek Wash without the restriction of the dam. East Fork will not be affected by the dam since its water comes from a different area.

Continued development along the banks of Cave Creek Wash would generally have very little adverse effect on the existing natural biotic resources. With the exception of areas mentioned above, the wash is very badly disturbed and little wildlife habitat remains. Similarly, there is virtually no chance of development conflicting with any highly sensitive wildlife species (e.g., threatened or endangered forms) or similar plant species.

TOPOGRAPHY

Inventory

The study area's topography was reviewed in terms of the general character, drainage patterns and channel slopes. Base map topography was derived from the City of Phoenix's quarter-section mapping. More detailed topographic information on the channel was obtained from FEMA's flood insurance work maps dated 4/1/80. Finally, USGS quadrangle maps were used as an additional source of general information.

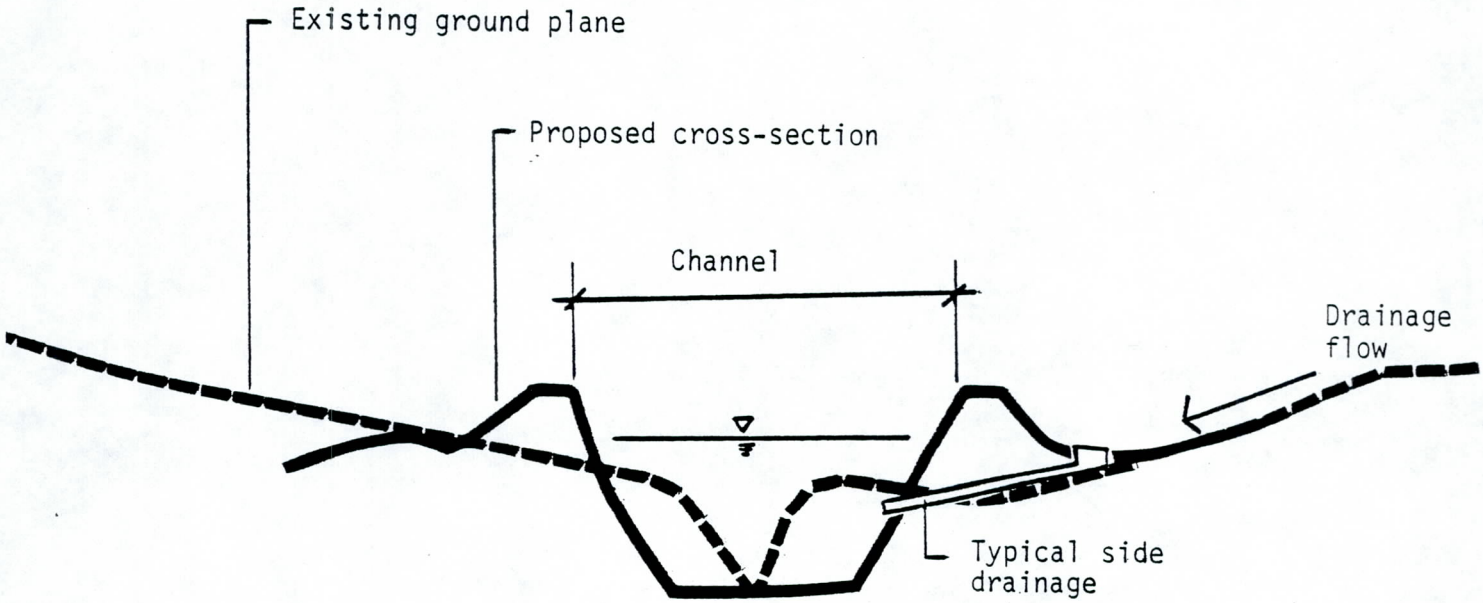
In general, Cave Creek Wash drains southwesterly and is a major drainage into the Salt River tributary system. The main channel of Cave Creek Wash cuts across the study area's tributary which slopes from northeast to southwest. Therefore, the tributary area to the wash is north and east of the floodplain. The area west of the main channel drains westerly away from the channel. The channel runs adjacent to Cave Buttes, Fort Mountain and Union Hills on the north and Moon Mountain on the south. Elevations vary from 2,400 feet in the mountain areas to the north, to 1,600 feet at the southern boundary of the study area at 19th Avenue. Channel slopes are relatively flat, varying from 0.004 to 0.0065 along the thalweg (low point in channel). Depths of flow along the channel range from 4.5 to 12.5 feet with an average depth from thalweg to water surface of 6 to 8 feet.

Implications

Implications of the topographic information are twofold. Because of the drainage patterns adjacent to the channel, numerous small washes along the east side of the main branch and both sides of the East Fork of Cave Creek Wash will have to be intercepted by adjacent developments and routed to the channel. Therefore, levee systems of protection (Figure 9, Typical Levee Systems) for these developments could create side drainage problems within the development. The typical channel section showing a fill-pad type of protection is strongly recommended (Figure 10, Typical Fill Pad Systems).

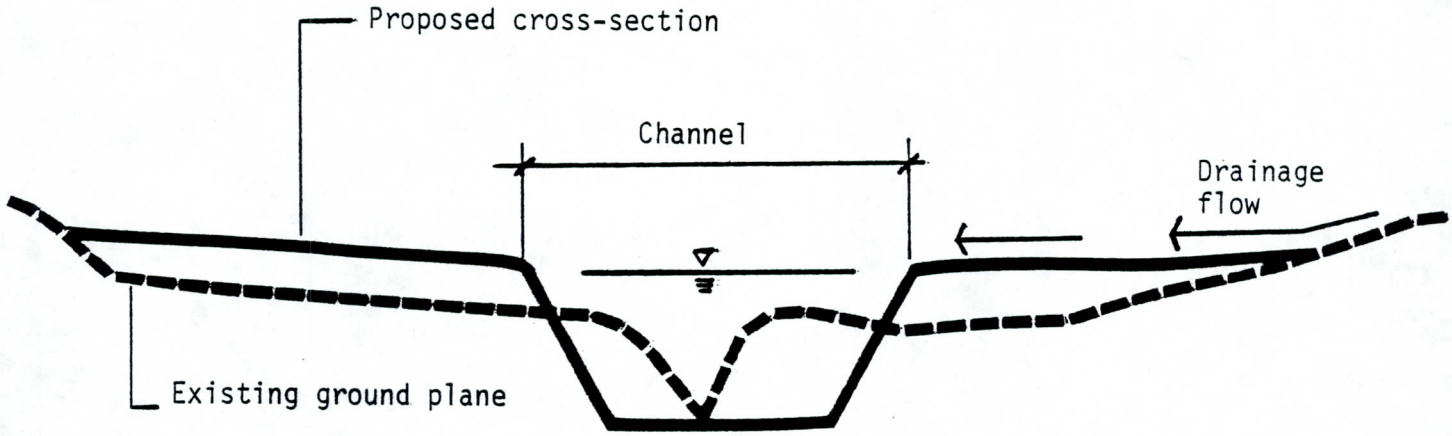
Along the west side of the main channel, significant side drainage will not be present since the area generally drains westerly away from the channel into the residential area between the channel and Black Canyon Freeway. While this eliminates side-drainage problems, it could result in "breakouts" from the channel. Any water going into the overbank will flow away from the channel, flooding homes to the west. The breakout occurring between Beardsley and Deer Valley roads will be discussed in detail in the sections addressing Hydraulics/Hydrology/Flood Control.

Channel slopes in the study reaches are steep enough to cause velocities in excess of what, ordinarily, would be stable for earth-lined channels. Refer to the Hydraulics section for the evaluation of this problem.



CROSS-SECTION OF TYPICAL
LEVEE SYSTEM OF PROTECTION

FIGURE 9



CROSS-SECTION OF TYPICAL
FILL PAD SYSTEM OF PROTECTION

FIGURE 10

GEOLOGY AND SOILS

Inventory

Major geologic features and soil characteristics were reviewed for development opportunities and limitations. The channel bed and banks were examined for erosion potential and for the presence of potential armoring-size material.

The primary source of information was the result of field reconnaissance conducted in June 1981. Two written sources of information were also utilized: a report by the U.S. Department of Agriculture titled, "General Soils Map for Maricopa County" dated 1973 and a boring log report by ATL for the Deer Valley landfill (downstream of the project) dated June 20, 1980. Boring log information with sieve analysis of the bed material was not available, resulting in a very rough scour and degradation analysis.

Two soil types were found in the study area. The Gilman-Estrella-Avondale Association is the predominate soil type found. The association consists of deep loam and clay loam soils on nearly level, broad, featureless valley plains and floodplains. These soils formed in recent alluvium and are derived from a variety of rocks. The natural vegetation in the area are creosotebush, cacti, annual grasses and forbs, along with scattered mesquite and paloverde trees.

The Gilman-Estrella-Avondale soils profile is moderately alkaline and slightly-to-strongly calcareous. The Gilman soil is yellowish brown and light yellowish-brown loams. The Estrella soils have a brown and light brown surface layer with a buried brown or yellowish-red, clay loam subsoil. The Avondale soils have a dark grayish clay loam surface and a light yellowish-brown and pale brown loam subsoil.

The soils of this association may be used for irrigated crops, seasonal grazing, sites for homes, industry, recreation and wildlife habitat. The Gilman and the Estrella type soils have a fair use for roadfill and has a classification of ML. The Avondale soil has a fair use for roadfill also and is classified as ML and CL.

The Gilman-Estrella-Avondale Association soils (soil classification ML) have a low-to-moderate shrink-swell potential, a pH of 7.9 to 8.4, is highly corrosive to uncoated steel and low-to-moderately corrosive to concrete. The soil is in Hydrologic Group B, and in the fair range for use as roadfill. This soil is unsuited for sand and or gravel mining operations.

The other soil type in the upper part of the main wash is the Cherioni-Gachado-Rock Outcrop Association. This association is composed of shallow and very shallow gravelly and cobbly soils and exposures of bedrock. They occur on moderately sloping to steep mountains which are composed of granite-greiss, basalt, andesite, rhyolite, tuff, schist and granite. This soil, in

Hydrologic Group D, has the same soil properties as the Gilman-Estrella-Avondale Association soil except for being potentially suitable for sand and gravel operations. A number of sand and gravel operations are, in fact, now operating in the upper reaches of the main channel.

Field visits indicated the presence of a colloidal graded silt to cobble soil in the banks with a noncolloidal gravel in the bed. The mountain slopes adjacent to the channel consist of loose boulders. Land subsidence cracks are not known to be present in the area. Groundwater levels are at or below approximately 400 feet in depth.

HYDROLOGY

Inventory

The hydrology data were taken directly from work completed for the FEMA Floodplain Information Study by the COE and Cella, Barr, Evans & Associates. The hydrology section addresses the flow rates in the channel and not their derivation.

In addition to the FEMA study, additional data were obtained from telecons with Dave Burris (City of Phoenix Floodplain Section), Dave Johnson (FCDMC) and Nick Romanzoff (Los Angeles District, COE).

The COE recently completed construction of Cave Buttes Dam at the northern (upstream) end of the study area. Operation and maintenance of the dam and the floodplain below (study area) is the responsibility of the FCDMC. The COE requires maintenance of a floodway capable of handling the "future 100-year flood." FEMA delineations, however, are for a 100-year event under "present conditions." The two flow rates are approximately the same from the dam down to the main channel/East Fork junction, north of Greenway Road with one major discrepancy between the COE and FEMA numbers. The FEMA floodplain is based on a breakout occurring in the main channel downstream of 7th Street and the COE's delineation assumes this area will be protected by levees. The COE's flow rates in the main channel are, therefore, higher than the FEMA numbers. The COE and FEMA numbers for the main channel and East Fork are shown in Tables V and VI, respectively.

The COE is preparing an operation and maintenance manual for the dam including the downstream floodplain (main channel). The manual will be available for review in January of 1982.

Implications

The hydrology data will be used to set design capacities for the channel and to look at various low-flow channel capacities. Design capacities of the channel

will be based on the 100-year flow rate including a minimum of one foot of freeboard. In the main channel, the COE's "future" 100-year flow rates are used since ultimately the breakout identified by FEMA must be confined to the channel thus eliminating the possibility of significant flooding in the residential area to the west. Low-flow channel capacities should be set at a minimum of 500 cfs (Cave Buttes Dam outflow capacity), due to the possibility of prolonged releases at this rate.

Flow rates on more frequent storms (2-, 5- and 10-year storms) can be expected to increase because of the proposed construction of storm drains which will pick up a tributary west of the main channel (presently not draining into the study reach). The storm drains will also be a constant source of nuisance water.

HYDRAULICS

Inventory

Scour and sedimentation evaluations as well as open-channel hydraulics information was obtained to examine the effects of various channel schemes on road crossings, side drainage, utility relocations, land recovery and potential capital and maintenance costs. The primary data source utilized was the latest FEMA floodplain information in the form of work maps and HEC-2 backwater printouts.

A number of major natural and man-made features affect the hydraulics and scour potential within the study reaches. They are: Indian Bend Wash, which drains the area east of the Cave Creek tributary; Scatter Wash intercepting drainage from northwest of the tributary; Cave Creek and Cave Buttes dams that reduce the peak flow rates from the massive tributary to the northeast as well as intercept sediment and prolong the outflow into the channel; CAP dikes and overshoot, further defining limits on the tributary and channel on the north; existing bridges at 19th Avenue, Bell Road and 7th Street which define channel-crossing locations; and existing channelization and channel lining south of Bell Road on the main channel which fixes the channel configuration through that reach. In order to understand the effects of these features on the existing channel and potential alternatives, the character of distinct reaches of the study area is presented in tabular form (see Table VII).

As an overview of the study area, two reaches have very ill-defined braided floodplains. The braided portion of East Fork upstream of Central Avenue is headcutting towards 7th Street from the downstream incised channel. If allowed to continue, eventually the channel upstream will take the form of the downstream channel. This process would be expected to accelerate as a result of adjacent developments, concentrating flows entering the channel. The braided portion of the main channel between Bell Road and Union Hills Drive

would similarly be expected to become more well-defined by concentration of flows from adjacent developments.

Upstream of Union Hills Drive to 7th Street, on the main channel, gravel mining has significantly changed the character of the land adjacent to the channel. In the absence of any additional man-made channel protection measures, shifting of the channel can be expected to eventually occur. This will result in significant upstream headcutting since the bottom of the materials pits are well below the present channel invert.

Existing inverts and water-surface elevations for the main channel and East Fork are shown in Tables VIII and IX. In addition, the number of acres within the FEMA floodplain are tabulated, by reach, in Table X.

A number of alternative, typical channel crossings were developed to obtain an approximation of the channel widths and depths necessary for the variety of channel linings considered. Grassed and unlined earth channels are evaluated using the following basic parameters/procedures.

1. Grassed channel lining was evaluated for an allowable channel velocity of 10 fps and a Manning friction factor of n = 0.035.

2. Earth-lined channel sections were based on an allowable channel velocity not to exceed 5 fps and three Manning friction factors to account for various states of maintenance. Manning n = 0.025 and 0.03 were used for a newly-completed or freshly-cleaned channel and a n = 0.045 factor was used for a non-maintained, heavily-planted channel condition.

3. The channel flow rates used are the COE's future 100-year quantities.

4. A Manning equation ($Q = \frac{1.486}{n} AR^{2/3} S^{1/2}$) was used matching existing average depths from the FIA backwater analysis so that to start, normal depth would be close to the existing depths at the downstream control points.

5. An average width was calculated using the conservation of mass equation (Q = VA) and the allowable velocity. The actual velocity with the existing average slope was determined for information purposes along with the slope required to keep velocities at or below the maximum allowable (5 fps for earth, 10 fps for grass). This allowable slope is compared to the actual to assess the need for drop structures.

Alternatives Considered

The following three alternative channel cross section shapes are examined: (1) a minimum-width channel alternative; (2) a terraced alternative with a 10-

year low-flow channel within the 100-year channel; and (3) a 500 cfs low-flow channel alternative to minimize the area occupied by low-flow channel. The dam release rate, of 500 cfs, was determined as the minimum capacity necessary for erosion control purposes and, in addition, minimizes disruption of the recreation overbank areas during periods of prolonged dam releases.

Two alternative cross sections are considered for the East Fork between Central Avenue and 7th Street (Figures 11a and b, Hydraulic Channel Cross Sections). In addition, the reach upstream of 7th Street was examined for use in evaluation of the bridge at 7th Street. The minimum-width alternative for the main channel was extrapolated to a higher flow rate for the East Fork; this calculation was not done separately as it is not considered a serious alternative for this reach. The terraced, 10-year low-flow channel alternative is included in the following tables (Tables XI, XII, XIII and XIV and Figure 12, Typical Section East Fork) summarizing the calculations for the East Fork and main channel. The technical data in these tables is adequate to draw conceptual conclusions only.

Detailed backwater analysis will be necessary for final determination of allowable widths and depths on the channel; this was not within the scope of the present study. Recommendations on the road crossings (Figure C-9) will be based on reasonable downstream channel configurations. The channel configurations should be set as a design constraint for development of the channel.

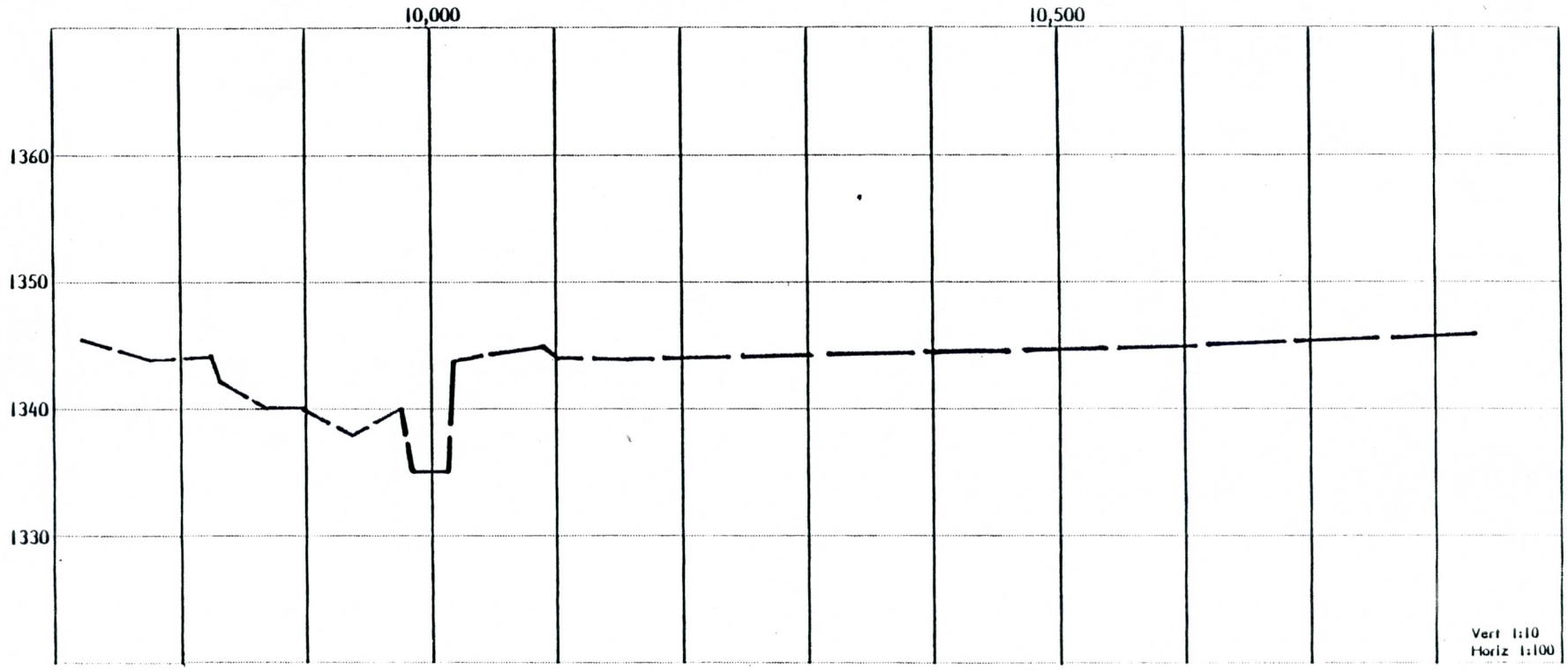
Allowable velocities were determined in part from work done by Fortier and Scobey for canals. The study areas soils would fit into classification 10 or 11 on the following tabulation of the referenced source (Table XV).

Implications

A number of conclusions and implications can be drawn from the data, in addition to those previously given for the channel alternatives. Refer to Figures C-9 and 11a-1 when reviewing this section. General conclusions/implications of the data concern:

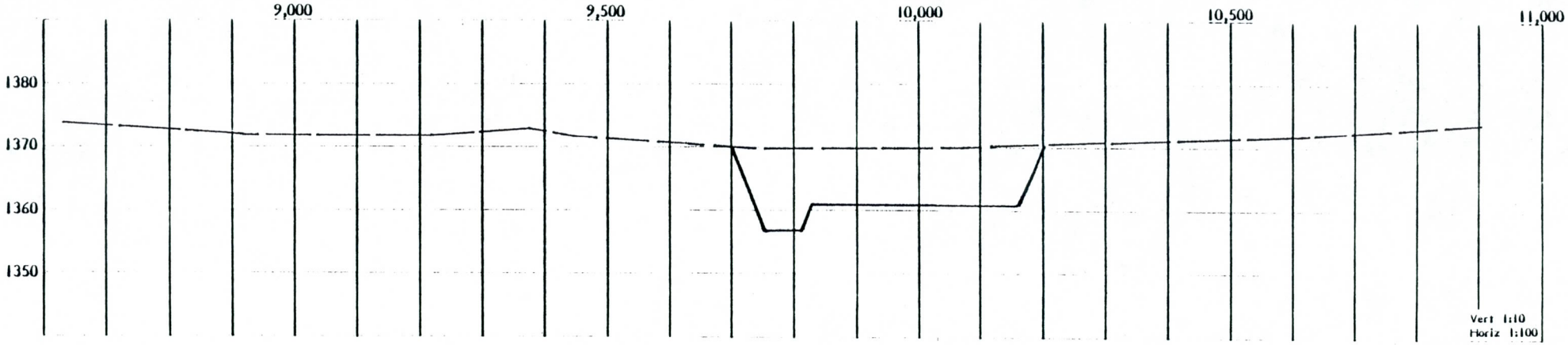
Flood-control benefits may be obtained by removal of the breakout north of Beardsley Road, protecting a large residential area to the southwest. This work, however, will result in a diversion of water into a channel that, at present, is inadequate downstream to Bell Road. This is primarily an implementation problem and is discussed in more detail as a separate issue in that section.

On the East Fork there is an apparent unmapped flooding area on the south side of the channel at 7th Street. Based upon FEMA water surface elevations, channelization upstream and downstream with a 100-year crossing will

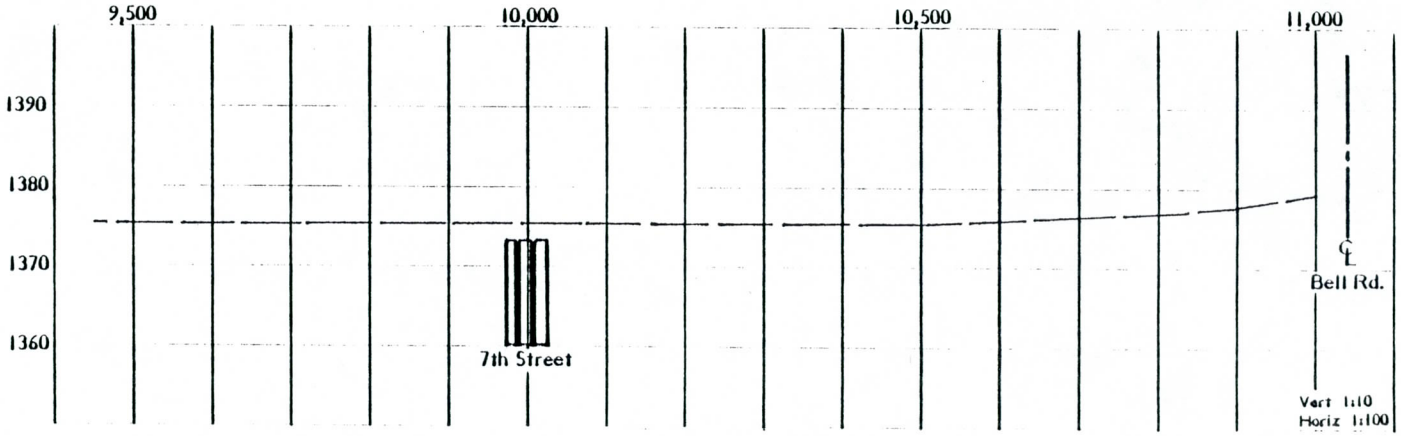


Section .654

FIGURE 11-a

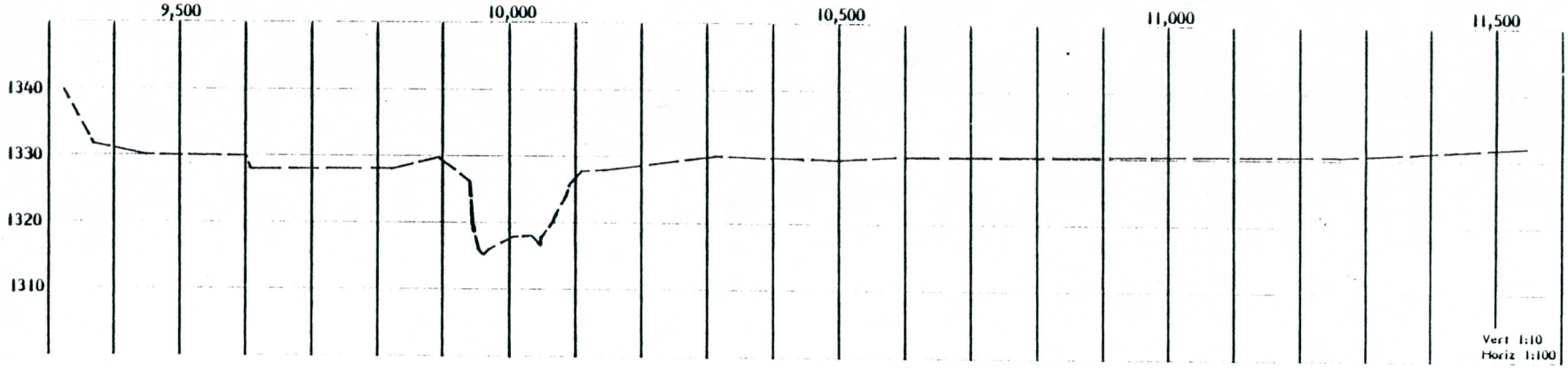


Section 1.856



Section 2.076

FIGURE 11-b



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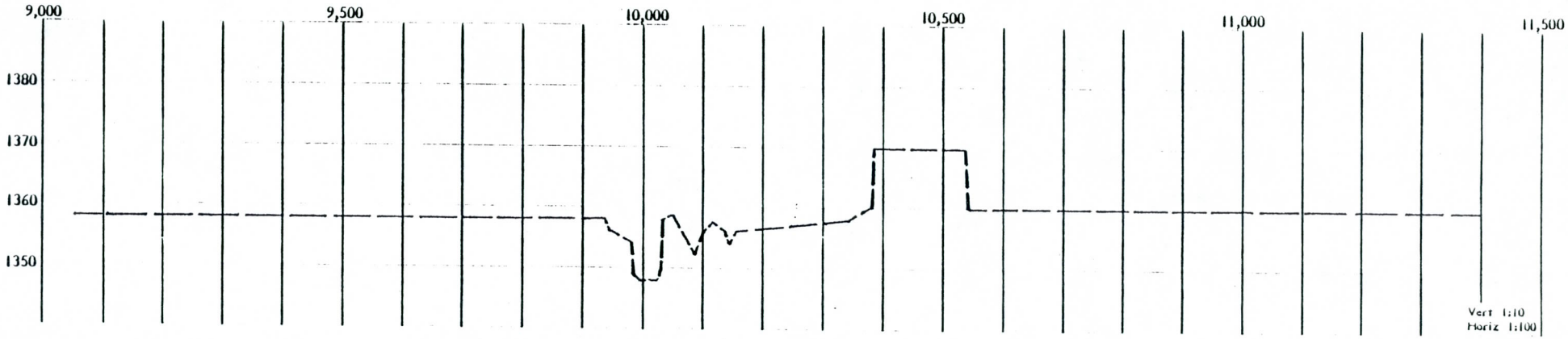
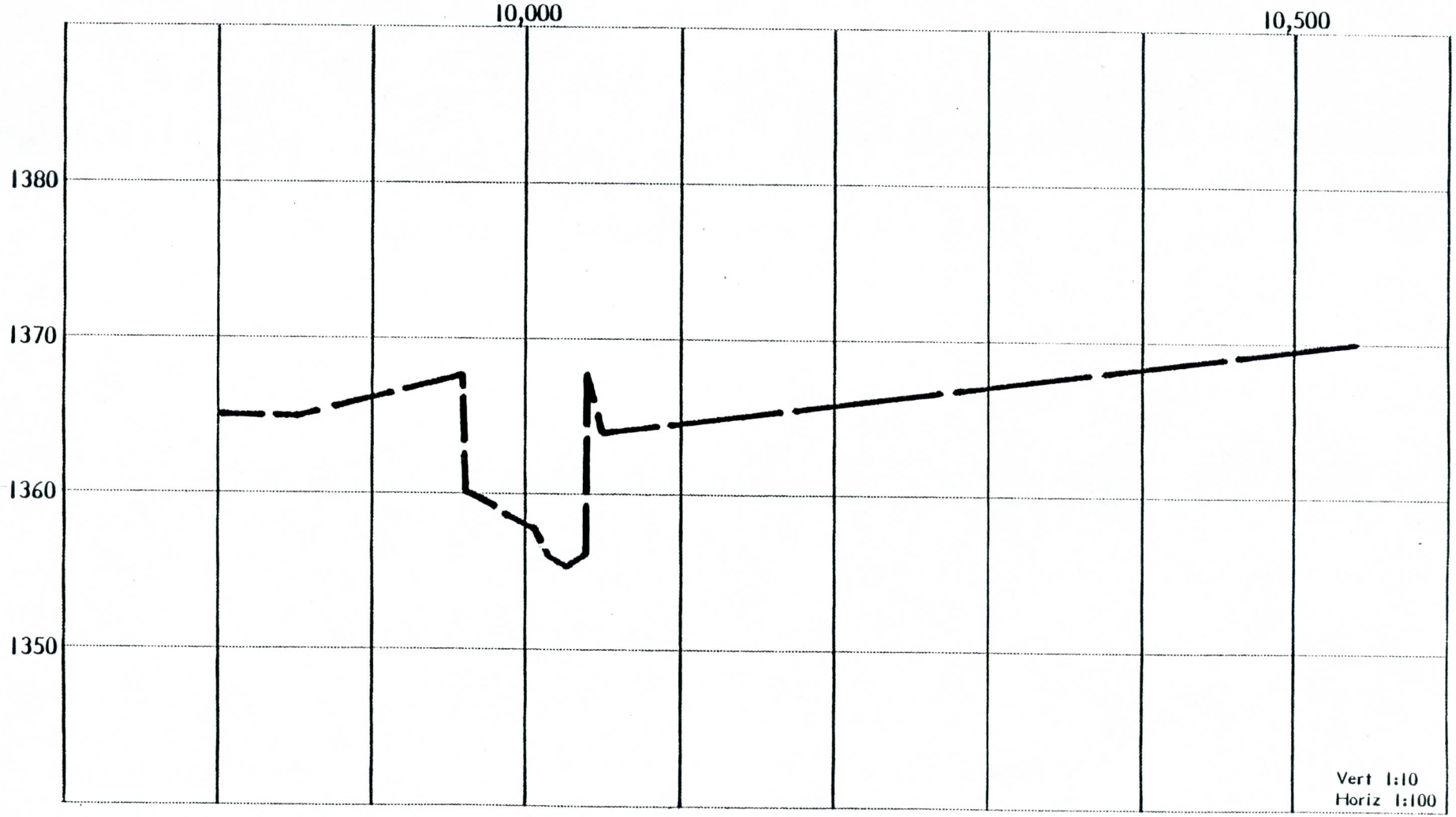


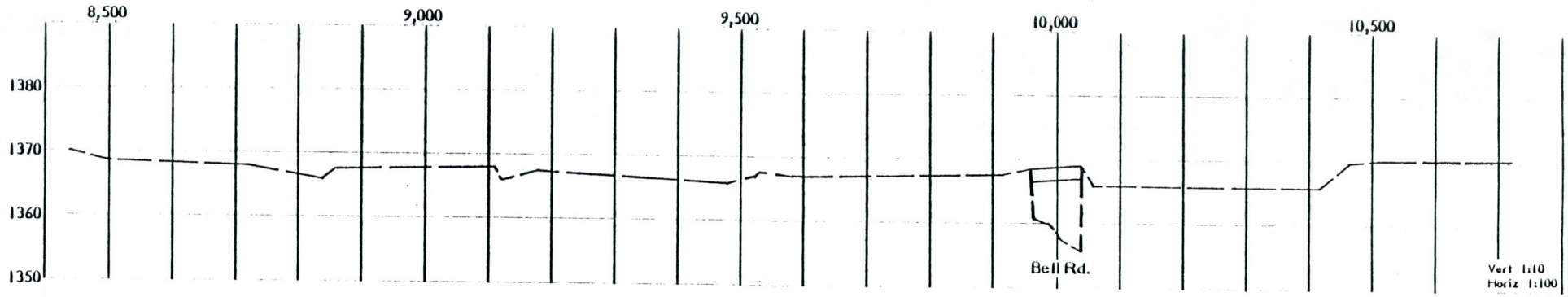
Section 5.250

FIGURE 11-c



Section 5.540

FIGURE 11-d



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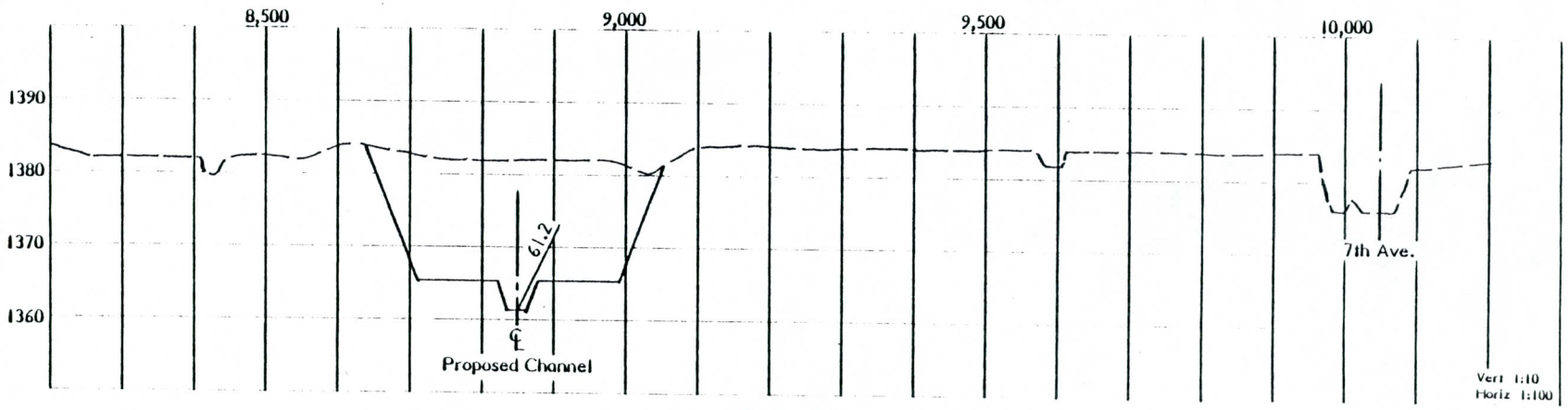
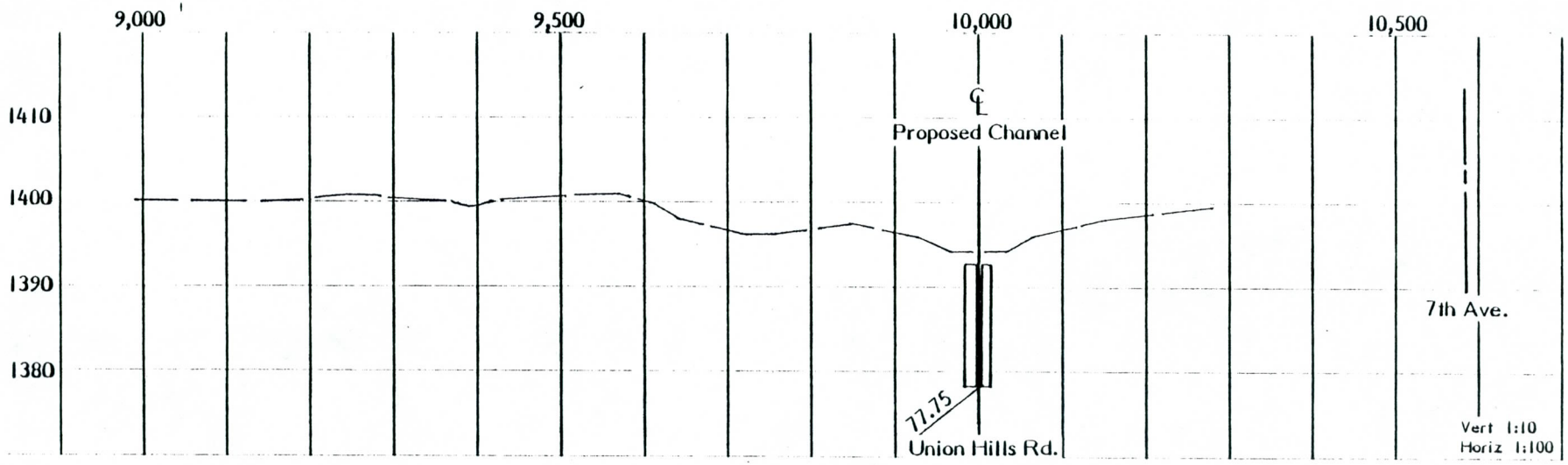


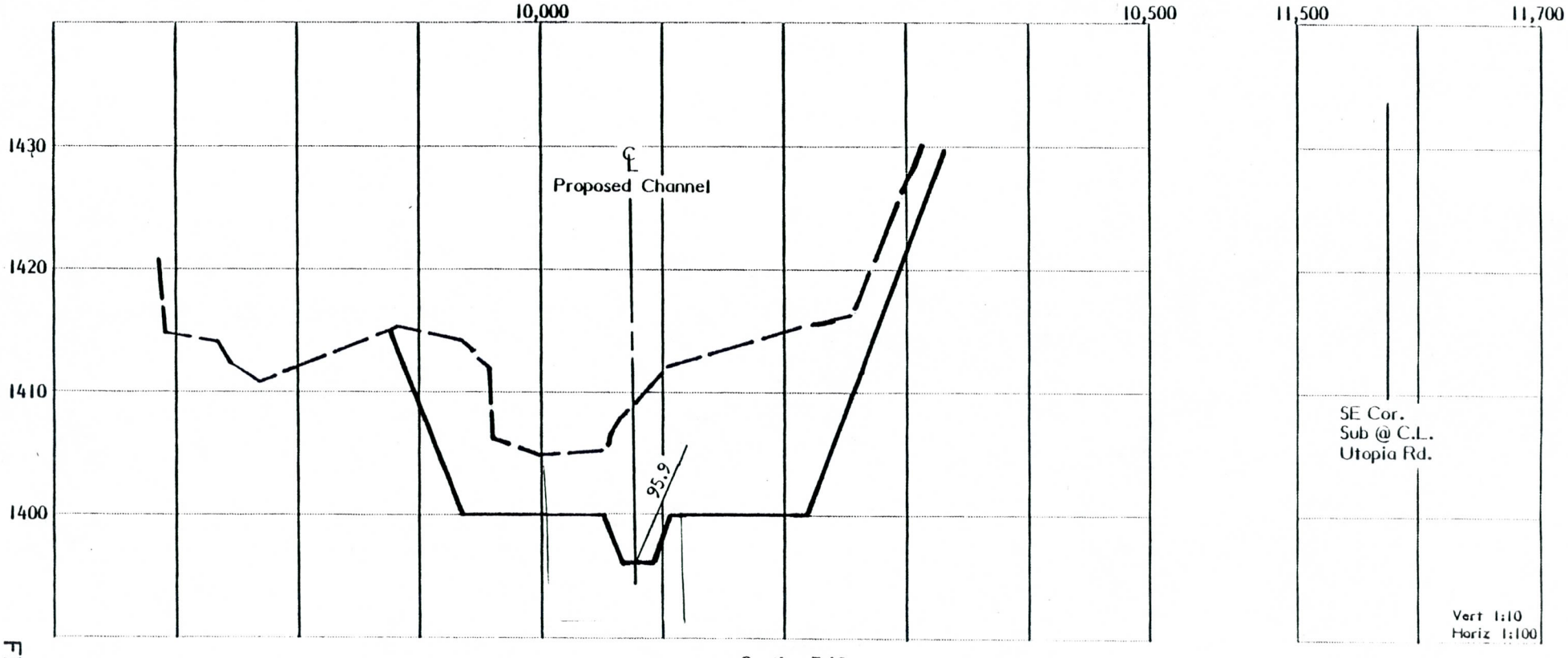
Section 6.100

FIGURE 11-e



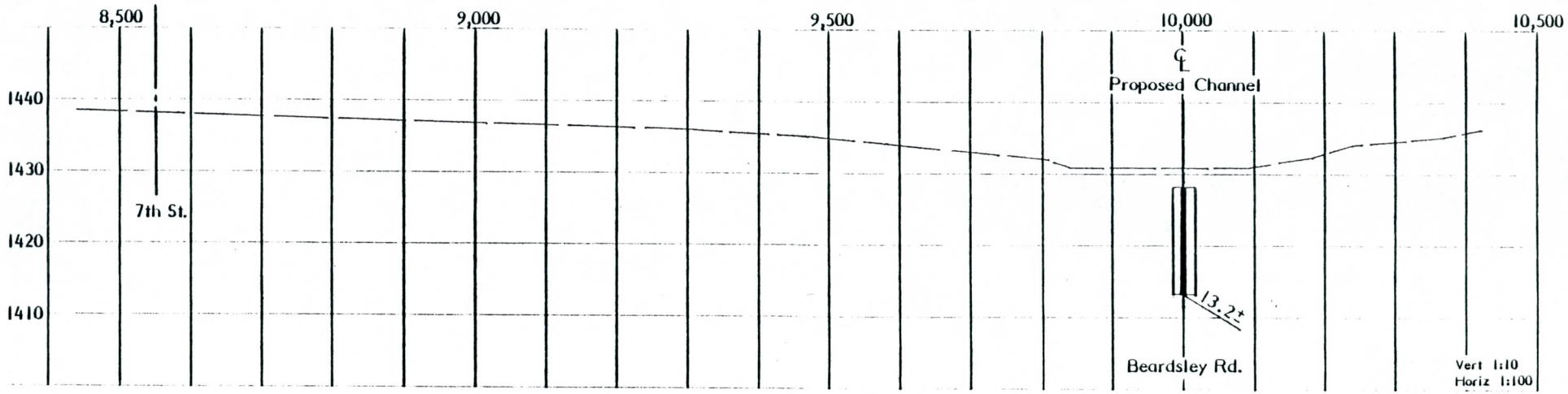
Section 6.665

FIGURE 11-f

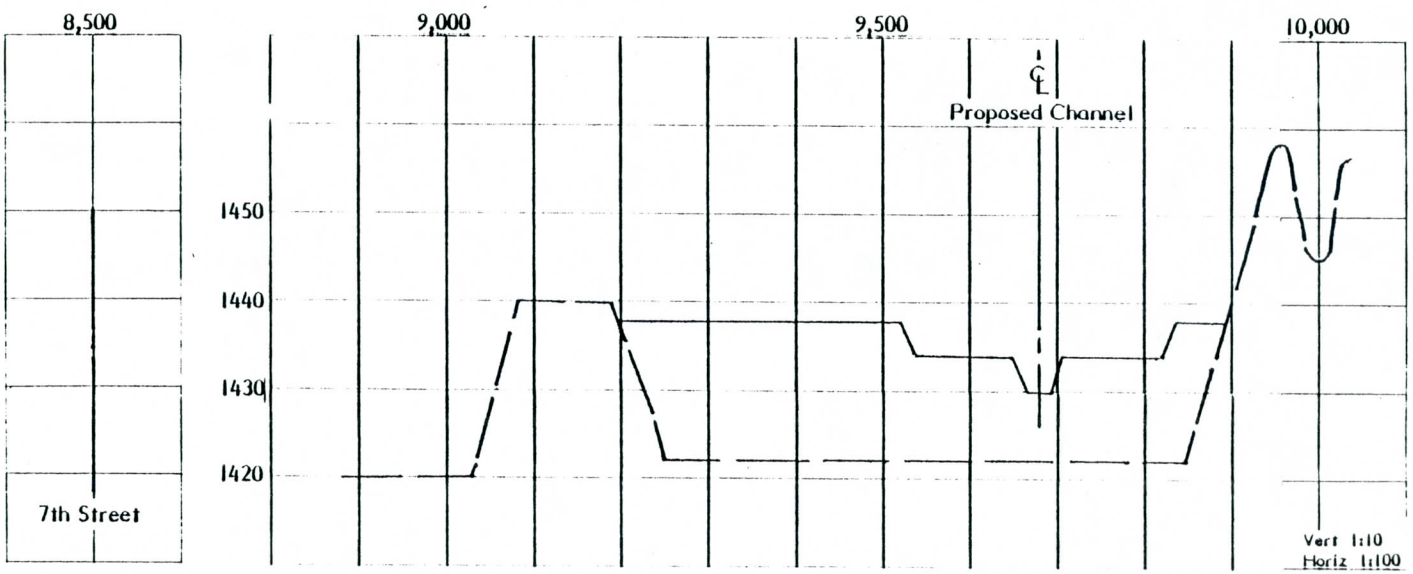


Section 7.19

FIGURE 11-9

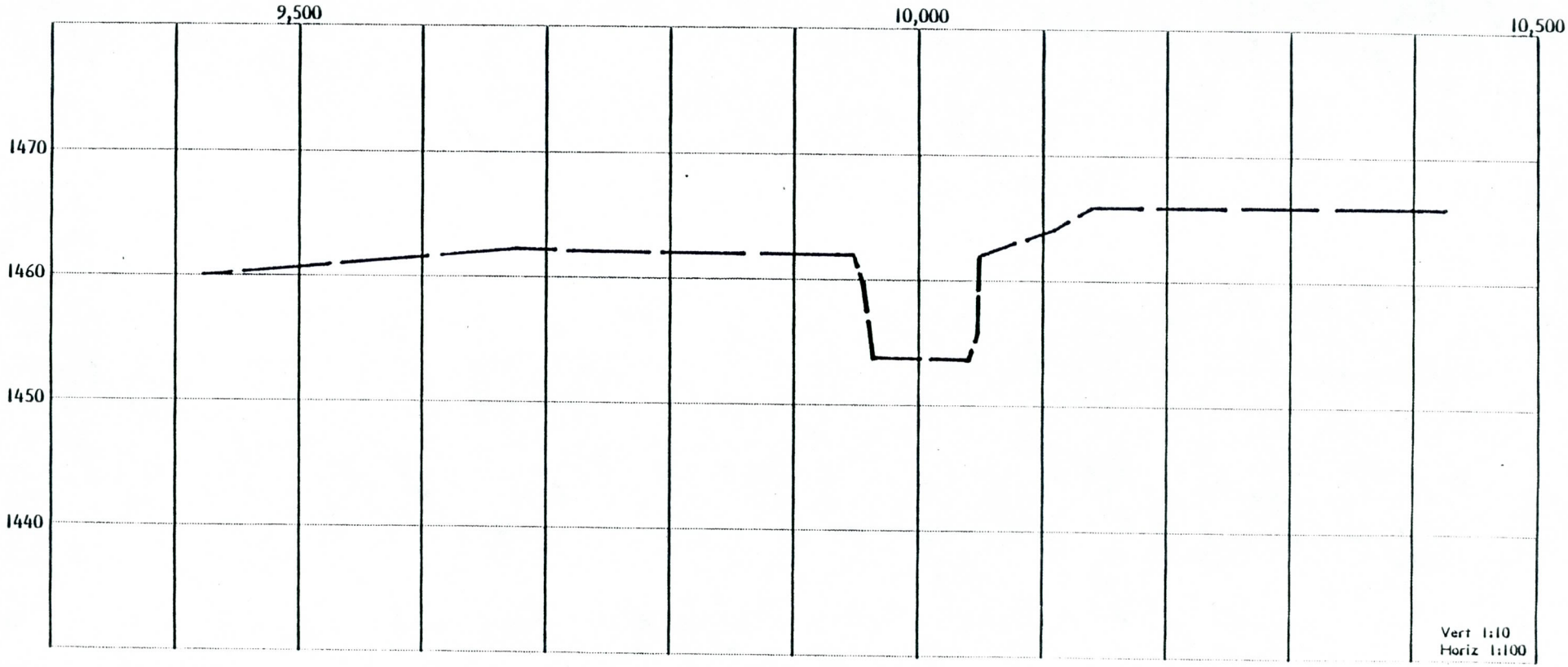


Section 7.855



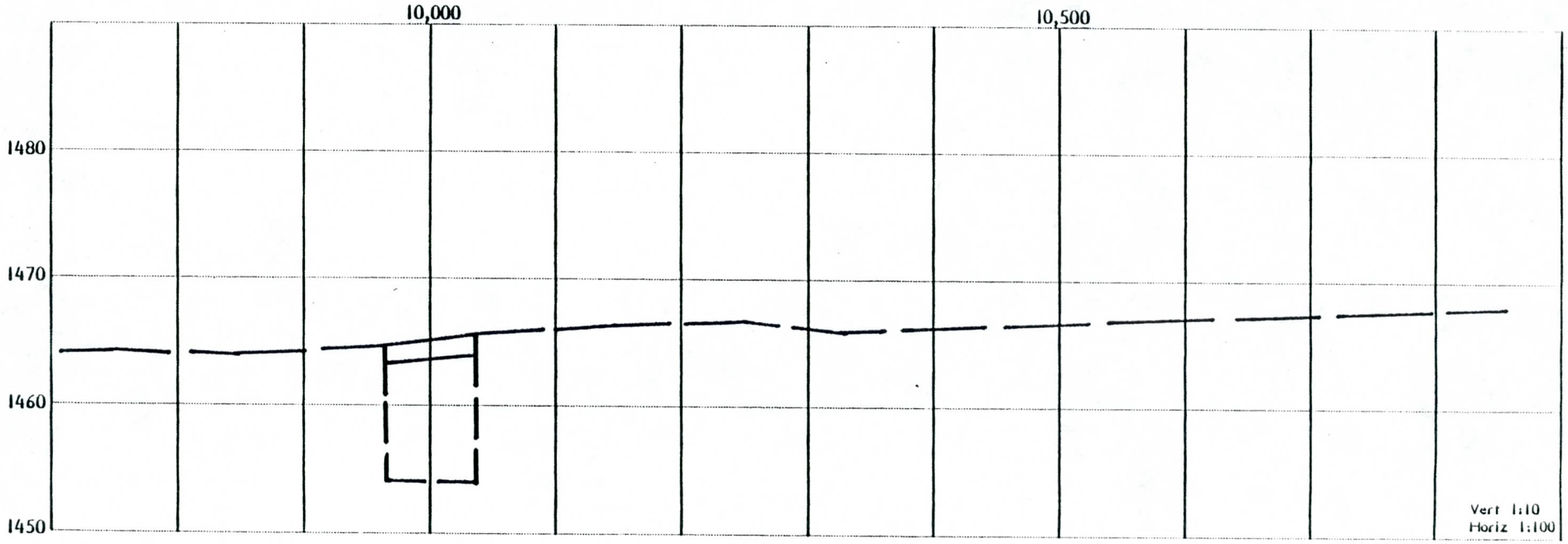
Section 8.34

FIGURE 11-h



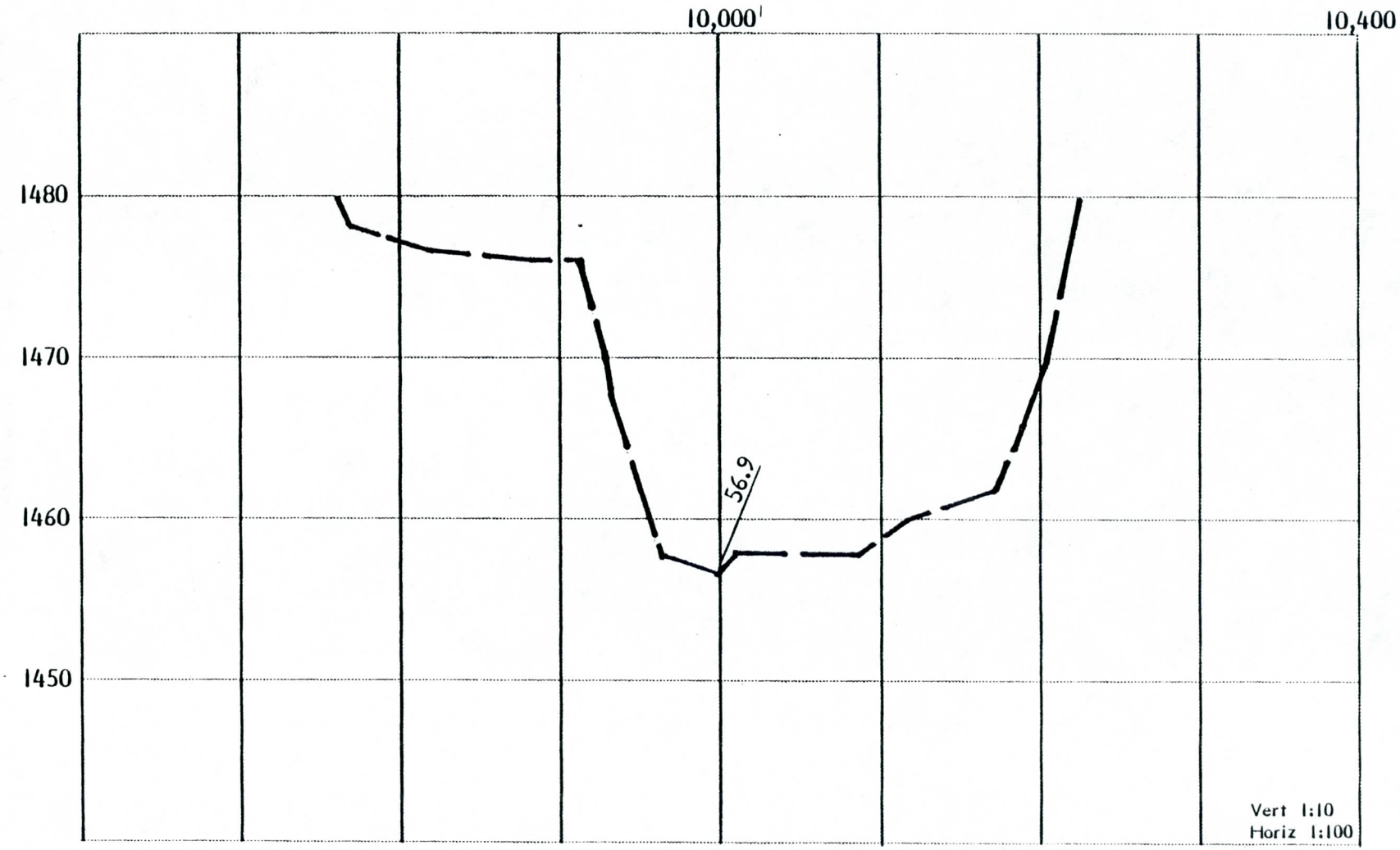
Section 8.78

FIGURE 11-i



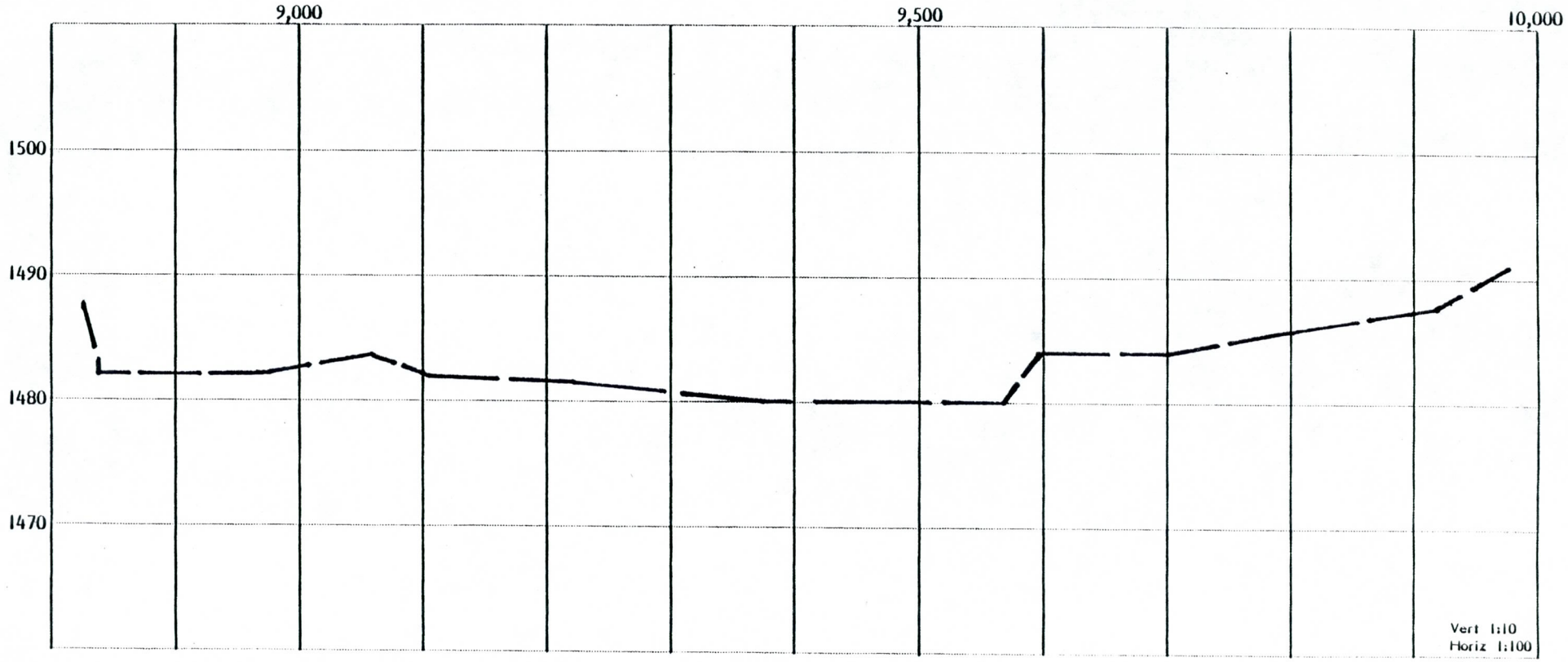
Section 8.79

FIGURE 11-j



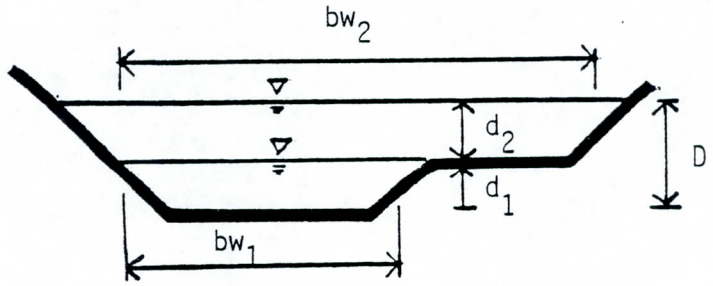
Section 9.09

FIGURE 11-k



Section 9.60

FIGURE 11-1



Dimensions are based on average width

TYPICAL SECTION - EAST FORK

FIGURE 12

eliminate the flooding threat to the adjacent residential area. Discussions with city staff indicate that the finish floor elevations in the area have been raised above that indicated on the FEMA maps.

An increase in developable land will result from channelization. The change will depend on the channel section and type of lining. The channel widths developed previously have been tabulated for comparison purposes only (see Table XVI). Note that these figures do not account for meandering in the channel alignment and banks. Two hundred thirty to 280 acres will be recovered from the main channel floodplain and 90 to 120 acres will be recovered on the East Fork.

The channel lining chosen will depend on, among other decisions, whether to fund grass or a stable earthlined channel. Cost estimates for the purpose of comparison have been prepared for typical channel sections with grass and earth lining. The results in the form of costs per unit length of channel are summarized in Table XVII. The following assumptions were made in development of the comparative costs.

1. The cross section of the channel is as shown for the main wash with the 500 cfs low flow channel. Configuration of the grass channel is 215 feet wide and 8 feet deep; the earth channel is 350 feet wide and 9.5 feet deep. The depths are from top of bank to low flow invert where the low flow is 4 feet below the overbank grade.

2. Excavation cost is $1.50/cy.

3. Cost of land is $20,000/acre. The additional land required (350 minus 215 feet = 135 feet) is added to the earth channel costs.

4. Cost of grass and sprinkler system = $12,000/acre (10-year amortization).

5. Cost of structure concrete = $300/cy in place.

6. Maintenance cost: grass = $3000*/acre/year; desert = $500/acre/year.

7. Ten-foot-high drop structures are installed between the one-mile grid streets.

The results of cost tabulation were used as a basis for an annual cost and present worth comparison of earth versus grass. The results are summarized below.

---

*Based on 5.8' of water required per year at $0.0037/cu ft = $1000 in water cost/acre and an estimated maintenance cost of $2000/acre/year.

Interest Rate	Annual Cost 7½%	10%	15%	Present Worth (millions) 7½%	10%	15%
Earth Channel	137,000	160,000	210,000	1.399	1.363	1.315
Grass Channel	148,000	161,000	188,000	1.509	1.371	1.777

Annual costs are in $/mi/yr including capital costs and maintenance costs. Assuming equal useful project life of 20 years, no salvage value by capitol recovery and present cost factors.

A number of observations are appropriate in order to put these results into perspective with respect to the study area.

1. If the developer installs the grass to recover the additional land and then turns the channel over to the city for maintenance, the earth channel would be, by far, a superior savings for the city of approximately $65,000/yr/mi.

2. Water availability is a critical factor in this area and a grassed channel would, for the typical section, consume approximately 150 to 200 acre-feet/mi/yr. This amount of water could support 50 to 70 single-family lots (7,000 square-foot average lot size). Therefore a grassed channel approach would only be feasible from a water-use standpoint if the long-term water supply were to come from an unpotable well or from the outfall of a future satellite treatment plant capable of tertiary treatment perhaps serving the undeveloped area north of the CAP, west of Cave Creek Wash. Considering the pending water shortage for the area and the call for water conservation, a grass-lined channel may not prove feasible. The location and tributary for the treatment plant is noted in the Additional Investigations Recommend.

3. The economic analysis is based on an assumed project life of 20 years. In fact, the sprinkler system life may be considerably shorter while the drop structure life considerably longer. This would tend to reduce the cost effectiveness of the annual costs for the grass alternative.

4. The costs for the earth channel could be reduced by not carrying the drops across the full channel width. The drops could be limited to the low-flow with the overbank at a steeper slope. This would increase the erosion potential of the overbank and therefore, the maintenance and lateral migration problems. Larger setbacks from the channel would be needed with this approach.

In summary, grass could be considered a financially superior solution for the city than an earth channel if: (1) maintenance is handled by private interests or by a trust set up by the developer; (2) a long-term nonpotable water supply such as tertiary treated sewage effluent can be identified and eventually used as a source of water; and (3) interest rates continue to increase.

Side drainage as overland flow collected in streets and from storm drains will enter the channel primarily at roadway crossings. In addition, adjacent development will convey washes entering the property into the channel along with stormwater generated on site. As proposed, the channel will be entrenched, making the routing of side drainage through the development much easier. The low-flow channel will be deepened at roadway crossings for more economical culverts (also for pedestrian/equestrian trails). This also will make it possible to outlet storm drains into the low-flow channel with adequate cover to place culverts under the overbank portion of the channel. Outlet structures on the storm drain will, in addition to normal requirements, have to be "child-proofed." This would involve placing handrails along the top of headwalls and recessing and grating-off any flapgates or other such structures. The storm drain or side drainage outlet area may also require additional erosion protection for local scour problems.

Any side drainage entering the channel should be carried to the low-flow channel bottom, accounting for local scour across the channel overbank.

Channel shape, slope and scour potential has been examined conceptually and it can be concluded that, in general on the main channel, in order to maximize the usable land within the channel (for recreation features), the 500 cfs low-flow channel shape should be considered (Figures C-9 and 11a-1). The low-flow channel itself can meander within the larger channel, however, it should be confined to the middle third. The radius of curves for changes in direction should be kept at approximately 10 times the channel width to minimize the extra shear stress on the outside of bends.

In the East Fork a 2- to 10-year low-flow channel should be located along the side of the 50± foot-wide strip of existing channel to be saved. This will minimize lateral instability problems and provide a source of water to help sustain the existing growth. The existing growth, therefore, will separate the new channel from the building pad on the south side of the channel.

Earth lining will require flatter slopes than existing for stability, making drop structures necessary to control the depth of the channel. Slopes of 0.002 ft/ft is adequate in the main channel and slopes as steep as 0.004 in the East Fork can be used. Grassed channels can be placed on existing slopes and remain stable; therefore, drop structures would not be required.

The typical alternative channel cross sections were, for the ease of calculation, taken as flat bottomed; however, the actual construction plans should have cross-slope to concentrate extremely low flows and nuisance water near the center. This will minimize future maintenance problems caused by lateral meandering across the full width of the channel.

Drop structures may be required on portions of the channel where the existing slope is greater than that necessary to maintain non-erodable velocities. The

structures can take a number of alternative forms. Classically, the structure is on approximately 1:1 slope with concrete placed on the slope, upstream and downstream to prevent erosion from the high velocities and turbulence present at a drop.

The slope on the drop can, however, be flattened to be more accessable. The surface treatment can, in addition to concrete, be grouted cobbles or gabions (wire baskets) as per the typical sections (Figure 13, Typical Drop Structure Profiles and Figure 14, Plan and Cross Section of Typical Drop Structure). Gabions are desirable on the apron of the drop since they are much less susceptible to undermining.

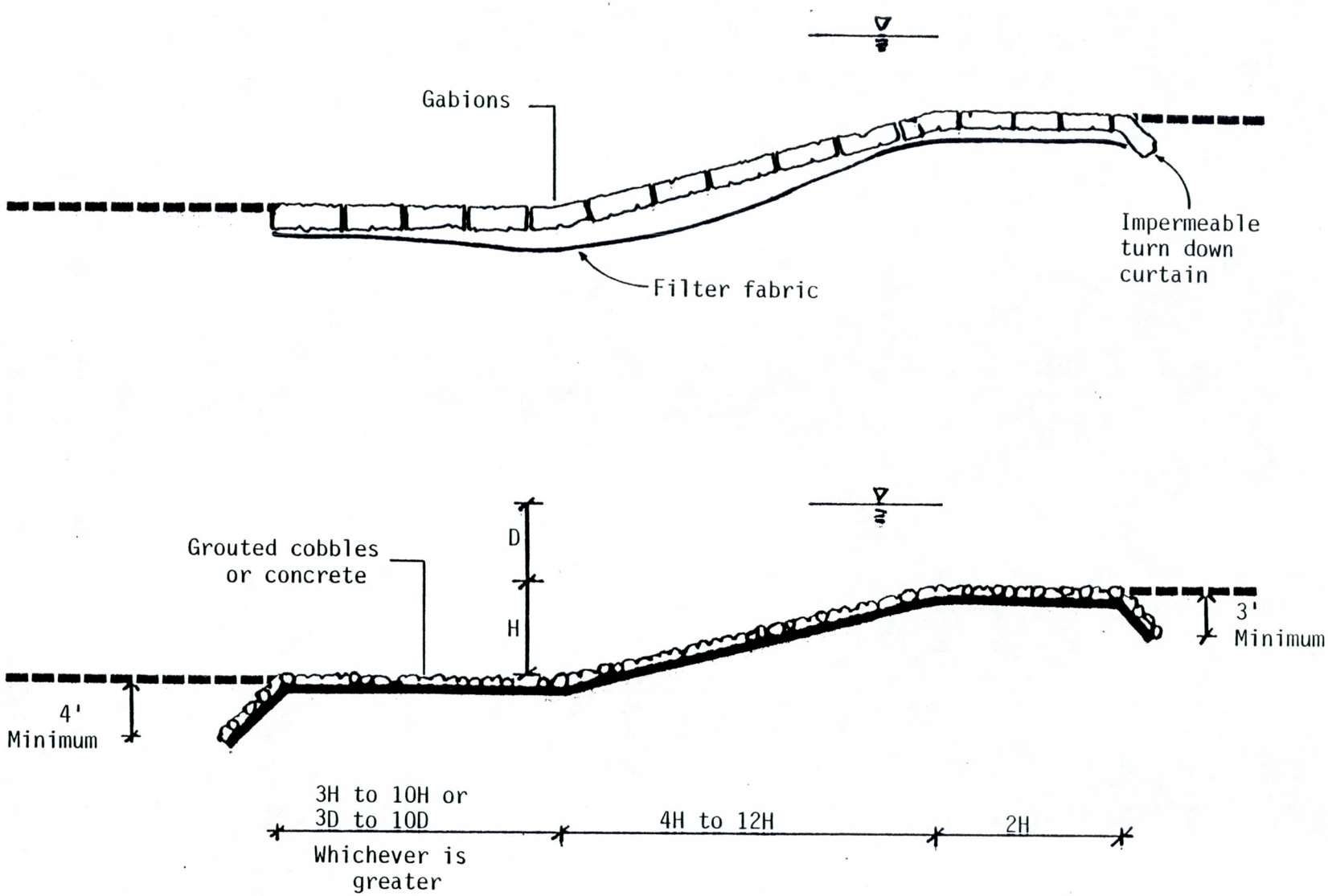
The drop structure may be able to be incorporated into a recreational feature. Elevated seating such as for amphitheaters or baseball stadiums can be designed to serve a flood-control function (Figure 15, Amphitheater Drop Structure Concept). An example of this sort of approach is the amphitheater at McDowell Exhibit Plaza on Indian Bend Wash. The drop structure should extend across the entire channel to provide a solid control for erosion upstream. Hiking and equestrian trails may be brought out of the channel around the drop structure and return to the channel. The trail surface elevation should be higher than the top of the drop structure to prevent storm flow and break out (Figure 16, Typical Drop Structure).

Utility relocations or protection will be necessary to implement the channelization and road crossing plans. The services affected are discussed in more detail in the Infrastructure section and under road crossings in this section.

Road crossings of the channel have been minimized by planning local and minor collector streets to run parallel to the channel. The only crossings proposed, therefore, are at the major streets now crossing the wash (7th Street on the East Fork and Union Hills Drive; Beardsley Road and Deer Valley Road on the main channel). Bell Road, 19th Avenue and 7th Street (on the main channel) have existing bridges and the crossing on 7th Avenue just north of Bell Road is proposed for relocation out of the channel.

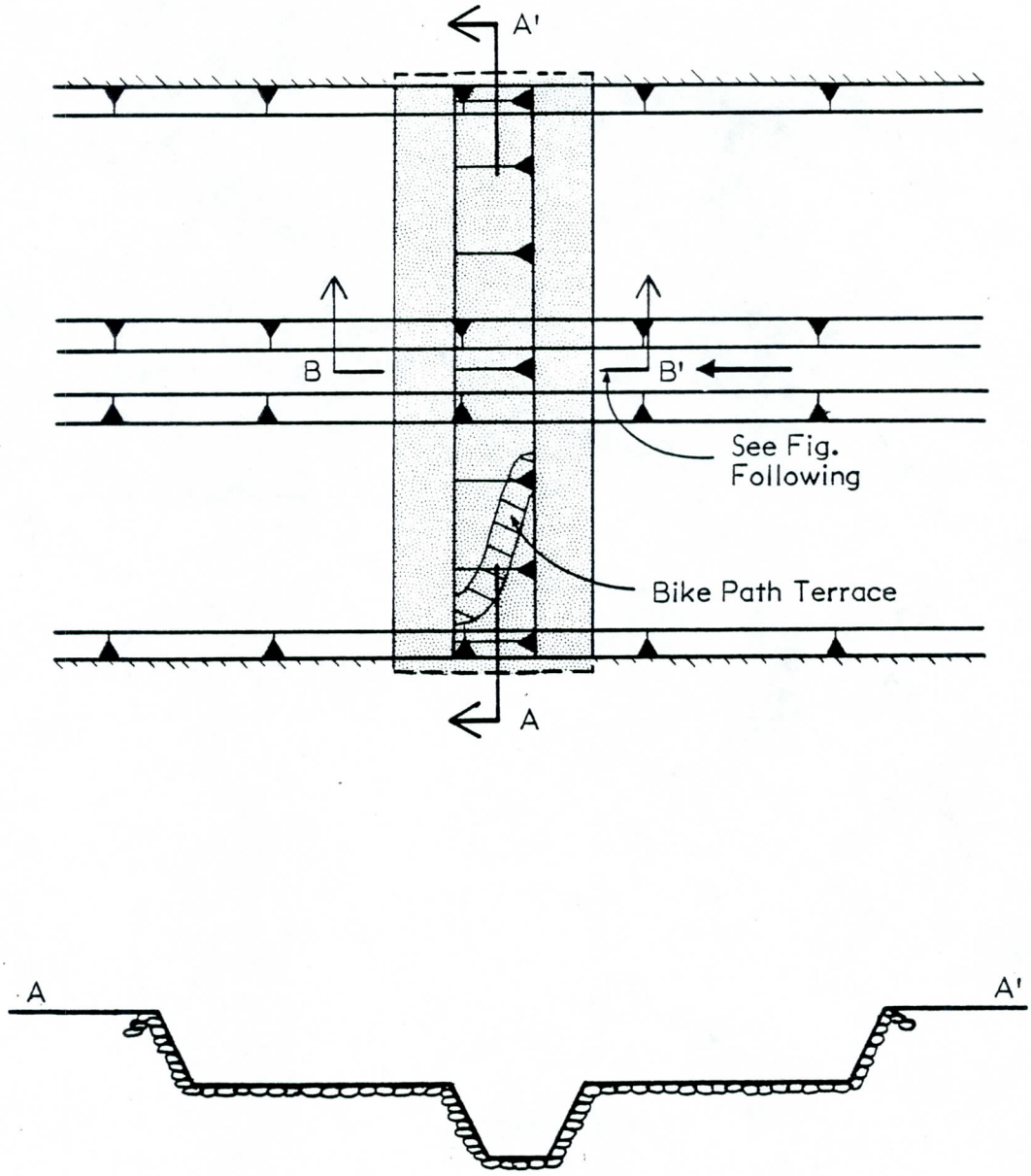
Crossings of the channel on the proposed extension of Greenway Road at the main channel-East Fork junction and on the East Fork near Central Avenue is planned to serve a parkway extending from 19th Avenue to beyond 7th Street. The level of service proposed for the individual crossings is discussed in the Transportation section and is summarized below.

Location	Frequency Dry
Main Channel	
19th Avenue (existing)	100-year (not verified)
Greenway Road	100-year



TYPICAL DROP STRUCTURE PROFILES

FIGURE 13



Plan & Cross Section of Typical Drop Structure

FIGURE 14

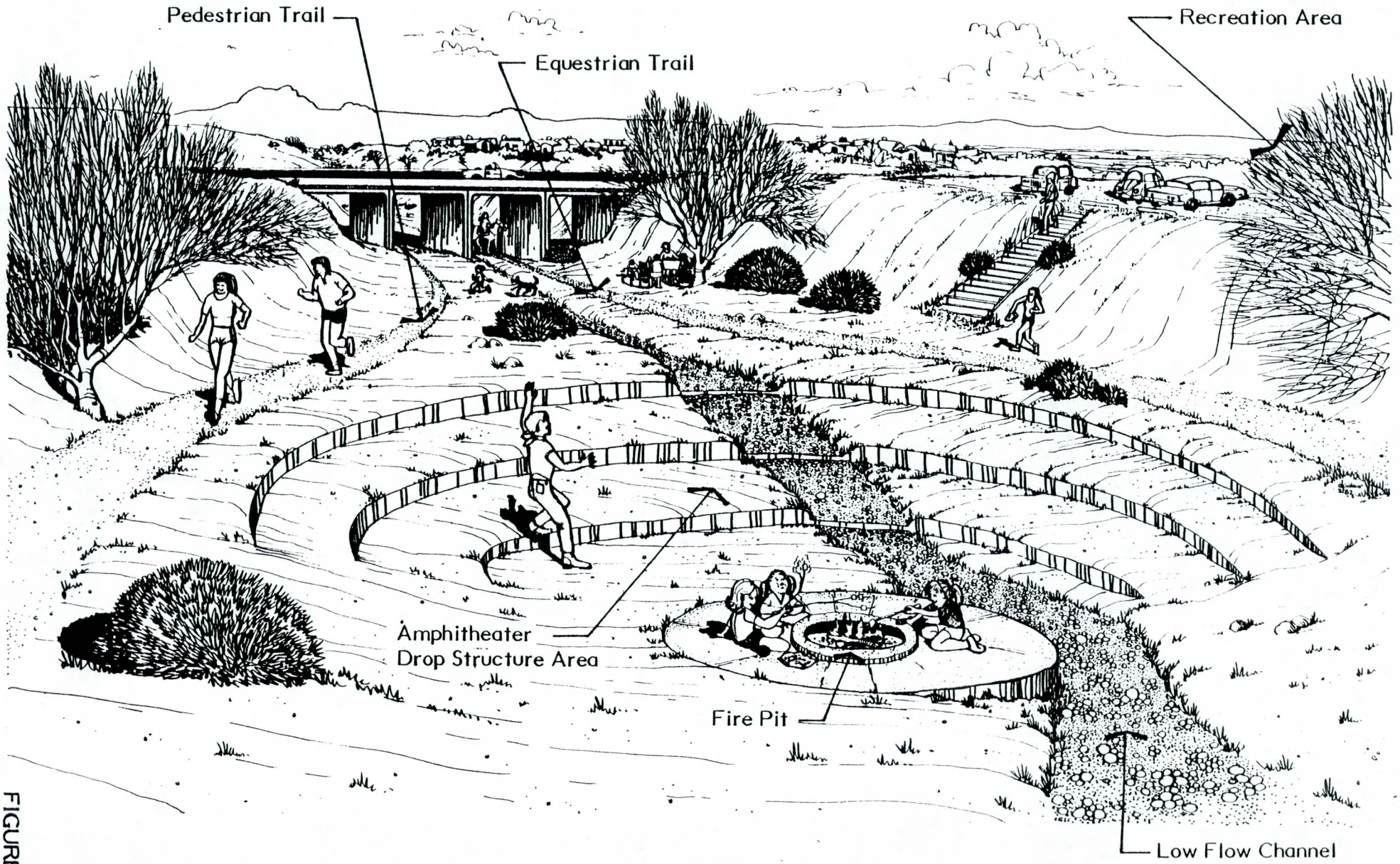
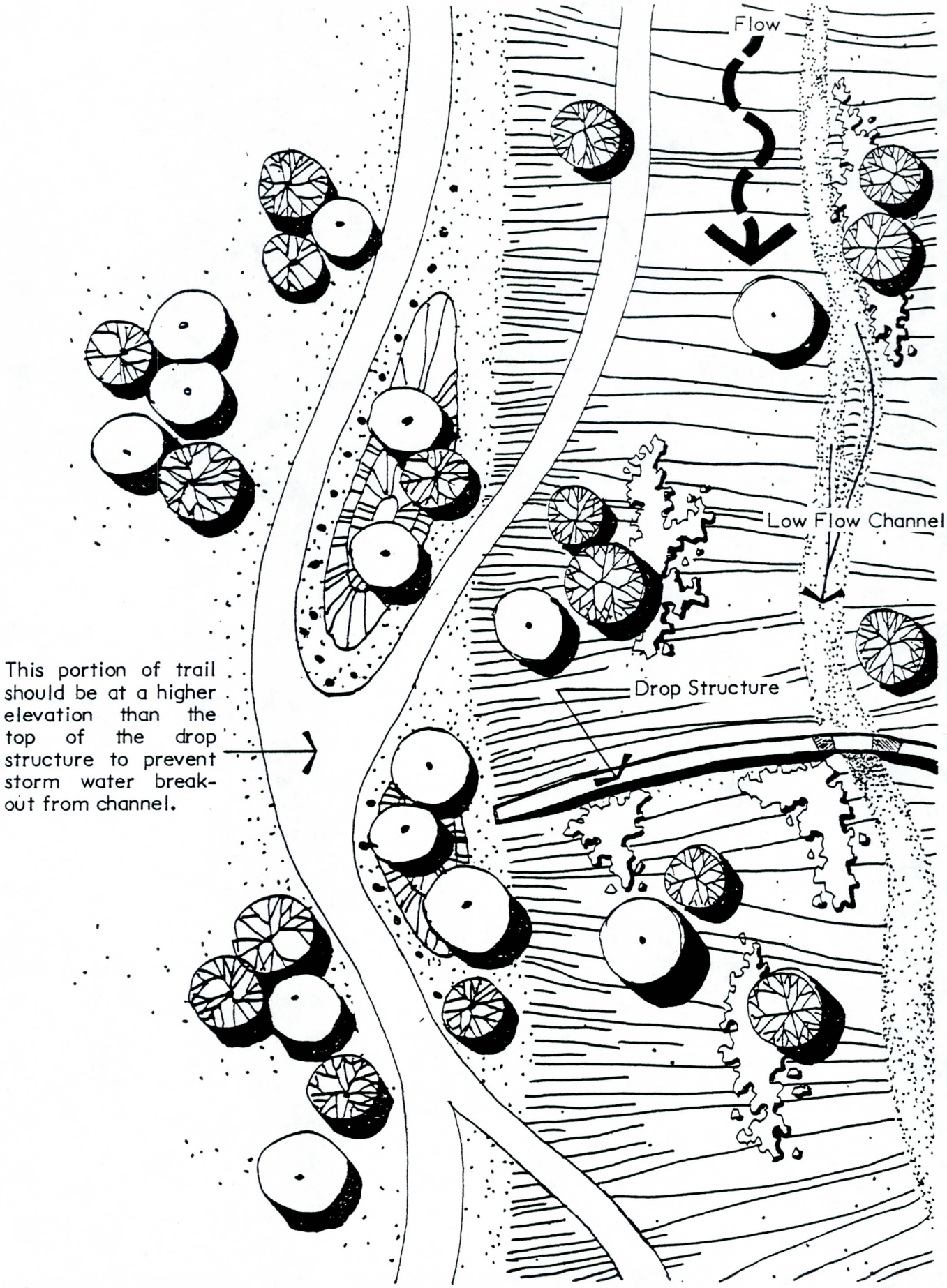


FIGURE 15

AMPHITHEATER DROP STRUCTURE CONCEPT



TYPICAL DROP STRUCTURE

FIGURE 16

Location	Frequency Dry
Bell Road (existing)	100-year (not verified)
Union Hills Drive	100-year
Beardsley Road	10-year to 100-year
7th Street (existing)	100-year (not verified)
Deer Valley Road	100-year
East Fork	
Greenway Road at Central Avenue	100-year
7th Street	100-year

The downstream channel depth from the crossings where channelization is proposed will be increased to allow between 8 and 15 feet of clearance with the deck near existing road grades. This will allow pedestrian, bicycle and possibly equestrian use of the structure as an underpass. Setting the deck at existing road grades will minimize approach work. An upstream drop structure will be necessary to return the channel to the design depth. A typical crossing has been prepared for illustration purposes (Figure 17, Typical Roadway/ Channel Crossing) and detailed design of each of the proposed crossings is included in Appendix B.

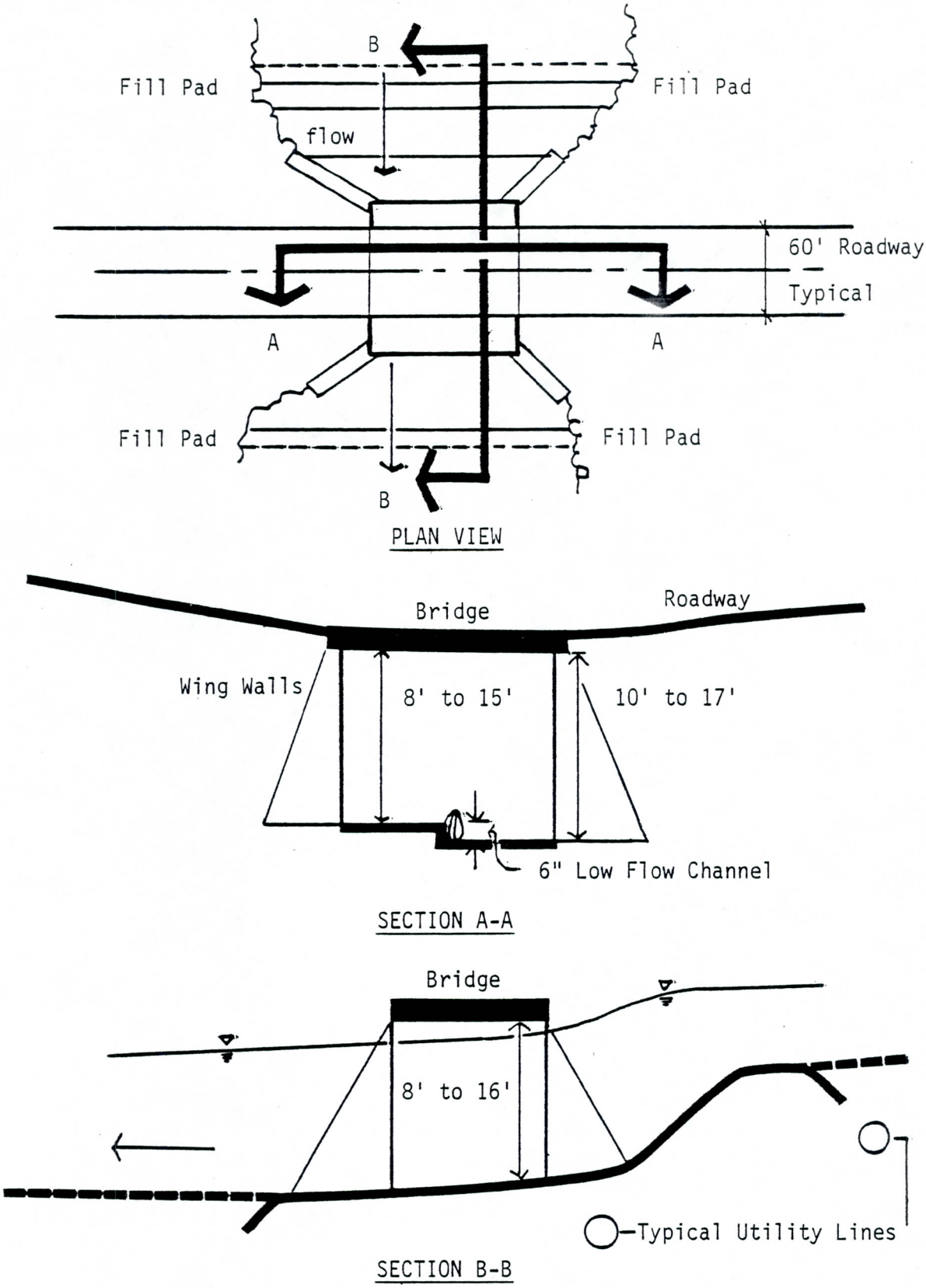
Freeboard on the fill pads adjacent to the channel should be set at one foot or to the velocity head ($V^2/2g$), whichever is greater. The velocity head could be significantly larger than one foot near drop structures and road crossings.

Recreation amenities and landscaping within the channel have been considered relatively dense with the assumed n = 0.045. It is recommended, however, that trees planted in groupings, other than parallel to the flow, be spaced a minimum of 20 feet on center. This will avoid the potential for debris, dams and the resulting higher water surface and increased local scour.

Ramadas, etc. within the channel should be well anchored to prevent damage. Large trash containers should be located outside the channel, since they are subject to flotation and can cause severe damage and flooding at roadway crossings.

Relatively heavy landscaping in the form of trees is encouraged to lend stability along the banks of the low-flow channel, as well as along the banks adjacent to fill pads.

Structures on development adjacent to earth-lined portions of the channel should be set back a minimum of 30 feet to preclude the possibility of failure due to lateral migration and allow an emergency maintenance corridor to be left open along the top of the channel banks.



TYPICAL ROADWAY/CHANNEL CROSSING

FIGURE 17

Chain-link fences could be placed within portions of the channel (backstops, tennis courts, etc.), if properly designed, swinging out of the way with the flow of water. Fencing to limit access within the channel should be post and cable to reduce obstruction.

Where the channel widens through park sites, some silting can be expected to occur as a result of the reduced velocity and transport capacity.

The earth channel alternative will be particularly susceptible to off-road vehicle and motorcycle use. This has proven to be a maintenance problem as well as a nuisance to adjacent land uses. The problem can be reduced by policing, providing alternative areas for such uses, and with the addition of physical features to the channel to limit vehicle access and circulation along the wash. These features may take the form of post and cable fencing at potential access points, particularly along roadways, and installation of loose cobble strips across the channel, perhaps doubling as outlets for side drainage. These features should be adequately marked for safety and liability purposes and spaced so as to discourage off-road vehicle and motorcycle use.

OPPORTUNITIES AND CONSTRAINTS

The Cave Creek Wash study area was evaluated in relation to three basic categories: (1) natural resources and actions such as biology and soils; hydrology and hydraulics; (2) bridges, utilities and development of inhabited areas; and (3) recreation, parks, and circulation patterns. The evaluation (question/problem) addressed two issues: what are the major opportunities and/or constraints presented by the existing wash in relation to the three categories; and what opportunities and/or constraints can be predicted from interjection of previously-uninvolved use and/or development modifications necessary for the various alternatives to function?

The identified opportunities and/or constraints (Figure C-10, Opportunities and Constraints) can affect the development proposed in the master plan. The basic goal of the plan is to prepare a phased master plan concept that can be implemented to result in balanced land use, provide parks and open space, a trails system, a flood-control system and rehabilitation of the channel and surrounding areas.

Opportunities and/or constraints can work singularly or in combination to enhance or offset a given amenity or problem within the study area. For example, at the north end of the study area, a biologically valuable area of the wash coincides with large areas of open space, the airport clear zone and public ownership. The area lies within a medium-large floodplain, encompasses part of an archaeological district, is adjacent to the CAP and is next to an identified COE recreation area. This combination of uses and site characteristics, along with visual interest of surrounding landform, provide ample evidence that the key opportunity for the area is for recreation and interpretive use.

The study area was divided into eight reaches defined by significant features, limits of vegetation, need for channelization and major street crossings. These are described as:

Reach A - The old Cave Buttes Dam across the new Cave Buttes Dam downstream across the CAP channel to the wash intersection with 7th Street;

Reach B - 7th Street downstream to Beardsley Road;

Reach C - Beardsley Road downstream to Union Hills Drive;

Reach D - Union Hills Drive downstream to Bell Road;

Reach E - Bell Road downstream to the confluence of the East Fork and the main Cave Creek channel;

Reach F - 7th Street downstream to the Central Avenue alignment (East Fork);

Reach G - Central Avenue alignment downstream to the confluence with the main channel of Cave Creek Wash (East Fork); and

Reach H - The confluence of the East Fork of Cave Creek Wash and the main channel of Cave Creek Wash south across 19th Avenue.

Each reach of the wash study area was reviewed in the context of five planning factors to list opportunities and constraints present or anticipated as a part of the reach's development. These factors are: (1) land use/recreation/visual; (2) hydrology/hydraulics; (3) infrastructure; (4) transportation; and (5) cultural/biological resources. The following chart (Table XVIII) examines each reach and records significant opportunities and constraints.

Once the opportunities and constraints were recorded, allowing for comparison and development of relationships, assumptions were made concerning the eight reaches. These assumptions were utilized to neutralize constraints by taking greater advantage of present opportunities.

In the following section, opportunities and constraints related to each plan alternative will be analyzed.

ALTERNATIVES

INTRODUCTION

Based on identified opportunities and constraints for Cave Creek Wash, four major channel design concepts were evaluated using 10 planning criteria to determine the three master plan alternatives to be considered by the TAG.

Evaluation of Channel Design and Density Options

The four channel design concepts evaluated were as follows:

1. Natural Channel - A natural channel with minor revegetation and vegetation enhancement (grass and shrubs); little or no excavation.

2. Structural Channel - A concrete channel.

3. Combination (shallow channel) - A combination of (1) and (2) with a low-flow channel and a defined shallow floodway (a modified natural channel concept with a graded ditch located as intrusively as possible).

4. Combination (deep channel) - A combination of (1) and (2) with a low-flow channel and a better defined, deep floodway (as deep as 15 feet). This channel would be more intrusive in the landscape than (3) but narrower in width.

Each of the four channel design concepts was evaluated in the context of three development density options (high, medium and low density) according to 10 planning criteria. The planning criteria, in keeping with the city's goals, are:

(A) Initial implementation costs
(B) Maintenance/operation costs
(C) Opportunity for private funding
(D) Cost for vehicular circulation (bridges, etc.)
(E) Cost for relocating existing utilities (sewer, water, etc.)
(F) Response to natural resources (preservation)
(G) Reduction of potential hydraulic failure (channel failure)
(H) Past general public acceptance (based on COE attempts to channelize Goleta, California; Skunk Creek, Arizona; and Indian Bend Wash, Arizona)
(I) Recreation development opportunity assumed the following:
   1. Natural channel would include large open space areas and few developed parks
   2. Structural channel would virtually eliminate recreation except for trails

3. Combination (deep floodway) channel would involve city parks keeping permanent structures out of the floodplain
4. Combination (shallow floodway) channel would include larger park areas, more open space than deep floodway option

(J) Response to city identified goals (unified organized development pattern (controlled growth) that allows public recreation and open space while assuring flood control with the financial responsibility removed from the city whenever possible).

Table XIX displays the qualitative evaluation of the four channel design concepts. The evaluation resulted in the elimination of the structured (concrete) channel since it would not meet TAG goals as well as other basic constraints. The "natural" or undisturbed channel was ruled out for basically the same reason.

The density levels (high, medium, low) were then combined with the shallow and deep channel designs to develop final alternatives. In considering methods of meeting various goals, a range of alternatives were evaluated initially: (1) a combination of shallow, graded earthform ditch and undisturbed channel surrounded by either high, medium or low density development (a modified natural channel concept in which the graded ditch is as unintrusive into the landscape as possible); and (2) a combination of deeper graded earthform ditch (down to 15 feet) and undisturbed channel surrounded by either high, medium or low density development (the earthen channel is more intrusive into the landscape, but narrower in width).

- The high-density, combination deep channel alternative was eliminated because of its inability to relate to the density of the village plans (Figure C-6).

- The high-density, combination shallow channel, while still not agreeing with the village plan, was included to show the only method considered practical to develop the shallow open-space concept; high-density development with considerable homeowner association potential.

- A low-density shallow channel was disqualified because of the high costs to the city for implementation, operation and maintenance because of predominance by single-family detached dwellings.

- The low-density deep channel alternative requires the city to provide a large portion of the operation and maintenance cost, although initial improvement costs may be passed on to the developer.

- Medium-density, combination deep channel, while not absorbing all initial improvement, operation and maintenance costs, does encompass a large percentage of cost while still serving as an efficient flood-

control channel and providing organized parks and recreation and open-space trails.

Alternatives

The following sections discuss the three alternatives identified:

1. Concept Master Plan Alternative A (Figure C-11) - Low-density with a deep channel. With the low-density alternative the city may be faced with maintenance funding.

2. Concept Master Plan Alternative B (Figure C-12) - High-density with a shallow channel. This alternative varies from the 1985 Interim Plan.

3. Concept Master Plan Alternative C (Figure C-13) - The medium-density/combination (deep floodway) channel. This alternative appears to be the most reasonable since it follows the 1985 Interim Plan and requires the private developer to pay for project implementation.

There are several general assumptions and recommendations common to the three alternative preferred developed plans. These are:

1. Flood control measures be maintained or enhanced;

2. Significant vegetation will be preserved in all cases possible;

3. The private developer/owner will pay the cost of implementation and operation/maintenance whenever possible;

4. Contiguous trails systems for biking, hiking and equestrian will be established;

5. A system of "neighborhood" parks will be established and the parks, open space and trail system would interlock with all adjacent recreation systems;

6. A program of development will be favored that prevents lots from backing onto the wash or that establishes a road buffer between the wash and low-density development;

7. Surrounding development will interlock open space and recreation areas into the wash open space;

8. Development will follow the density and land uses proposed in the 1985 Interim Plan and Phoenix Concept Plan 2000; and

9. General health, safety and welfare will be enhanced by implementation of the plan.

Circulation is established with a street network along and across the wash. All-weather crossings are recommended on a one-mile grid and on 7th Street at Cave Creek and at East Fork. The all-weather crossings will have underbridge access for trails. A potential corridor for a Greenway Road connection between east of I-17 and 7th Street, immediately south of the East Fork, is identified (Figure C-4). This corridor may have considerable effect on both the desired preservation of the East Fork and on the density/land use adjacent to the corridor.

Response to plans developed and approved by the city to date has led to rejection of high density as a development option. Villages I and 2 are predominately single-family and high density over a large area is in conflict with the general objectives of the plans. Low density, however, will not establish the operation and maintenance base desired by the city TAG. The city would like to encourage private sector's paying the cost for continuation of the wash as a recreation/open space entity. While low-density developers may fund initial improvements, it is difficult for them to assure continued maintenance through homeowner organizations or other assessment-financed groups. Medium density development allows for more initial improvements and maintenance/operation funding (than low density), yet has a balanced mix of high and low density development. Therefore, medium density development is considered the approach which optimizes the objectives of the city, TAG and the adopted plans.

Certain assumptions concerning recreation have been made:

- A continuous trails system is present in all alternatives;
- The three city parks are sited in all alternatives (although of varying size);
- The north end of the project from 7th Street to the Cave Buttes Dam is to remain in open space to complement recreation opportunities.

The city has an opportunity to acquire several Federal land areas for recreation including a portion of Union Hills and the inundated floodplain above the new dam. Acceptance of Federal lands should be carefully considered due to the many potential strings attached, especially the COE property above the dam. As a part of the flood-control scheme, the inundated area must be maintained to COE requirements and no building is allowed below the high-water line. Access over and around the dam must be addressed.

There are strong potential trail linkages between Cave Creek Wash and other valley trails systems. Cave Creek crosses the CAP with its proposed trail

systems. The CAP ties to Indian Bend Wash and to the Sun Circle Trail and Lake Havasu. The Cave Creek Wash Trail could be extended north to Carefree and south to the Sun Circle Trail as well as west along the Sun Circle Trail to Skunk Creek Wash. A bicycle facility may be developed on Beardsley and perhaps on 7th Street, tying into the proposed Union Hills Park (Figure C-1). A city water treatment plant just outside the study area (CAP, east) may also furnish space for recreation.

Concept Master Plan Alternative A (Figure C-11)

Alternative A includes industrial between Williams Road and Rose Garden Lane, on the west side of the main channel, and mainly multi-family between Rose Garden Lane and Beardsley Road. Single-family development is recommended between Beardsley Road and Bell Road.

On the east side of the main channel, multi-family residential uses are shown between Deer Valley Road and Beardsley Road. Except for a small area of single-family residential and mobile homes (between Beardsley Road and Union Hills Drive), the remaining will be multi-family uses. An equestrian residential development is proposed from Paradise Lane to Greenway Road. Along the East Fork, the alternative shows multi-family between 7th Street and Central and an area for single-family between 3rd Street and Central.

Concept Master Plan Alternative B (Figure C-12)

The most notable difference between Plan A and B is the larger park areas north of Utopia Road and at Grover Avenue made possible by the wider channel. Another major difference (relative to Plan A) is shown between Deer Valley Road and Bell Road. On the east side of the wash, an increase in density is recommended, while on the west side of the channel, multi-family units will replace the single-family units shown in Plan A.

Concept Master Plan Alternative C (Figure C-13)

This plan is similar to Alternative A although multi-family uses are substantially increased on the west side of the main channel and on the north side of the East Fork. The industrial area east of Deer Valley Airport is eliminated in Plan C.

ADDITIONAL INVESTIGATION RECOMMENDED

While a conceptual master plan provides the city with a plan that can be implemented, details for individual parcel development must be provided. If

the city decides to proceed with one of the master plan alternatives, the following detailed design and planning investigations should be conducted:

1. Park, open space and trails system master plan which includes grading plans (to be provided to developers).

2. Impact on abandonment of sand and gravel operations relative to channel stability (includes estimated life of existing operations).

3. Detailed design for road crossings.

4. Feasibility study to determine potential sources and availability of nonpotable water.

5. Impact of zoning changes on study area's water requirements.

IMPLEMENTATION

FUNDING

Funding considerations examined in this study include maintenance and operations as well as capital expenditures associated with flood control and recreation features in the channel area. Contacts with public officials provided the primary data source for this subsection.

Capital funding for the channel and recreation features could include a combination of such items as land, channel excavation, utility relocations, bridge or box culvert roadway crossings, drop structures, side drainage structures, landscaping, pathways and park facilities. These specific improvements can be consolidated into four general categories: (1) land, (2) channel improvement, (3) roadway crossings, and (4) recreation and aesthetic amenities. These general funding categories are discussed below with respect to the following potential sources of funding: city, county flood control district, school district, state, Federal and private.

1. Land required for the channel can come under City of Phoenix control for flood control and/or recreation purposes through different legal mechanisms. City ownership may be accomplished by acquisition, condemnation, dedication, or land or density transfer. City control (not ownership) can be obtained through protective covenants, easements or leases. It should be noted that the "control" options will keep the land on the tax roles while city ownership will not.

   The funding sources for these land control options are listed below with a brief discussion of each:

   City: The city can fund for the purchase of necessary rights in the property.

   School District: School district land acquisitions have been by dedication from the private sector.

   County: The FCDMC can fund for the land acquisition on Federally-funded flood control projects and can fund for the acquisition or easements on state flood control projects where FCDMC is responsible for 50 percent of the cost. The county-owned land in the project can be turned over to the city by agreement. Maintenance funds can potentially come from FCDMC as part of their control responsibility to the COE downstream of Cave Buttes Dam.

   State: The state can fund, partially, for the land acquisition which is a "local requirement" for a Federal flood control project and can

fund for the matching 50 percent to FDCMC on projects (approved for funding) under the "Arizona State Alternative Assistance Program" (ARS 45-2721). This funding is available on projects with present-day benefit/cost ratios of at least one to one. The State Land Department can lease state land to the city. State land trades for city or private property to be leased by the city can also take place.

Federal: Funding for local acquisition on COE flood control projects is a "local responsibility." A number of Federal grants are available for land acquisition on recreation projects (BuRec, etc.). Federally owned land can be leased for nominal amounts; however, the time required for this process can be quite lengthy. Land trades are also available on Federal lands.

Private: Private participation can come in the form of dedications, easements, leases or trades to the city in return for land or density adjustment.

It may also be possible to generate revenues by leasing wash land to private concessionaires for uses such as golf courses, equestrian facilities, and agricultural activities such as orchards. Experience in the area has, however, shown that the best that can be hoped for from a private lessor of wash land is to defer maintenance costs the city would otherwise incur. The city should not expect a direct profit from the concessionnaire.

2. Channel improvement will directly benefit owners of adjacent undeveloped land by allowing floodplain reclamation. Property owners within areas of existing development also benefit by eliminating a potential flood hazard.

   Funding sources for the channel improvements are listed below:

   City: Channel improvements in those areas that have public flood control benefits can logically be funded by the city as a direct expenditure or by improvement district on behalf of those benefitted. Improvement-district-funded improvements must have a minimum 10-year life.

   School District: Where parks can be integrated into the facilities required for the school, joint funding of grounds development and maintenance are possible. This has been carried out locally with some success.

   County: The FCDMC can fund channel improvements as part of the county's local flood control projects' funding. Funding for these

projects has in the past been very limited. In the study area on the main channel, the county's "local responsibility" to the COE could help justify FCDMC participation in the public flood control portions of the project. County-owned land within the project could be left in that ownership to eliminate acquisition of the maintenance responsibilities.

State: State funds as discussed in the first category (land) are available for all portions of a flood control project including channel improvements under the "State Alternative Assistance Program."

Federal: Federal channel improvement funds are only available if the project is adopted as a Federal project. The time required for this process (minimum 10 years) is too lengthy, given private development pressures within the study area proposed for channelization. Limited Federal funding for channelization can be obtained if any of the roadway crossings are Federally funded.

Private: A majority of the channel improvements proposed are for the benefit of adjacent land owners. The channel work serves not only to allow encroachment into the floodplain but also provides a source of dirt for adjacent fill pads. An incentive to providing this work is for the city to allow the improvements to be put in by the improvement district.

Maintenance of the wash can be funded privately by large commercial or industrial owners through a trust, or by a homeowners association. Homeowners associations have not proven successful where single-family developments (single-family zoning) occur adjacent to the channel. Therefore, maintenance will probably be a city responsibility in single-family use areas.

Multi-family residential areas commonly have homeowners associations capable of maintaining channel areas; however, experience has shown that privately maintained channel areas must be for the exclusive use of the homeowners. Security barriers must be included in the channel work to separate the private and public uses.

3. Roadway crossings can be of substantial private benefit as well as overall public benefit and a number of alternative funding sources are available as summarized below:

   City: Road crossings can, as with the channel improvements, be funded as a direct expenditure or by the improvement district. Assessing those benefitted to an improvement district makes this funding vehicle difficult to implement.

County: County highway funds are available for roadways within the county only. Flood Control District of Maricopa County funds would be available for a Federal, state or "local county" funded project.

State: State funds are available as previously discussed under the "State Alternative Assistance Program" and for any state/urban highways projects.

Federal: Federal Highway Administration funds will be available only on an urban freeway (within the study area no urban freeways currently exist or are planned). Road relocations within COE projects are a "local responsibility."

Private: Those portions of a road crossing project that have direct benefit to an adjacent developer can be assessed to that developer as a development requirement. An example of such a benefit is where a 100-year crossing is constructed, resulting in a narrowing of the channel to allow more developable land to be recovered from the floodplain. The value of that land has in a number of cases been used in a privately funded portion of the crossing construction.

4. Recreation and aesthetic amenities within the channel have a number of funding sources:

City: To date, the city has funded these amenities by direct expenditure (including the selling of bonds) in the absence of other sources. As applicable, these funds have been used as matching funds for Federal programs.

School District: Where joint facilities are planned, school district funds are available for capital and maintenance costs for school related recreation amenities. This has been limiting in scope of facilities available and difficult in packaging to match against Federal funding.

County: Flood Control District of Maricopa County funds are not available for recreation or aesthetic amenities on flood control projects. Only those aesthetic actions required for acceptance of land acquisition programs are fundable. Land acquisition is considered a match against several Federal funds should FCDMC wish to provide recreation and/or open space. The FCDMC funds can be used for studies which involve recreation.

State: State flood control funds are not available for recreation or aesthetic amenities except as required for acceptance of land

acquisition programs. State Park funds can be available for recreation within floodplains including acquisition, operation and maintenance. Funds for recreation can be requested of the legislature by any state agency wishing to become involved in recreation, such as the Arizona State Land Department or the State Game and Fish. Historically, this has not happened. The State Lake Improvement Fund funds recreation facilities on any water body potentially used by boaters. The Arizona Water Commission can become involved in a situation involving dam safety, i.e., spillway development or surrounding land rehabilitation.

Federal: Federal funds for recreation are very limited at this time. Obtaining Federal funding for these amenities is not foreseen in the near future. However, should Federal funding become a potential fund source, the following agencies may be of assistance: BLM, EDA (possibly with local Public Works money), COE, National Park Service, BuRec, Fish and Game Department, Department of Housing and Urban Development, Historic Preservation Grant money (available through the State Historic Preservation Officer), and the Land and Water Conservation Fund (should it be reinstated).

Private: Private funding on capital costs for channel beautification for adjacent developments is logically borne by the benefitted private parties. Maintenance of the recreation and aesthetic amenities within the channel would require, as discussed previously, a homeowners association with exclusive rights to use, or a large commercial or industrial owner.

In summary, the most likely funding source for capital and maintenance costs associated with land acquisitions, channel improvements, roadway crossings and recreation and aesthetic amenities is from private sources benefitting from the wash development. Some limited funding may be available from the FCDMC or "State Alternative Assistance Program" in those areas where substantial flood control benefits can be shown. Limited funding from the city for operation and maintenance, specifically in the park development areas of the plan, can be expected.

The majority of cost for development must be from private sources, while the operation and maintenance will be of mixed funding and could include such options as maintenance districts. The city will have to make some definite commitments to BLM (e.g. lease of property for recreation use). Therefore, the limited city funds will be committed to these types of contractual expenditures rather than open space along the channel which is mainly benefitting the adjacent developers/owners.

DEVELOPMENT

Implementation of the selected plan will require phasing construction and funding aspects of the project. The following section looks at critical progressive steps in implementation, how piecemeal development can be handled, and possible implications of various scenarios for development of the wash.

Implementation problems will be most important in areas where channelization is proposed. On the main wash, channelization will involve a complete realignment between Bell Road and Union Hills Drive and partial channelization with some realignment between Union Hills Drive and Deer Valley Road. Upstream of Deer Valley Road and downstream of Bell Road, no additional channelization is proposed. On the East Fork, the only channelization proposed is upstream of approximately 3rd Avenue. Some channelization upstream of 7th Street will also be needed for construction of the roadway crossing at 7th Street.

On a major flood control project the normal procedure would be to start with underground utility relocations, then begin downstream channel work proceeding upstream. Implementation in this case is primarily a scheduling problem. In the Cave Creek Wash, implementation problems for the most part result from staged construction by both private and public entities out of the normal downstream-to-upstream sequence (piecemeal development). With this sort of an implementation procedure it is necessary to identify critical initial steps.

Protection for piecemeal floodplain encroachment cannot be designed with the assumption that all proposed flood control improvements will be built. It must be designed to stand on its own as to the hydraulics conditions existing at the time of development. This may, where the developer does not control the entire channel or where the channel is not completed downstream, be less than could ultimately be developed since the channelization may not be functioning at 100 percent efficiency (at that point in time). Therefore, developers could be required to consider staged development into the floodplain. In addition, it will be necessary to obtain letters of map amendment from FEMA for relief of flood insurance requirements.

Road crossings must be established first for upstream channel work to be functional. Crossings could precede channelization where the crossing is set at grade. Even if not fully functional, the structure will pose no obstruction with respect to increasing upstream water surface elevations.

Drop structures must be in place prior to development adjacent to the channel to eliminate the possibility of failure due to lateral migration. In addition, the upstream end of piecemeal channel excavations must have temporary armoring where uncontrolled headcutting upstream can cause failure or significant damage to existing structures.

In the main channel, the most significant implementation problem is eliminating the breakout of flood waters north of Beardsley Road identified by the FEMA study (see Hydrology section). Prior to this flood water being diverted back into the channel, the capacity downstream to Bell Road must be increased. Should developers within the breakout area choose to begin work prior to the downstream capacity being increased by others, the burden of carrying out this work will be on those benefitted. Short of waiting for the necessary work to be completed downstream, those benefitted must work directly with the downstream channel properties or take an improvement district approach to completing the work.

It is possible with a piecemeal implementation of the master plan to end up with isolated channelized sections having no outlets until downstream properties are developed. Outlets can be provided by maintaining present invert elevations. This will work north of Beardsley Road; however, from Beardsley Road south to Bell Road, in order to save on the Beardsley Road and Union Hills Drive crossings, the channel must be deepened.

If not having outlets becomes a major problem, the city may have to construct a pilot channel at the finish grades within the alignment of the low-flow channel.

ZONING

Contract Zoning

Contract zoning allows a government entity to obtain private sector financial support for specific improvements by providing development regulation guarantees. The government enters into a contract with a developer or property owner. In this contract the developer agrees to help finance improvements on or through his property.

The government agrees to allow the developer specified development rights within a stated time frame. These rights may include rezoning, phasing of development-related improvements (utilities, streets) and others negotiated as part of the contract. In the case of flood control improvements, fairly obvious benefits accrue to both parties in the contract. The government obtains immediate financing for the improvements needed to assure public safety and protect property at a time when public funds for such improvements have been severely curtailed. The developer often reclaims floodplain land, adding to his developable acreage, and has guarantees of zoning and other negotiated development rights. The contract may be tied to a given time limit or, as in the case of land to be reclaimed from sand mining, left somewhat open. When the mining resource is depleted, development will occur as per contract.

The contract zoning concept is fairly new and represents a growing awareness of the needs to provide strong incentives if the private sector is to participate in public sector improvements.

Overlay Zoning District

The City of Phoenix may wish to consider designation of an overlay zoning district along Cave Creek Wash. The overlay district could build on the new residential zoning ordinance revisions to encourage private sector participation in flood control and recreation improvements along the wash and to encourage site planning that will focus on the wash as an amenity and build a stronger area identity.

An overlay zoning district for Cave Creek Wash could include elements such as:

- After density bonuses for public recreation improvements, trails, landscaping, other site amentities.
- Require participation in flood protection improvements with density bonuses related to land reclamation.
- Provide site planning and design standards that will assure: that development focuses on the wash as an amenity; that the wash has good visibility; that the relationship between wash and nearby development is planned to help build a positive neighborhood/village identity.
- Encourage use of either an average lot or planned residential development planning approach, with higher densities concentrated near the wash corridor.
- Encourage provision of private open space and recreation facilities that link with public improvements in the wash. Provisions can be made for long-term maintenance of private open space within this context.

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APPENDIX A
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TABLE II
SUMMARY OF UTILITY/WASH INTERFACES

Gas (APS)

	Size	Location
1.	10"	19th Avenue, 550 feet south of Greenway
2.	4"	19th Avenue, 550 feet south of Greenway
3.	2" PVC	Gables Drive and Greenway Road, 800 feet west of 7th Avenue (E)
*4.	2-4"	7th Avenue and Bell Road
5.	4"	7th Street east along Bell Road (E)

Telephone (Mountain Bell)

	Size	Location
1.	8 D-4" Trans Buca	On Greenway from 19th Avenue to 7th Avenue
*2.	6 PC-4"C	On 7th Street, Paradise Lane to Bell Road (E)
*3.	6 PC-4"C	Bell Road and 7th Avenue
*4.	T-cable	Grovers Avenue east of 7th Avenue
*5.	2 PC-4"D	Union Hills between 7th Avenue and Central
*6.	6 PC-4"C	Beardsley Road between Central and 7th Street

D - Ducts
Buca - Buried Cable
C - Diameter

Trans - Transite
PC - Plastic Cable
T-cable - Telephone cable (buried)

Electric (APS)

	Above or Below Ground	Location
1.	Above	On Greenway, 19th Avenue to 7th Avenue (E)
*2.	Below	On Central Avenue and Paradise (E)
*3.	Above	On Bell Road and 7th Avenue
4.	Above	On Bell Road, 7th Street eastward (E)
*5.	Above	On both sides of Grovers Avenue just east of 7th Avenue
*6.	Above	On Union Hills Drive between 7th Avenue and Central Avenue
*7.	Above	On Beardsley Road between Central Avenue and 7th Street

Table II (continued)
Summary of Utility/Wash Interfaces

Electric (APS)

	Above or Below Ground	Location
*8.	Above	On 7th Street between Rose Garden Lane and Deer Valley Road
*9.	Above	On 12th Street and Deer Valley Road

Water (City of Phoenix)

	Size	Location
1.	12"	19th Avenue, 550 feet south of Greenway
2.	8"	1500 feet east of 19th Avenue on Greenway (E)
3.	12"	Greenway Road between 19th Avenue and 7th Avenue (E)
4.	8"	Paradise Lane just west of Central Avenue (E)
5.	8"	Central Avenue south of Bell Road (E)
*6.	20"	7th Street between Paradise Lane and Bell Road (E)
7.	12"	South side of Bell Road, east of 7th Street (E)
8.	20"	North side of Bell Road, east of 7th Street (E)
*9.	29"	South side of Union Hills Drive between 7th Avenue and Central
*10.	12"	North side of Union Hills Drive between 7th Avenue and Central
*11.	8"	Central Avenue, 1800 feet north of Union Hills
*12.	12"	Beardsley Road between Central Avenue and 7th Street
*13.	12"	Bell Road at 7th Avenue
14.	66"	Beardsley Road (proposed)

Sanitary Sewer (City of Phoenix)

	Size	Location
1.	30"-24"-27"	Greenway Road between 19th Avenue and 7th Avenue (E)
2.	27"	Central Avenue south of Paradise Lane (E)
*3.	12"	Central Avenue north of Paradise Lane (E)

Table II (continued)
Summary of Utility/Wash Interfaces

Sanitary Sewer (City of Phoenix)

	Size	Location
4.	21"	1350 feet north of Paradise Lane, east of 7th Street (E)
*5.	18"	Bell Road west of 7th Avenue
*6.	15"	7th Avenue between Bell Road and Grovers Avenue
*7.	15"	7th Street between Paradise Lane and Bell Road (E)

Proposed Sanitary Sewer

	Size	Location
*1.	45"	Tierra Buena, 3200 feet east of 19th Avenue
*2.	45"	1250 feet south of Bell Road and west of 7th Avenue (E)

Storm Drain Proposed (City of Phoenix)

November 1981

	Size	Location
1.	33"	Central Avenue at Paradise
2.	72"	7th Street south of Bell Road
3.	42"	Grovers Avenue at 7th Avenue
4.	93"	Union Hills east of 7th Avenue
5.	87"	Beardsley Road west of 7th Street
6.	69"	19th Avenue at Cave Creek Wash

January 1982 (Note: Storm drains are subject to change in size and location.)

	Size	Location
1.	90"	19th Avenue north
2.	60"	7th Avenue north
3.	42"	Grovers Avenue west
4.	48"	Deer Valley Road east
5.	72"	Beardsley Road east

Table II (continued)
Summary of Utility/Wash Interfaces

Storm Drain Proposed (City of Phoenix)

January 1982

	Size	Location
6.	96"	Union Hills east
7.	66"	Bell Road east
8.	72"	7th Street north (E)
9.	48"	Greenway Road east (E)

(E) - East Fork

* - May require relocation or protection (crossings between Bell Road and 7th Street on main wash and Central to 7th Street on East Fork).

TABLE III
CAVE CREEK WASH RECORDED PREHISTORIC SITES

Site No.	Other Site Designations	Site Type	Temporal Affiliation	Site Description
T:8:1(ASM)		Sherd area, possible campsite	Hohokam (Santa Cruz)	Small scattered concentration of Gila Plain, Wingfield Plain and other plain ware sherds, possibly on a campsite. Badly washed.
T:8:4(ASM)	G.P.A:8:7	Village	Hohokam	Gila Plain (Wingfield Plain), 2 projectile points, 2 irrigation canals, mano fragments, trash mound. Potted but trash undisturbed. Located within Cave Creek Dam Archaeological District at base of Fort Mountain.
T:8:5(ASM)	G.P.A:8:4, T:8:34(ASU), Fort Mountain	Fortified hilltop, petroglyphs	Hohokam (AD 700-1125)	Elongated, oval-shaped rock wall-enclosed area (approximately 26 x 90 m.) on crest of Fort Mountain. Three rock structures (rooms). Walls are coursed masonry (basalt). Seven petroglyph loci identified.
T:8:6(ASM)	Included in T:8:31(ASU)		Hohokam (AD 900-1200)	Refer to T:8:31(ASU).
T:8:7(ASM)	P.G. Ariz. T:8:1	Sherd area	Hohokam	Gila Plain, unidentifiable red-on-buff sherds.
T:8:8(ASM)	P.G. Ariz. T:8:3	Sherd area	Hohokam	Gila Plain sherds.
T:8:9(ASM)		Agricultural terraces and farmhouses	Hohokam	Gila Plain, redware sherds, mano and metate fragments, traces of canals, agricultural terraces. Located within Cave Creek Dam Archaeological District at base of Fort Mountain.
T:8:30(ASU)		-	-	Located within Cave Creek Dam Archaeological District. No site information available.
T:8:31(ASU)	T:8:6(ASM)	Agriculture and habitation	Hohokam (AD 900-1200)	Two components. 1) Complex of agricultural terraces, garden plots, water control structures, canals, subsurface ovens, field houses. 2) Cluster of habitation units and three large refuse mounds. Located within Cave Creek Dam Archaeological District.

Table III (continued)
Cave Creek Wash Recorded Prehistoric Sites

Site No.	Other Site Designations	Site Type	Temporal Affiliation	Site Description
T:8:32(ASU)		Habitation	Hohokam (AD 1000s)	Consists of three habitation units of contiguous rooms with coursed masonry foundations, an area of garden plots. Located within Cave Creek Dam Archaeological District.
T:8:33(ASU)		Habitation	Hohokam (AD 1000s)	Habitation unit with coursed masonry foundations about 90 m. north of T:8:32. Located within Cave Creek Dam Archaeological District.
T:8:34(ASU)	G.P.A:8:4, T:8:5(ASM), Fort Mountain	Fortified hilltop, petroglyphs	Hohokam (AD 700-1125)	Refer to T:8:5(ASM).
T:8:35(ASU)		Agriculture and structures	Hohokam (AD 900-1100)	Includes large system of agricultural terraces and surrounding features identified as field plots, temporary habitation units or graneries, subsurface ovens, work areas and part of canal. Located at base of Fort Mountain within Cave Creek Dam Archaeological District.
T:8:36(ASU)		Petroglyphs		Fifteen loci of geometric and life form petroglyphs scattered among the basalt boulders along base of Fort Mountain. Life forms are the majority of the 39 petroglyphs recorded; of the zoomorphs the big horn sheep occurs most often.
T:8:37(ASU)		Habitation	Hohokam (AD 900-1100)	Sherd and lithic scatter 30 x 50 m., remains of water control system of large cobble alignments and habitation unit. Largely destroyed by gravel mining operation (recent). Located within Cave Creek Dam Archaeological District.
T:8:38(ASU)		Habitation	Hohokam	Stone masonry room and large trash mound on east side of Cave Creek south of Cave Buttes. Old Rio Verde Canal (late 1800s) cut through portion of structure. Located within Cave Creek Dam Archaeological District.

Table III (continued)
Cave Creek Wash Recorded Prehistoric Sites

Site No.	Other Site Designations	Site Type	Temporal Affiliation	Site Description
T:8:44(ASU)		Sherd scatter	Hohokam (AD 1100-1450)	Limited area of scattered sherds, including several types, which suggests a use or occupation area. Located within Cave Creek Dam Archaeological District.
T:8:45(ASU)		Lithic and sherd scatters		Lithic and sherd scatters. No structures evidenced, maybe subsurface.
T:8:46(ASU)		Lithic and sherd scatters		Pronounced distribution of rocks, lithics and sherds. No structures visible.
T:8:47(ASU)		Sherd scatter		Sherds and stone, possible subsurface.
*T:8:48(ASU)		Sherd scatter		Several dense sherd areas, 2 hearths, fire-cracked rock. Maybe subsurface structures.
*T:8:49(ASU)		Sherd scatter		Small sherd scatter.
T:8:77(ASU)		Food processing	Hohokam (Sedentary)	Probably food processing, ceramics, lithics, rock wind deflector, agricultural architecture. Located within Cave Creek Dam Archaeological District.
T:8:87(ASU)		Campsite	Hohokam	Campsite and temporary seasonal use. Destroyed by housing development.
T:8:100(ASU)		Collecting site	Hohokam (AD 900-1100)	Lithic scatter of artifacts: lithics, mano, metate, tools, sherds. Primary surface, little depth. 100% surface collection. Destroyed by housing development.
T:8:101(ASU)		-	-	Plotted on site map, but no site information available.
T:8:102(ASU)		-	-	Plotted on site map, but no site information available.

TABLE IV
CAVE CREEK WASH RECORDED HISTORIC SITES

Site No.	Other Site Designations	Site Type	Temporal Affiliation	Site Description
No #	Rio Verde Canal		1890s	Part of planned system of dams and irrigation canals to deliver water to the valley between Verde River and New River for agriculture. Of the entire system, only the canal segment from the headgate on the Verde River to Cave Creek was completed. A later, similar project intended to use the canal, but the project was also abandoned. Part of the canal is located within Cave Creek Archaeological District.
No #	Cave Creek Dam		1923	Multiple arch reinforced concrete dam, built for the purpose of flood control, was one of the first of its kind to be built in the U.S. Located within Cave Creek Dam Archaeological District.
No #		Irrigation ditch and structures	Historic/ Modern (post 1930s)	Shallow irrigation ditch generally parallels prehistoric canal alignment. Several parallel lateral ditches extending west from main ditch. Concrete slab structure (?) foundations. Trash area. Located within Cave Creek Dam Archaeological District.
No #	Union Mine	Mine	Late 1800s	
No #		Pipeline	Late 1800s	1895 General Land Office map indicates a water pipeline from Union Mine to a mill.
No #	Old Cave Creek Road	Road		Early road from Phoenix to Cave Creek.

TABLE V
MAIN CHANNEL FEMA AND CORPS FLOW RATES

FEMA Flow Rates

Mile Section Reaches	Q_{10} (cfs)	Mile Section Reaches	Q_{100} (cfs)
4.14- 4.32	3,100	4.14- 4.32	11,000
4.37- 7.65	1,600	4.37- 7.65	4,200
7.75- 9.30	1,400	7.75- 8.08	3,800
9.32-10.18	1,300	8.15- 8.60	3,600
10.25-10.98	1,000	8.68- 9.30	5,400
11.15-11.39	150*	9.32-10.18	5,000
		10.25-10.98	4,000
		11.15-11.39	500*

Corps Flow Rates

Mile Section Reaches	Q_{100} (Future)** (cfs)
4.14- 4.32	14,000
4.37- 7.65	5,800
7.75- 9.30	5,400
9.32-10.18	5,000
10.25-10.98	4,000
11.15-11.39	500

*Main Channel Section Locations

Mile Section No.	Street
4.03	19th Avenue
5.54- 5.57	Bell Road
6.10 and 6.12	7th Avenue
6.665	Union Hills Drive
7.855	Beardsley Road
8.780	7th Street
9.34	Deer Valley Road
11.39	End of Project

* Cave Buttes Dam Release

** Future if flow at Beardsley Road (Sec. No. 7.85) is not diverted and kept in the wash.

TABLE VI
EAST FORK FEMA* FLOW RATES

Mile Section Reaches	Q_{100} (cfs)	Mile Section Reaches	Q_{10} (cfs)
4.21 -4.40	9,000	4.21 -4.40	2,300
0.118-0.775	9,000	0.118-1.191	2,300
0.893-1.191	8,900	1.275-1.972	2,200
1.275-1.192	8,400	2.076-2.927	1,900
2.076-2.927	7,500	3.079-3.079	1,100
3.079-3.079	4,200	3.231-4.334	1,000
3.231-4.334	3,900	4.541-5.458	800
4.541-5.458	3,000	5.555-	600
5.555-5.962	2,100		

East Fork Section Locations

Mile Section No.	Street
4.03	19th Avenue
0.65±	7th Avenue
1.492	Central Avenue
2.076	7th Street
3.079	16th Street
3.790	20th Street
4.43±	Cave Creek Road
4.85±	Union Hills Drive
5.449	Utopia Road
5.962	Beardsley Road - End of FEMA Delineation

*NOTE: The COE did not produce separate East Fork flow rates.

TABLE VII
CHARACTER OF DISTINCT REACHES

Location of Reach	Character of Channel	Floodplain Width (ft)	Floodplain Depth (ft)	Floodplain Velocity (fps)	Average Slope (ft/ft)
Main Channel (going upstream)					
1. 19th Avenue to the junction with East Fork at the extension of Greenway Road	well defined, adjacent to an old landfill, little vegetation	150 to 200	10 to 12	8 to 12	.0056
2. Greenway Road to Bell Road	mostly channelized with gabions, no vegetation	150 to 200	6 to 12	6 to 14	.0056
3. Bell Road to Union Hills Drive	braided wide channel with some scrub vegetation	1,000 to 2,100	6 to 9	3 to 10	.0064
4. Union Hills Drive to Beardsley Road	gravel operations along well-defined channel, some vegetation	150 to 400	5 to 11	3 to 11	.0045
5. Beardsley Road to 7th Street	gravel pit along east side of well-defined channel, little vegetation, breakout where channel has insufficient capacity	100 to 500	4 to 12	4 to 14	.0055
6. 7th Street to Cave Buttes Dam	well-defined channel with several adjacent gravel operations where channel has been realigned, significant vegetation in portions of the channel	200 to 1,600	6 to 14	2 to 12	.005

Table VII (continued)
Character of Distinct Reaches

Location of Reach	Character of Channel	Floodplain Width (ft)	Floodplain Depth (ft)	Floodplain Velocity (fps)	Average Slope (ft/ft)
East Fork (going upstream)					
1. Junction with main channel at Greenway Road and 7th Avenue to the Central Avenue extension	well defined, relatively undisturbed, some lateral migration, significant vegetation along and within channel	200 to 500	8 to 11	5 to 12	.0048
2. Central Avenue to 7th Street	braided, wide poorly-defined channel with some vegetation in center of channel (50± feet in width)	800 to 1,500	2 to 8	5 to 8	.0022

TABLE VIII
CAVE CREEK WASH TABULATION OF MAIN CHANNEL
FEMA ELEVATIONS

Comments	X-Sec. No.	Invert (El. Min)	Exising 100-Year Water Surface
	4.00	1309.00	
	4.01	1313.00	
	4.015	1313.00	
	4.025	1313.00	
19th Avenue	4.03	1313.00	
	4.05	1313.10	

Comments	X-Sec. No.	Invert (El. Min)	Existing 100-Year Water Surface
19th Avenue	4.08	1313.20	
	4.14	1314.00	1324.59
	4.21	1315.00	1325.41
	4.28	1318.00	1326.44
Q=11,000 cfs	4.32	1319.30	1328.95
Q=4,200 cfs	4.37	1320.60	1331.68
	4.40	1321.10	1331.70
	4.45	1322.70	1332.01
	4.55	1324.00	1332.81
	4.62	1327.40	1333.98
	4.67	1329.00	1334.46
	4.72	1329.60	1335.99
	4.79	1332.00	1338.80
	4.86	1334.50	1341.97
	4.94	1337.00	1343.35
	4.98	1338.00	1346.10
	5.02	1338.80	1347.72
	5.05	1339.50	1346.98
	5.08	1340.60	1349.35
	5.15	1343.00	1350.00
	5.20	1347.00	1352.18
	5.25	1347.90	1355.09
	5.29	1348.00	1357.44
	5.37	1350.60	1359.94
	5.45	1353.10	1362.31
	5.52	1356.00	1364.22
Bell Road	5.54	1355.40	1363.83

Table VIII (continued)
Cave Creek Wash Tabulation of Main Channel
Fema Elevations

Comments	X-Sec. No.	Invert (El. Min)	Exising 100-Year Water Surface
Bell Road	5.57	1356.00	1364.12
	5.58	1358.00	1365.52
	5.65	1361.00	1366.36
	5.72	1363.40	1368.44
	5.78	1365.60	1372.79
	5.85	1367.00	1374.90
	5.91	1369.00	1376.35
	5.97	1371.00	1377.79
	6.03	1374.00	1380.77
	6.07	1375.00	1381.63
7th Avenue	6.10	1376.00	1382.38
	6.12	1376.70	1382.65
	6.21	1379.50	1385.44
	6.30	1381.40	1387.86
	6.38	1383.50	1391.92
	6.46	1386.00	1393.81
	6.56	1390.50	1396.66
	6.63	1392.50	1398.85
Union Hills Drive	6.665	1394.20	1399.65
	6.68	1394.30	1399.87
	6.80	1395.50	1402.76
	6.90	1397.50	1404.85
	7.00	1400.70	1408.20
	7.08	1404.20	1410.56
	7.12	1404.50	1412.32
	7.135	1404.70	1413.01
	7.190	1404.80	1414.70

Comments	X-Sec. No.	Invert (El. Min)	Existing 100-Year Water Surface
Union Hills Drive	7.250	1405.70	1414.89
	7.30	1406.70	1414.42
	7.38	1409.40	1415.53
	7.48	1412.00	1415.75
	7.56	1413.40	1420.02
Q=4,200 cfs	7.65	1415.70	1423.25
Q=3,800 cfs	7.75	1422.00	1425.69
	7.81	1424.00	1429.35
	7.84	1428.00	1431.62
Beardsley Road	7.855	1430.70	1432.12
	7.91	1430.00	1434.07
	8.00	1434.00	1441.48
Q=3,800 cfs	8.08	1436.40	1443.45
Q=3,600 cfs	8.15	1441.70	1445.42
	8.19	1443.00	1449.28
	8.25	1443.90	1452.20
	8.34	1445.10	1454.60
	8.37	1445.50	1456.05
	8.42	1446.30	1456.47
	8.53	1448.00	1458.08
Q=3,600 cfs	8.60	1448.80	1458.95
Q=5,400 cfs	8.68	1450.00	1459.91
	8.70	1450.50	1460.60
	8.73	1451.50	1460.88
7th Street	8.78	1453.50	1462.42
	8.79	1454.00	1462.47
	8.81	1454.00	1463.51

Table VIII (continued)
Cave Creek Wash Tabulation of Main Channel
Fema Elevations

Comments	X-Sec. No.	Invert (El. Min)	Exising 100-Year Water Surface
7th Street	8.90	1453.70	1463.81
	8.97	1454.00	1463.90
	9.09	1456.70	1464.38
	9.20	1459.50	1466.75
Q=5,400 cfs	9.30	1466.00	1471.73
Q=5,000 cfs	9.32	1468.00	1472.48
	9.33	1468.30	1474.02
Deer Valley Road	9.34	1468.00	1474.00
	9.44	1474.00	1480.54
	9.60	1479.90	1483.35
	9.80	1487.30	1489.89
	9.86	1488.00	1492.18
	9.97	1492.00	1495.11
	10.04	1495.00	1499.65
	10.05	1498.00	1503.15

Comments	X-Sec. No.	Invert (El. Min)	Existing 100-Year Water Surface
Deer Valley Road	10.10	1497.30	1504.15
	10.14	1500.00	1507.13
	10.145	1505.90	1511.07
	10.165	1505.90	1513.68
Q=5,000 cfs	10.18	1506.00	1515.07
Q=4,000 cfs	10.25	1506.70	1515.40
	10.40	1511.50	1516.71
	10.55	1515.50	1523.45
	10.68	1519.70	1526.61
	10.74	1521.00	1527.54
	10.82	1523.50	1530.40
Q=4,000 cfs	10.98	1524.00	1531.09
Q=500 cfs	11.15	1522.00	1531.21
Cave Buttes Dam	11.39	1551.80	1553.11

TABLE IX
CAVE CREEK WASH TABULATION OF EAST FORK
FEMA ELEVATIONS

Comments	X-Sec. No.	Invert (El. Min)	Exising 100-Year Water Surface
	4.21		
	4.28		
Junction with Main Channel	4.32	1319.30	1327.74
	4.37	1320.50	1330.75
	4.40	1321.20	1332.81
	.118	1322.00	1332.69
	.173	1323.00	1335.36
	.241	1325.00	1335.81
	.299	1327.00	1337.36
	.348	1328.00	1338.64
	.407	1330.00	1339.04
	.470	1331.00	1339.44
	.543	1333.00	1342.50
7th Avenue	.654	1335.00	1345.14
Q=9,000 cfs	.775	1338.00	1347.99
Q-8,900 cfs	.893	1340.00	1350.40
	1.013	1342.00	1352.05
	1.106	1344.00	1353.46
Q=8,900 cfs	1.191	1345.00	1354.97
Q=8,400 cfs	1.275	1346.00	1356.05
	1.390	1350.00	1359.03
Central Avenue	1.492	1354.00	1361.00
	1.621	1357.00	1365.11
	1.744	1362.00	1369.01
	1.856	1370.00	1372.81
Q=8,400 cfs	1.972	1371.30	1375.37

Comments	X-Sec. No.	Invert (El. Min)	Existing 100-Year Water Surface
7th Street,	2.076	1375.60	1377.62
Q=7,500 cfs	2.206	1379.60	1381.43
	2.301	1381.20	1384.42
	2.444	1384.30	1387.71
	2.575	1388.90	1391.41
	2.755	1393.00	1395.91
Q=7,500 cfs	2.927	1399.30	1402.49
16th Street,	3.079	1404.20	1407.83
Q=4,200 cfs			
Q=3,900 cfs	3.231	1409.60	1412.08
	3.429	1416.50	1418.86
	3.619	1424.40	1426.13
20th Street	3.790	1429.30	1431.95
	3.929	1434.10	1436.03
	4.099	1438.30	1441.39
Cave Creek Road,	4.217	1443.30	1445.28
Q=3,900 cfs	4.334	1446.40	1449.37
Q=3,000 cfs	4.541	1452.80	1455.61
	4.673	1458.40	1460.69
Union Hills Drive	4.832	1463.30	1465.95
	4.980	1465.30	1470.33
	5.130	1468.30	1474.73
	5.265	1471.60	1479.76
	5.432	1476.00	1483.41
	5.441	1476.00	1484.08
Utopia Road	5.449	1479.50	1484.47

Table IX (continued)
Cave Creek Wash Tabulation of East Fork
Fema Elevations

Comments	X-Sec. No.	Invert (El. Min)	Exising 100-Year Water Surface
Q=3,000 cfs	5.458	1479.50	1484.47
Q-2,100 cfs	5.555	1479.70	1485.62
	5.669	1483.00	1489.01
	5.835	1486.40	1493.96
Beardsley Road	5.962	1492.10	1496.88

TABLE X
TABULATION OF ACRES WITHIN FEMA FLOODPLAIN

Reach Limits	Acres
Main Channel	
19th Avenue to Bell Road	82
Bell Road to Union Hills Drive	199
Union Hills Drive to Beardsley Road	56
Beardsley Road to 7th Street*	102*
7th Street to Cave Buttes Dam	368
East Fork	
Junction to 7th Avenue	55
7th Avenue to 3rd Avenue	17
3rd Avenue to Central Avenue	40
Central Avenue to 7th Street	117

*Excluding breakout

TABLE XI
MAIN CHANNEL
MINIMUM WIDTH ALT.
(NO SEPARATE LOW-FLOW CHANNEL)

	Reach	Q_{100}	n	Exist S %	d	bW	Allow-able V_{max}	$R^{2/3}$	Velocity* with Existing Slope	Allowable** Slope (%)
Bell Road to Union Hills Drive	5.65-6.80	5800	.045	.6505	7.3	159	5	3.55	9.45	.1823
			.030	.6505	7.3	159	5	3.55	14.18	.0809
			.035	.6505	7.3	80	10	3.365	11.55	.487
			.025	.6505	7.3	159	5	3.55	17.02	.0562
Union Hills Drive to Beardsley Road	6.80-7.65	5800	.045	.45	8.2	142	5	3.78	8.37	.1606
			.030	.45	8.2	142	5	3.78	12.56	.0713
			.035	.45	8.2	71	10	3.54	10.11	.4405
			.025	.45	8.2	142	5	3.78	15.07	.0495
Beardsley Road to 7th Street	7.75-8.60	5400	.045	.597	8.0	135	5	3.71	9.47	.1666
			.030	.597	8.0	135	5	3.71	14.21	.0740
			.035	.597	8.0	68	10	3.474	11.43	.4573
			.025	.597	8.0	135	5	3.71	13.45	.0514

Conclusions: Top width could go as low as 180 feet to 200 feet (earth) and 150 feet to 170 feet (grass) on the main channel and 270 feet to 300 feet (earth) and 225 feet to 250 feet (grass) on the East Fork. Grassed channels could be built at or very near to the existing slopes (some flattening necessary on the East Fork) and earth channels will require slopes on the order of 0.0015 to 0.002. Even with these flat slopes, some erosion can be expected in the invert and drop structures should be tied down well below the invert.

* Approximate velocity using the existing slope with the design channel. Note that VA = Q design.
** Allowable slope for the channel design using the allowable velocity.

TABLE XII
MAIN CHANNEL - 10-YEAR LOW-FLOW CHANNEL ALT.
(See Figure 14 for Terminology)

	Reach	Q_{100}	d_1	bw_1	Existing S (%)	Allow-able V_{max}	N	$R^{2/3}$	Low-Flow* Velocity with Existing Slope	Low-Flow** S (%)	D	bw_2	$R^{2/3}$	Velocity with Existing Slope	Allowable** Slope (%)
Bell Road to Union Hills Drive	5.65-6.80	5800	4.40	73	.6505	5	.045	2.46	6.55	.3794	8.0	233	2.79	7.42	.2950
			4.40	73	.6505	5	.030	2.46	9.83	.1684	8.0	233	2.79	11.14	.13098
			4.40	37	.6505	10	.035	2.39	8.04	1.006	8.0	117	2.67	9.16	.7749
			4.40	73	.6505	5	.025	2.46	11.80	.1169	8.0	233	2.79	13.37	.09096
Union Hills Drive to Beardsley Road	6.80-7.65	5800	4.80	67	.4500	5	.045	2.60	5.76	.339	8.2	247	2.69	5.95	.3180
			4.80	67	.4500	5	.030	2.60	7.42	.2042	8.2	247	2.69	8.93	.1412
			4.80	34	.4500	10	.035	2.91	6.88	.9500	8.2	124	2.57	7.35	.8329
			4.80	67	.4500	5	.025	2.60	8.90	.01418	8.2	247	2.67	10.12	.09806
Beardsley Road to 7th Street	7.75-8.60	5400	4.20	67	.5970	5	.045	2.41	6.13	.397	8.0	232	2.80	7.13	.2935
			4.20	67	.5970	5	.030	2.41	9.22	.1755	8.0	232	2.80	10.70	.1303
			4.20	34	.5970	10	.035	2.25	7.39	1.094	8.0	116	2.68	8.82	.7671
			4.20	67	.5970	5	.025	2.41	11.06	.1219	8.0	232	2.80	12.84	.0905

Conclusions: Top width of the low-flow channel is approximately 100 feet for earth and 70 feet for grass. The top width for the entire channel varies from 290 feet for earth to 170 feet for grass. Slopes for a stable grass channel can match existing, however, an earth lining will require slopes in the 0.0015 to 0.002 range. Slopes could go as high as 0.003 with some erosion and lateral instability expected in the low-flow invert. Drop structures for the earth channel should be well tied down, but would not have to be as deep as the minimum width option.

* Approximate velocity using the existing slope with the design channel. Note that VA = Q design.
** Allowable slope for the channel design using the allowable velocity.

TABLE XIII
MAIN CHANNEL - 500 cfs LOW-FLOW CHANNEL ALT.
(See Figure 14 for Terminology)

	Reach	Q_{100}	d_1	bw_1	Existing S (%)	Allowable V_{max}	n	$R^{2/3}$	Low-Flow* Velocity with Existing Slope	Low-Flow** S (%)	D	bw_2	$R^{2/3}$	Velocity with Existing Slope	Allowable** Slope (%)
Bell Road to	5.65-6.80	5800	4.0	25	.6505	5	.045	2.09	5.57	.5235	8.0	265	2.57	6.85	.3467
Union Hills			4.0	25	.6505	5	.030	2.09	8.37	.2324	8.0	265	2.57	10.28	.1539
Drive			4.0	13	.6505	10	.035	1.78	6.22	1.6815	8.0	133	2.48	8.49	.9016
			4.0	25	.6505	5	.025	2.09	10.64	.1614	8.0	265	2.57	12.34	.1069
Union Hills	6.80-7.65	5800	4.0	25	.4500	5	.045	2.09	4.64	.5235	8.0	265	2.57	5.70	.3467
Drive to			4.0	25	.4500	5	.030	2.09	6.96	.2324	8.0	265	2.57	8.55	.1539
Beardsley Road			4.0	13	.4500	10	.035	1.78	5.17	1.6815	8.0	133	2.48	7.06	.9016
			4.0	25	.4500	5	.025	2.09	8.35	.1614	8.0	265	2.57	8.47	.1069
Beardsley Road	7.75-8.60	5400	4.0	25	.5970	5	.045	2.09	5.34	.5235	8.0	265	2.57	6.56	.3467
to 7th Street			4.0	25	.5970	5	.030	2.09	8.01	.2324	8.0	265	2.57	9.85	.1539
			4.0	13	.5970	10	.035	1.78	5.96	1.6815	8.0	133	2.48	8.13	.9016
			4.0	25	.5970	5	.025	2.09	9.61	.1614	8.0	265	2.57	9.76	.1069

Conclusions: Low-flow top widths vary from 45 feet for grass to 55 feet for earth and total channel top widths range from 200 feet for grass to 325 feet for earth lining. Grassed channel slopes can match existing grades, however, as for the 10-year low-flow the earth channel must be flattened to slopes of 0.0015 to 0.002 to be stable. Slopes up to 0.003 can be considered with adequate tie-downs on the drop structures.

* Approximate velocity using the existing slope with the design channel. Note that VA = Q design.
** Allowable slope for the channel design using the allowable velocity.

TABLE XIV
EAST FORK - 10-YEAR LOW-FLOW CHANNEL ALT.
(See Figure 14 for Terminology)

Reach	Q_{10}	Q_{100}	N	Existing S %	d_1	D	Allow-able V_{max}	bw_1	R_1	$R_1^{2/3}$	V_{10}	Scorr	bw_2	R_2	$R^{2/3}$	Velocity* with Existing Slope	Allow-able** Slope %
3rd Avenue to 7th Street																	
1.275-1.972	2200	8400	.045	0.00687	4.64	7.0	5	96.0	4.2	2.6	7.12	0.0034	518	3.17	2.15	5.88	.4955
	2200	8400	.030	0.00687	4.64	7.0	5	96.0	4.2	2.6	10.68	0.0015	518	3.17	2.15	8.84	.220
	2200	8400	.035	0.00687	4.64	7.0	10	48.0	3.86	2.46	8.66	.916	259	3.08	2.12	7.46	1.23
	2200	8400	.025	0.00687	4.64	7.0	5	96.0	4.2	2.6	12.82	0.00104	518	3.17	2.15	10.61	0.1528
7th Street to 16th Street																	
2.076-2.927	1900	7500	.045	.534	5	7.0	5	76.0	--	2.69	7.49	.3166	560	--	1.897	4.58	.638
	1900	7500	.030	.534	5	7.0	5	76.0	--	2.69	9.75	.1406	560	--	1.897	6.87	.283
	1900	7500	.035	.534	5	7.0	10	38.0	--	2.50	7.78	.8817	280	--	1.866	5.80	1.584
	1900	7500	.025	.534	5	7.0	5	76.0	--	2.69	11.70	.0976	560	--	1.897	8.20	.1965

Conclusions

Low-flow base widths range from 90 feet for grass to 140 feet for earth. Note that these widths can be halved by reducing the capacity down to a two-year frequency (a typical "natural" condition). Top widths of the entire channel vary from 320 feet for a grassed solution to 580 feet for a stable earth channel. Stable slopes for the grassed channel can match existing slopes. However, in order to entrench the channel and pick up grade for the 7th Street bridge crossing, the slope should be flattened. An earth lining will require slopes of 0.004 or less. Drop structure tie-downs for the earth lining will not require other than standard depths (3 feet plus).

* Approximate velocity using the existing slope with the design channel. Note that VA = Q design.
** Allowable slope for the channel design using the allowable velocity.

TABLE XV
MAXIMUM PERMISSIBLE VELOCITIES PROPOSED BY FORTIER AND SCOBEY (1926)*

Original material excavated for canals	n	Mean velocity, after Aging, of Canals (d 3 ft)					
		Clear water, no detritus		Water transporting colloidal silt		Water transporting noncolloidal silts, sands, gravels or rock fragments	
		ft/sec	m/sec	ft/sec	m/sec	ft/sec	m/sec
1. Fine sand (colloidal)	.02	1.5	0.46	2.50	0.76	1.50	0.46
2. Sandy loam (non-colloidal)	.02	1.45	0.53	2.50	0.76	2.00	0.61
3. Silt loam (non-colloidal)	.02	2.00	0.61	3.00	0.91	2.00	0.61
4. Alluvial silt when noncolloidal	.02	2.00	0.61	3.50	1.07	2.00	0.61
5. Ordinary firm loam	.02	2.50	0.76	3.50	1.07	2.25	0.69
6. Volcanic ash	.02	2.50	0.76	3.50	1.07	2.00	0.61
7. Fine gravel	.02	2.50	0.76	5.00	1.52	3.75	1.14
8. Stiff clay (very colloidal)	.025	3.75	1.14	5.00	1.52	3.00	0.91
9. Graded, loam to cobbles, when non-colloidal	.03	3.75	1.14	5.00	1.52	5.00	1.52
10. Alluvial silt when** colloidal	.025	3.75	1.14	5.00	1.52	3.00	0.91

Table XV (continued)
Maximum Permissible Velocities Proposed by
Fortier and Scobey (1926)*

Original material excavated for canals	n	Mean velocity, after Aging, of Canals (d 3 ft)					
		Clear water, no detritus		Water transporting colloidal silt		Water transporting noncolloidal silts, sands, gravels or rock fragments	
		ft/sec	m/sec	ft/sec	m/sec	ft/sec	m/sec
11. Graded, silt to** cobbles, when colloidal	.03	4.00	1.22	5.50	1.68	5.00	1.52
12. Coarse gravel (non-colloidal)	.025	4.00	1.22	6.00	1.83	6.50	1.98
13. Cobbles and shingles	.035	5.00	1.52	5.50	1.68	6.50	1.98
14. Shales and hard pans	.025	6.00	1.83	6.00	1.83	5.00	1.52

* Developed in the Imperial Valley area of California.
** Cave Creek Wash soil types.

TABLE XVI
SUMMARY COMPARISON OF ALTERNATIVE CHANNELS

Reach	Length	Grass Width	Area (AC)	Earth Width	Area (AC)	Existing Channel Area (AC)
Channel: Main (minimum width channel alt)						
Bell Road to Union Hills Drive	5,850	150	20.1	200	26.9	199
Union Hills Drive to Beardsley Road	6,100	150	21.0	200	28.0	56
Beardsley Road to 7th Street	4,600	150	15.8	200	21.1	102
		TOTAL	56.9		76.0	357
Channel: Main (10-year low-flow channel alt)						
Bell Road to Union Hills Drive	5,850	170	22.8	290	39.0	199
Union Hills Drive to Beardsley Road	6,100	17.0	23.8	290	40.6	56
Beardsley Road to 7th Street	4,600	170	18.0	290	30.6	102
		TOTAL	64.6		110.2	357
Channel: Main (500 cfs low-flow channel alt)						
Bell Road to Union Hills Drive	5,850	200	26.9	325	43.6	199
Union Hills Drive to Beardsley Road	6,100	200	28.0	325	45.5	56
Beardsley Road to 7th Street	4,600	200	21.1	325	34.3	102
		TOTAL	76.0		123.4	357

Table XVI (continued)
Summary Comparison of Alternative Channels

Reach	Length	Grass Width	Area (AC)	Earth Width	Area (AC)	Existing Channel Area (AC)
Channel: East Fork (minimum width channel)						
3rd Avenue to Central Avenue	2,000	225	10.3	300	13.8	40
Central Avenue to 7th Street	3,000	225	15.5	300	20.7	117
		TOTAL	25.8		34.5	157
Channel: East Fork (10-year low-flow channel alt)						
3rd Avenue to Central Avenue	2,000	320	14.7	580	26.6	40
Central Avenue to 7th Street	3,000	320	22.0	580	39.9	117
		TOTAL	36.7		66.5	157

TABLE XVII
EARTH VS. GRASS CAPITAL AND MAINTENANCE COST SUMMARY

	Capital Costs	Maintenance Costs
Grass		
Excavation = $\frac{36.3\ cy}{L.F.} \times \frac{\$1.50}{cy}$ =	\$54.45/L.F.	\$16.40/L.F. or \$86,600/mile/yr
Sprinklers & Grass = $\frac{238\ ft^2}{L.F.} \times \frac{\$0.276}{ft^2}$ =	\$65.56/L.F.	
	\$120.01/L.F. or \$0.634 million/mi.	
Earth		
Excavation =	\$111.50/L.F.	\$4/L.F./yr or \$21,120/mi/yr
Gabion Drop Structures = $\frac{0.53\ cy}{ft} \times \frac{\$90}{cy}$ =	\$47.70*/L.F.	
Land =	\$64.85/L.F.	
	\$224.05/L.F. or \$1.183 million/mi.	

*Approximately \$252,000/structure

TABLE XVIII
OPPORTUNITIES AND CONSTRAINTS

Land Use/Visual/Rec.	Hydrology/Hydraulics	Infrastructure	Transportation	Cultural/Biological
Reach A				
Constraints				
Airport clear zone development policy--limits people intensive use. One story only. Steep slopes, erosion, poor soil, hillside ordinance. State land jurisdiction turn over to state and be left in open space. No pedestrian crossing on CAP bridge, no crossing at overflow. Gravel operations--constraints for development.	Downstream erosion, lengthen time of water flow from dam, extensive floodplain, potential erosion upstream.	Transmission line. CAP canal access.	Deer Valley airport noise. No public access.	National Register District protection of resource from vandalism.
Opportunities				
No existing land use. Warehouses in industrial area. Area has been used by motorcycle park/off-road vehicles. Visual opportunity because of landform. CAP trails, BLM ownership, pathway system, open space existing. Gravel pits opportunity for open space. Sewage plant effluent, if treated, could be a lake in gravel pit areas.	Length and availability of water from dam for vegetation.	Transmission line--potential trails along existing right-of-way.	Improved access, park visibility. Large areas uninterrupted by major roadways. Good airport access.	Cultural interpretation program--because of location (hills) and resource quality. Potential for comparison of irrigation programs, prehistoric(?) to CAP. Undisturbed biological resources in wash and surrounding area. Best opportunity for wildlife habitat--especially if water is available.

Table XVIII (continued)
Opportunities and Constraints

Land Use/Visual/Rec.	Hydrology/Hydraulics	Infrastructure	Transportation	Cultural/Biological
Reach B				
Constraints				
Gravel pit (very large) on state land. Land between channel and 7th Street is isolated. Constraint to conventional development because of topography	Major breakout from main channel--severe flooding on west side. Constraint to Master Plan--some floodplain below must be fully developed before breakout can be removed. Potential erosion if channel breaks into gravel pit. Lateral drainage constraint on development. Channel is inadequate to contain water--must be channelized for entire reach.	No major utility constraints. Above ground utility line subject to damage.	Crossing necessary at Beardsley. Main access to Village Cove.	No significant constraint.
Opportunities				
North half--strong industrial development potential. South half (west side)--residential development. Potential trail linkage to BLM land at Beardsley.	Defer channelization by realigning the channel through the gravel pit. Removing breakout leaves large area open for development.	No significant opportunity.	Potential bike path connection at Beardsley. Save bridge crossing by not extending Rose Garden Lane. 7th Street bridge has potential for trail crossing.	No significant opportunity.

Table XVIII (continued)
Opportunities and Constraints

Land Use/Visual/Rec.	Hydrology/Hydraulics	Infrastructure	Transportation	Cultural/Biological
Reach C				
Constraints				
Extractive uses present landfill potential.	Braided channel with lateral migration potential--needs channelization.	No significant constraint.	Crossing necessary at Union Hills and Beardsley.	No significant constraint.
Opportunities				
Large amount of undeveloped land adjacent to wash. Large tract of city-owned land including channel. Landfill for recreation area.	Nuisance water at Beardsley.	No significant opportunity.	No significant opportunity.	No significant opportunity.
Reach D				
Constraints				
Development proposal for entire section does not agree with qualifications of this Master Plan.	Extremely wide, shallow floodplain. Existing channel could cause serious erosion damage to adjacent area. Tied to existing channel at Bell Road because of present channel.	7th Avenue sewer line moved.	7th Avenue realigned--connection to south. Inadequate crossing at 7th Avenue. Homes at west channel edge back up to channel.	No significant constraint.

Table XVIII (continued)
Opportunities and Constraints

Land Use/Visual/Rec.	Hydrology/Hydraulics	Infrastructure	Transportation	Cultural/Biological
Reach D				
Opportunities				
Proposed neighborhood park. (Large amount of undeveloped land adjacent to the rim.)	Two points of nuisance water--one at Grovers and one at Alt.	No significant opportunity.	Trail crossing under bridge at Bell Road.	Existing vegetation.
Reach E				
Constraints				
Turf Paradise development proposed for land east of wash (prospect unlikely). Landfill adjacent to channel. Existing mobile home park adjacent to channel.	Channelized with no low-flow channel.	45" sewer line.	No significant constraint.	No significant constraint.
Opportunities				
Large areas of vacant land east of wash. Equestrian facilities associated with Turf Paradise could be developed.	Gabion lining in channelized area.	No significant opportunity.	Greenway Road--increase park visibility of Cave Creek Wash, increase development opportunities. Opportunity for east-west connection.	No significant opportunity.

Table XVIII (continued)
Opportunities and Constraints

Land Use/Visual/Rec.	Hydrology/Hydraulics	Infrastructure	Transportation	Cultural/Biological
Reach F				
Constraints				
Both sides of wash proposed for intensive development (residential). South channel boundary fixed by existing development.	Wide, shallow floodplain, undefined point of entry at 7th Street. Significant lateral drainage along channel. Unmapped flooding problem east and south of channel.	High elevation of 15" sewer crossing at 7th Street. Existing 45" sewer (constraint for channelization). 12" sewer at Central Avenue.	Greenway Road tie at 7th Street. Crossing needed at 7th Street, would require significant upstream/downstream channel work.	No significant constraint.
Opportunities				
Channel development by private developers.	Two nuisance water outlets; at 7th Street and Central Avenue.	No significant opportunity.	Roadway would provide visibility of wash. Trails under bridge.	Limited biological resource (natural) worth saving.
Reach G				
Constraints				
Much land south of channel is developed and does not relate to wash. Existing trailer park.	Existing lateral drains not functioning properly. Potential unstable channel--lateral migration possible.	27" sewer line crosses in two places, goes to 30".	Main access point to property is from Bell Road. Potential roadway improvement along Greenway Road alignment.	No significant constraint.

Table XVIII (continued)
Opportunities and Constraints

Land Use/Visual/Rec.	Hydrology/Hydraulics	Infrastructure	Transportation	Cultural/Biological
Reach G				
Opportunities				
Existing park owned by city.	No significant channel work.	No significant opportunity.	Eliminate crossing at 7th Avenue and East Fork.	Good quality vegetation, good landform.
Large area of undeveloped land on north side of channel.	Soils are reasonably stable.		Increased access to existing park.	
Expand existing usable park area to include unchannelled portion of the wash.				
Reach H				
Constraints				
Steep slope/landfill limit development potential.	Lateral drainage entering through landfills.	Methane gas collection system on adjacent abandoned landfill.	Greenway Road approved.	No significant constraint.
North side constrained by mobile home park and landfill.	Unstable channel.			
Opportunities				
Linkage to golf course/Sun Circle trails.	Nuisance water at 19th Avenue.	No significant opportunity.	Existing bridge with trail crossing possibilities.	No significant opportunity.

TABLE XIX
EVALUATION OF CHANNEL DESIGN OPTIONS BASED ON PLANNING CRITERIA

Planning Criteria	Channel Design			
	Natural Channel	Structural Channel	Shallow Channel	Deep Channel
(A) Initial Implementation Costs	Low	High	Medium-to-Low	Medium-to-Low
(B) Maintenance/Operation Costs	High	Low	Medium-to-High	Medium-to-Low
(C) Opportunity for Private Funding	Poor	Fair-to-Poor	Fair	Fair-to-Good
(D) Cost for Roadway Crossings	High	Low	Medium-to-High	Medium-to-Low
(E) Cost for Relocating Existing Utilities	Low	High	Medium-to-Low	Medium-to-High
(F) Response to Natural Resources	Good	Poor	Fair-to-Good	Fair
(G) Reduction of Potential Hydraulic Failure	Fair-to-Poor	Good	Fair	Fair-to-Good
(H) Past General Public Acceptance	Fair-to-Good	Poor	Good	Fair-to-Good
(I) Recreation Development Opportunity	Fair-to-Good	Fair-to-Poor	Fair-to-Good	Good
(J) Response to City Goals	Poor	Poor	Fair	Good

Planning Acceptance Levels
Low/Poor - Least acceptable
Medium/Fair - Acceptable
High/Good - Most acceptable

APPENDIX B
ENGINEERING DATA

Proposed Roadway Crossings
Hydraulic Design Criteria

APPENDIX B
Part I

Proposed Roadway Crossings

The roadway crossings have been set to be built at or very near existing grade, in order to reduce the expense of approaches and associated side drainage. The channels are proposed for significant downstream deeping to minimize the required culvert spans and allow use of the culverts as underpasses.

The crossings proposed are:

7th Street and East Fork	3-13'H x 15'W BOX
Union Hills and Beardsley	2-15'H x 15'W BOX
Deer Valley	2-15'H x 20'W BOX

A number of culvert options are available (box, CMP arch, bridge) which could reduce costs; in any case, the culverts will require additional hydraulic analysis at the design stage. In addition, backwater analysis of the existing and design condition will be necessary as part of the design phase for each of the crossings. Since the crossings are at or near existing grade, incomplete channelization downstream will not create adverse backwater problems. The effect would be reduced crossing capacity until channelization downstream is complete. The crossing designs follow.

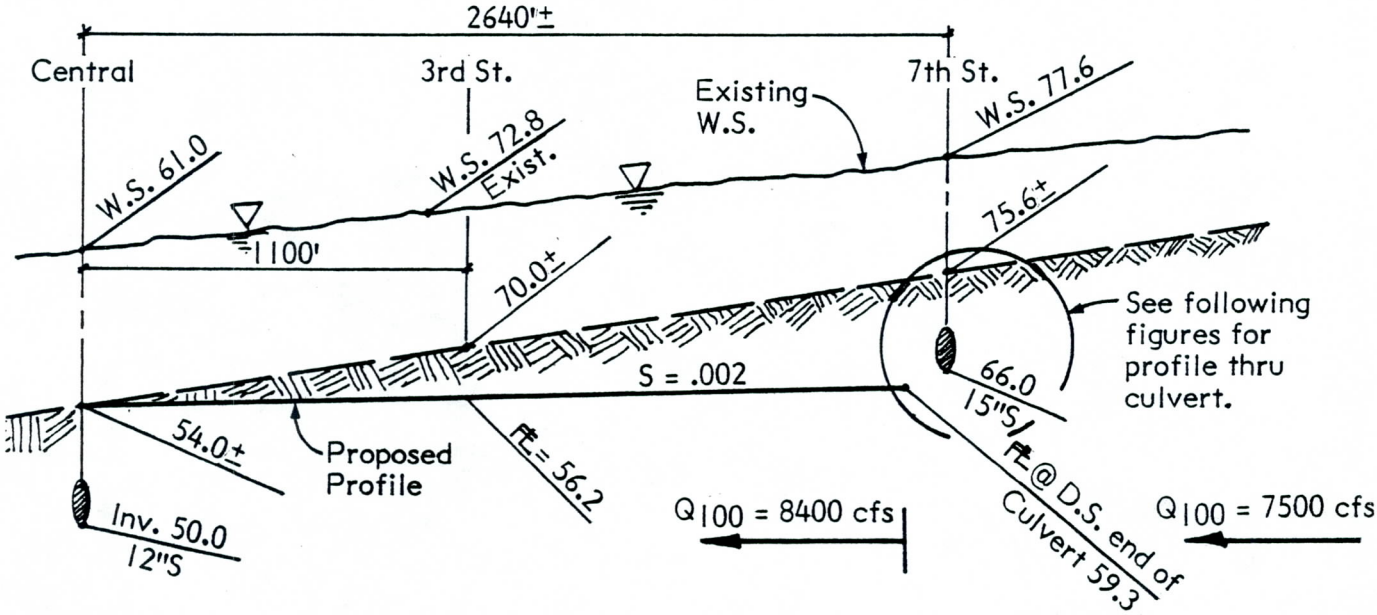
7th Street and East Fork Crossings Design

The existing crossing is now essentially at grade and is a wide sheet-flow type crossing. The objective of the design is to flatten the grade downstream and obtain an entrenched, relatively stable channel. The crossing itself will be constricted for economy and will use the lowered downstream water surface to compensate for the construction, so that the upstream water surface is at or below its existing elevation.

Design Grades and Water Surface

The existing water surface downstream at the point where the proposed channel will daylight (central) is 61.0± and the thalweg is 54.0±. The channel depth of seven feet will be used as a design criteria for normal depth in the channel downstream of 7th Street. The proposed downstream channel profile is shown as Figure B-1.

Holding the 54.0 elevation at central and using a 0.002 slope, the downstream invert is set at 60.0. This requires that two problems be solved. One is the 7th Street culvert design and adjacent channel design, and the second is the relocation problem of the 15" sewer in 7th Street. The sewer is six feet above the proposed invert of the channel crossing.



PROFILE DOWNSTREAM 7th STREET ON EAST FORK

FIGURE B-1

Sewer Relocation

The sewer will be relocated to an alignment along the top of the drop structure at the upstream side of the culvert. Existing slope of the sewer is 0.00152±. The proposed relocation is shown schematically in Figure B-2.

$S_{existing}$ = .001517

S_{new} = $\frac{0.44}{350}$ = .00126 if no drops are placed through the manholes

$S_{0min15''}$ = .0014, for 18"S S_{0min} = .0011

Discussion with Dan Raby at City of Phoenix Water and Sewer Engineering indicates that they may be able to live with a .0012 slope if scour velocities are being achieved. The alternative to the sewer relocation is realigning 7th Street to the west so that the top of the drop structure is on the alignment of the existing sewer line.

Hydraulic Design

(See Figure B-3 for profile of crossing.)

Preliminary Size by D.O.T. HEC-#13 August, 1972

18° to 33.7° and 45° wings with beveled inlet edge. Let
HW = 13' = D
HW/D = 1, and $Q/BD^{3/2}$ = 3.0

$$B_{reqd} = \frac{7500}{3(13)^{3/2}} = 53.3'$$

Compute Bridge Pier Losses by USCE Procedures:

Given: Rectangular channel section round nose piers (see Figure B-4)
Channel Discharge (Q) = 7500 cfs
Channel Width (W_c) = 49'
Total Pier Width (W_p) = 4' + 8 (for debris) = 12'
Depth Without Bridge Piers (d) = 13

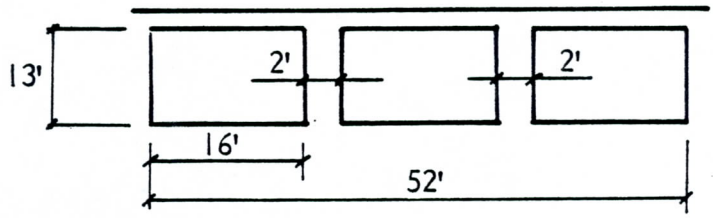
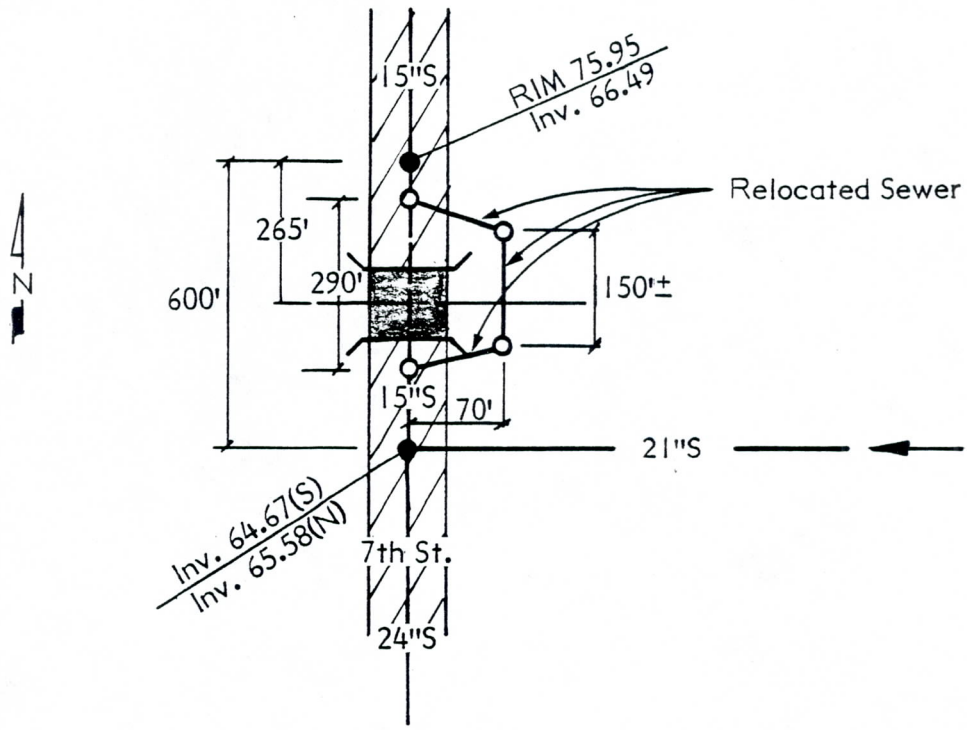
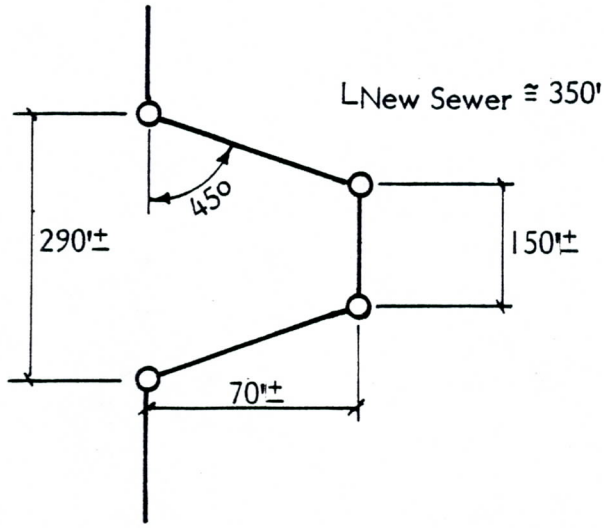


FIGURE B-4
Not to Scale

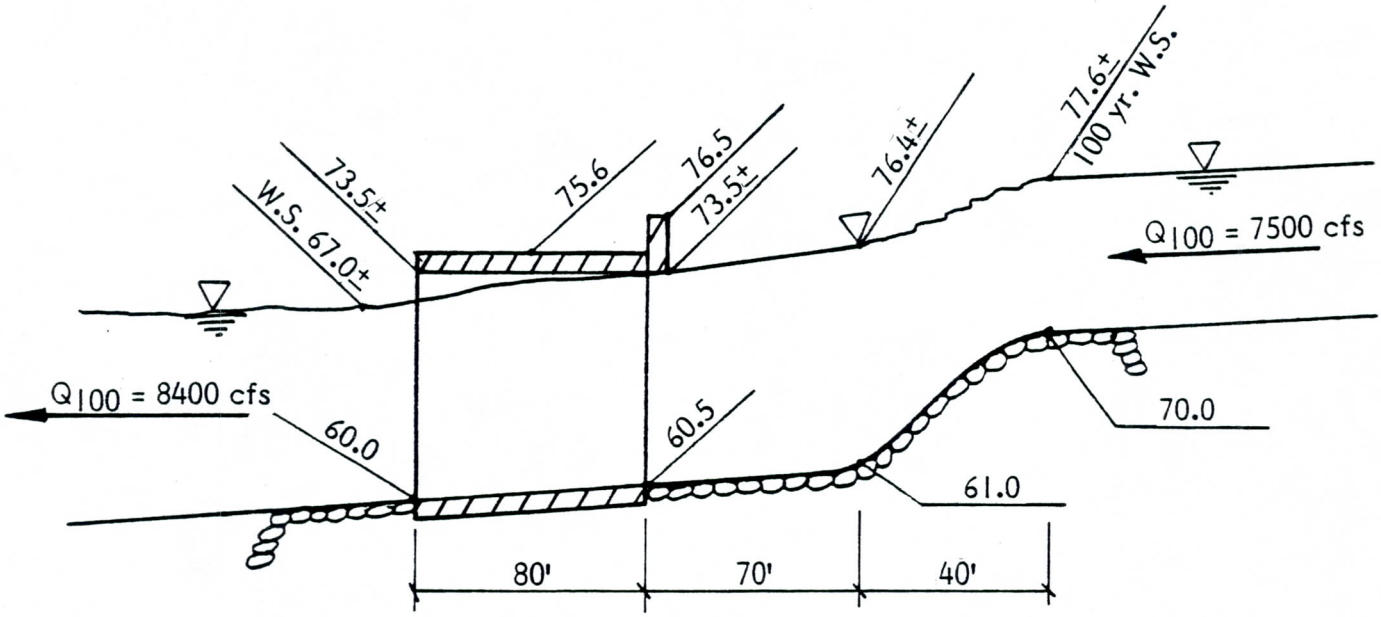


SCHEMATIC



BLOWUP OF SEWER RELOCATION

FIGURE B-2



PROFILE OF 7th STREET CROSSING

FIGURE B-3

Compute

1. Horizontal contraction ratio (α)

$$\alpha = \frac{W_p}{W_c} = 12/52 = 0.23$$

2. Discharge (q) per ft. of channel width

$$q = \frac{Q}{W_c} = \frac{7500}{52} = 144 \text{ cfs/ft}_{\text{unobstructed}}$$

3. Critical depth (d_c) in unobstructed channel from HEC #13 Chart 5 or USCE Chart 610-8.

$d_c = 8.6'$ for $q = 144$ cfs/ft

where $d_c = \sqrt[3]{q^2/g}$

4. $\lambda = d/d_c = 13/8.6 = 1.512$

5. Flow classification on Chart 010-6/1 intersection of

$\alpha = 0.23$ and $\lambda = 1.512$ is in zone classified as "B"

Note: This assumes a constriction with 8' of debris. Check both A and B flow types since classified as "A or B" with debris load halved.

6. Upstream depth (d_1)

a) Class A flow - Energy method

$d_1 = d_3 + H_3$ (Chart 010-6/2)

$H_3 = Xd_c$

$X = 0.152$ for $\alpha = 0.23$

and $\lambda_3 = \lambda = 1.512$

Note: This assumes downstream depth = 13' which is necessary if flow is in fact Class "A."

$H_3 = 0.152(9) = 1.37$

$d_1 = 13 + 1.37 = 14.37'$

b) Class B flow - Momentum method

$d_1 = \lambda_1 d_c$ (Chart 010-6/3)

$\lambda_1 = 1.77$ for $= 0.23$

$d_1 = 1.77\ (8.6) = 15.2'$

c) Class B flow - Energy method

$d_1 = \lambda_1 d_c$ (Chart 010-6/4)

$\lambda_1 = 1.70$ for $= 0.23$

$d_1 = 1.70\ (8.6) = 14.6'$

d) Compute constriction losses by assuming $0.5\ \frac{\Delta V^2}{2g}$

(as recommended by USCE engineering manual "Hydraulic Design of Flood Control Channels")

$V_{constriction} = 7500/13\ (52-12) = 14.4$ fps,

$V_{upstream} = 5$ fps

$$h_L = \left[\frac{(14.4-5)^2}{2g}\right] 0.5 = 0.68' \text{ say } 0.7'$$

Summary

Method	Dithl
Class A flow - Energy method	15.1'
Class B flow - Momentum method	15.9'
Class B flow - Energy method	15.3'

Use upstream depth = 15.9' for three bay 16'W x 13'H culvert (as a minimum size). Upstream water surface is therefore 60.5 + 15.9 $\cong$ 76.4 $<$ 77.6 the existing water surface. This will give 1.2' of head to carry water in a temporary channel upstream of 7th Street from north and south of the bridge structure coming in as sheet flow. This condition will be present until the channel is developed upstream of 7th Street (east).

Also, the headwall and grade north and south of the bridge along the roadway will be raised 0.9' to elevation 76.5 $\pm$ from 75.6 along the headwall of the bridge only. This elevation should, when the channel east of 7th Street is completed, be carried upstream by training dikes.

This crest of drop should have capacity for 7500 cfs at a depth of 77.6 - 70 = 7.6' say 7'. Crest of drop should have say 7', see Figure B-5 for profile.

The crest at the design flow will act as a broad crested wier only if

$d_3/d_1 \geqq 2/3$*

*King's Handbook of Hydraulics, 3rd edition, p. 163.

6.4/7.6 = 0.84 $>$ 2/3 therefore will <u>not</u> act as a wier.

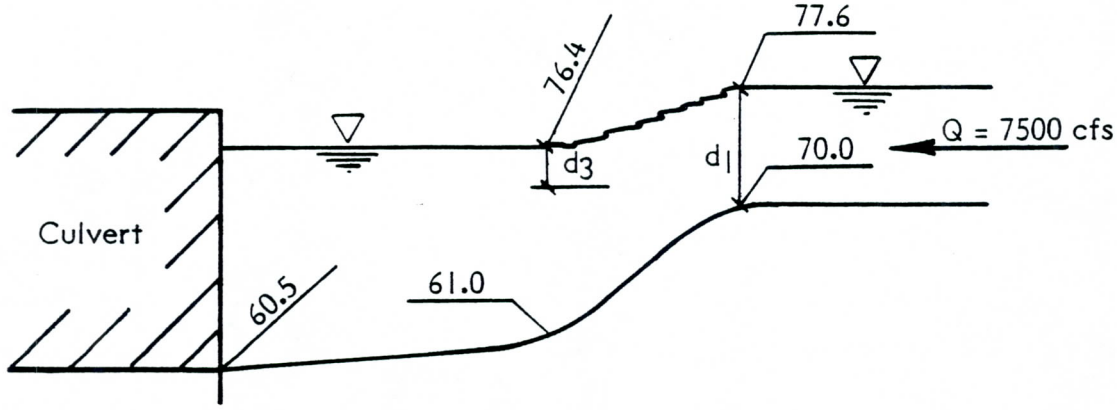
Assuming an allowable upstream velocity of 5 fps maximum and a depth of 7', then the required minimum width crest and upstream channel is approximately

A_{reqd} = 7500/5 = 1500 sq. ft., and W_{reqd} = 1500/7 $\cong$ 215'

Inlet Geometrics

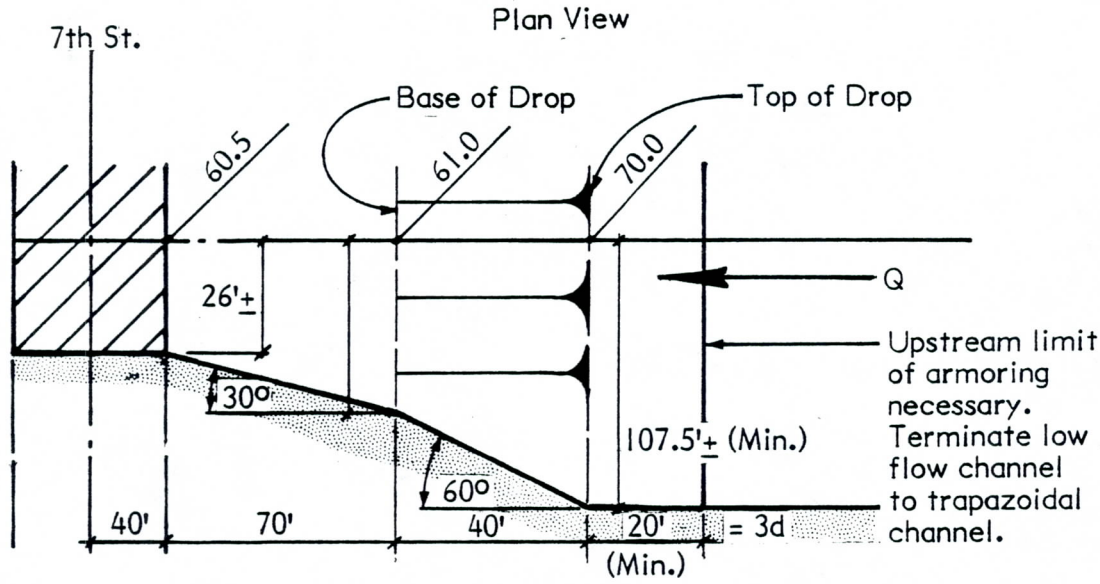
See Figure B-6 for layout of inlet.

Use a 60°/30° contraction with the base of the drop set at the transition from 60° to 30° as shown in Figure B-6.



PROFILE 7th STREET INLET

FIGURE B-5



INLET GEOMETRICS

FIGURE B-6

Outlet Geometrics

The outlet low flow channel is skewed to the south downstream and widths will depend on the low flow capacity chosen (two-year, ten-year) and whether the channel is grass-lined or earth. The 10-year low flow and earth-lined channel is used for illustrative purposes as to the relative geometrics.

The offset from the south abutment of the culvert to the south bank of the low flow channel is 225 feet using a 30° transition requires 390'±. The transition length should be set at 400 to 500 feet with the distance for armoring determined by backwater analysis of multiple flow profiles (lower flows may result in higher downstream velocities).

Temporary Side Inlet Channels

Design Flow

Until the channel upstream of 7th Street is constructed, flows entering the crossing will be as sheet flow. The Flood Insurance study ran backwater through the existing channel and that analysis gives a flow distribution for the section at 7th Street (section #2.076) and for a section approximately 700 feet upstream (section #2.206). The results of that flow distribution analysis is summarized in Table 1.

The firm's study results appear to be inconsistent from the section at 7th Street to the section 700'± upstream. Where the 7th Street section would require a design flow of 4000 cfs on the channel south of the bridge and 3500 cfs on the channel north of the bridge; the section upstream would require 1500 cfs on the south channel and 6000 cfs on the north channel.

Based on the temporary nature of the side channels and the fact that the roadway section at 7th Street is not being raised except on the bridge headwall itself, Option 3 in Table 1 to use an equal distribution of 3800 cfs from both directions seems reasonable. If the actual flow in the temporary condition is higher on the north channel, water will be free to flow over the roadway and enter the channel along the west side of 7th Street north of the bridge.

Side Channel Design

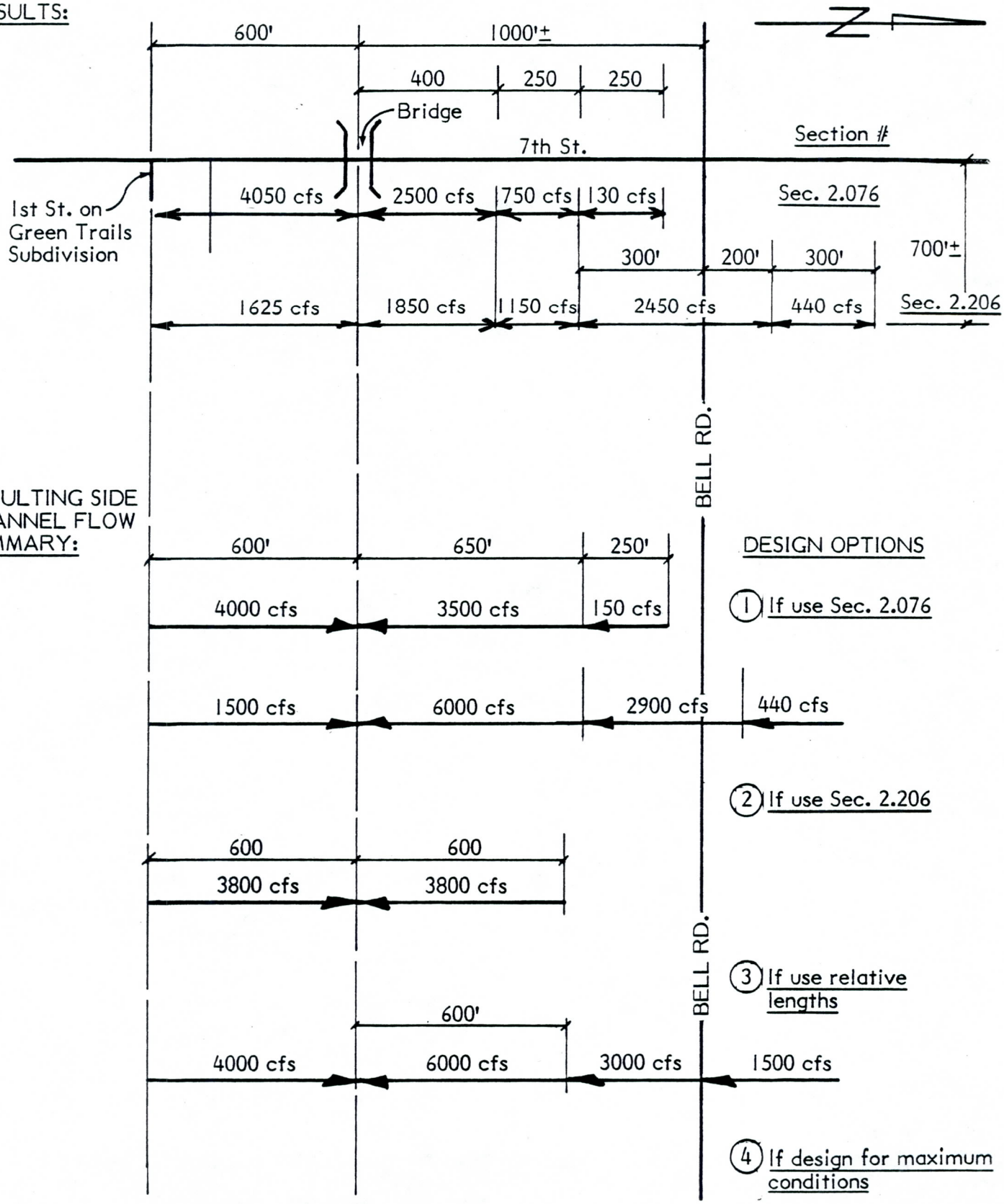
A 110-foot-wide channel will match the proposed drop structure configuration. The proposed channel profile along 7th Street is as shown in Figure B-7.

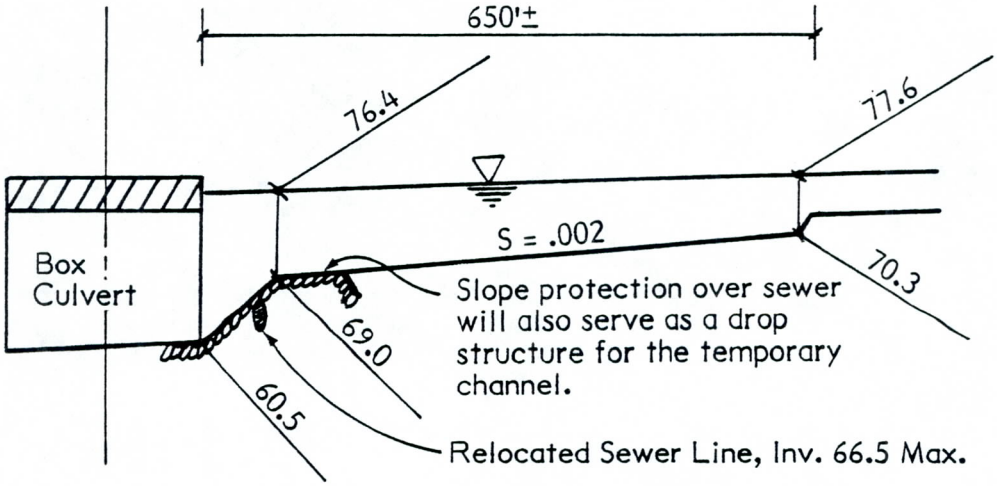
For a clean earth channel n = .03 and Q = 3938 cfs > 3800 cfs therefore OK.

TABLE I
FLOW DIST'N FOR 7500 cfs UPSTREAM OF 7TH ST. FROM FIRM BACKWATER

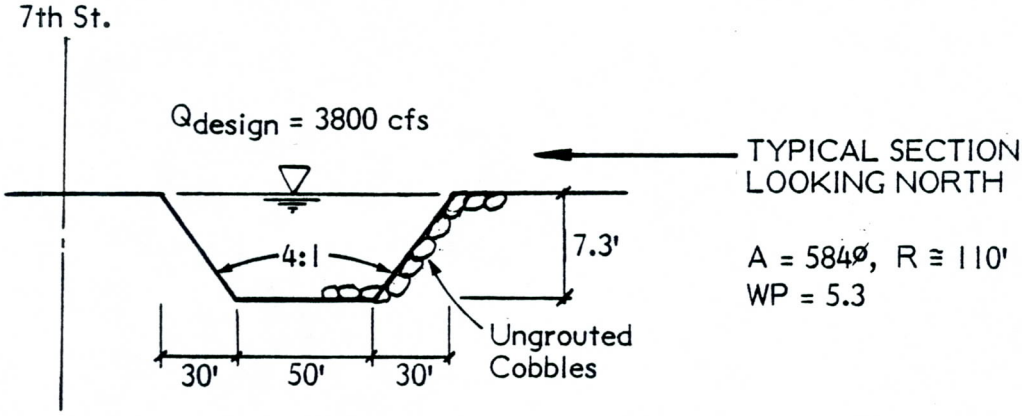
FLOW DISTRIBUTION

RESULTS:





Profile View



Cross Section View

PROFILE AND CROSSECTION OF TEMPORARY SIDE CHANNELS ON 7th STREET INLET

FIGURE B-7

Note that the upstream side will be subject to erosion without a lining and velocities in the channel are high enough (6.7 fps) to cause some erosion. Suggest using ungrouted cobbles on the upstream face of the ditch to control erosion.

This cross section and profile will be approximately symmetrical on both the north and south sides of the ditch.

Figure B-8 is a plan layout of the preceeding design information.

Union Hills and Beardsley Crossings Design

The existing crossings on Union Hills Drive and Beardsley Road are small culverts set near grade. The design objectives are similar to the 7th Street crossing. Downstream grades will be flattened to obtain an entrenched relatively stable channel. The crossings will be constricted for economy using the lowered downstream water surface and grades to compensate for the constriction.

The two crossings will be similar in hydraulic design.

Union Hills

The channel downstream of Union Hills will be realigned and daylighted at Bell Road. Between Bell Road and Union Hills Drive there is approximately 40 feet of drop. An earth-lined channel downstream will require a flatter slope (0.002) than now exists; this flattened slope requires 10 to 15 feet of fall over that same reach (Bell to Union Hills). The proposed downstream channel profile is shown in Figure B-9.

Hydraulic Design

Preliminary Size by D.O.T. HEC-#13 August 1972

18° to 33.7° and 45° wings with beveled inlet edge. Let
$HW = 15' = D$
$HW/D = 1$, and $Q/BD^{3/2} = 3.0$

(From FHA Chart October 10, 1971)
$Q_{design} = Q_{100\ yr\ future} = 5800$ cfs

$$B_{reqd} = \frac{5800}{3(15)^{3/2}} = 33'$$

Compute Bridge Pier Losses by USCE Procedures:

Given: Rectangular channel section round nose piers (see Figure B-10)
Channel Discharge (Q) - = 5800 cfs
Channel Width (W_c) = 32'
Total Pier Width (W_p) = 2' + 4 (for debris) = 6'
Depth Without Bridge Piers (d) = 15

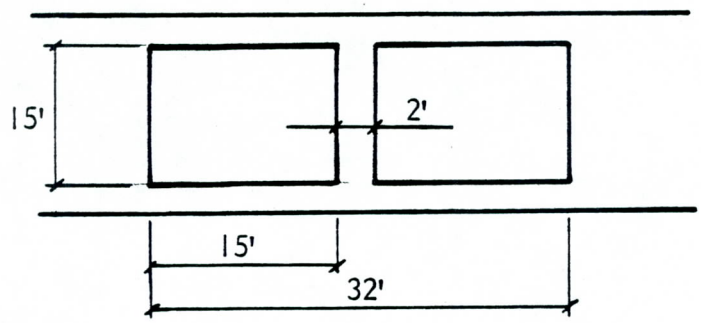


FIGURE B-10
Not to Scale

Compute

1. Horizontal contraction ratio (α)

   $\alpha = W_p/W_c = 6/32 = 0.188$

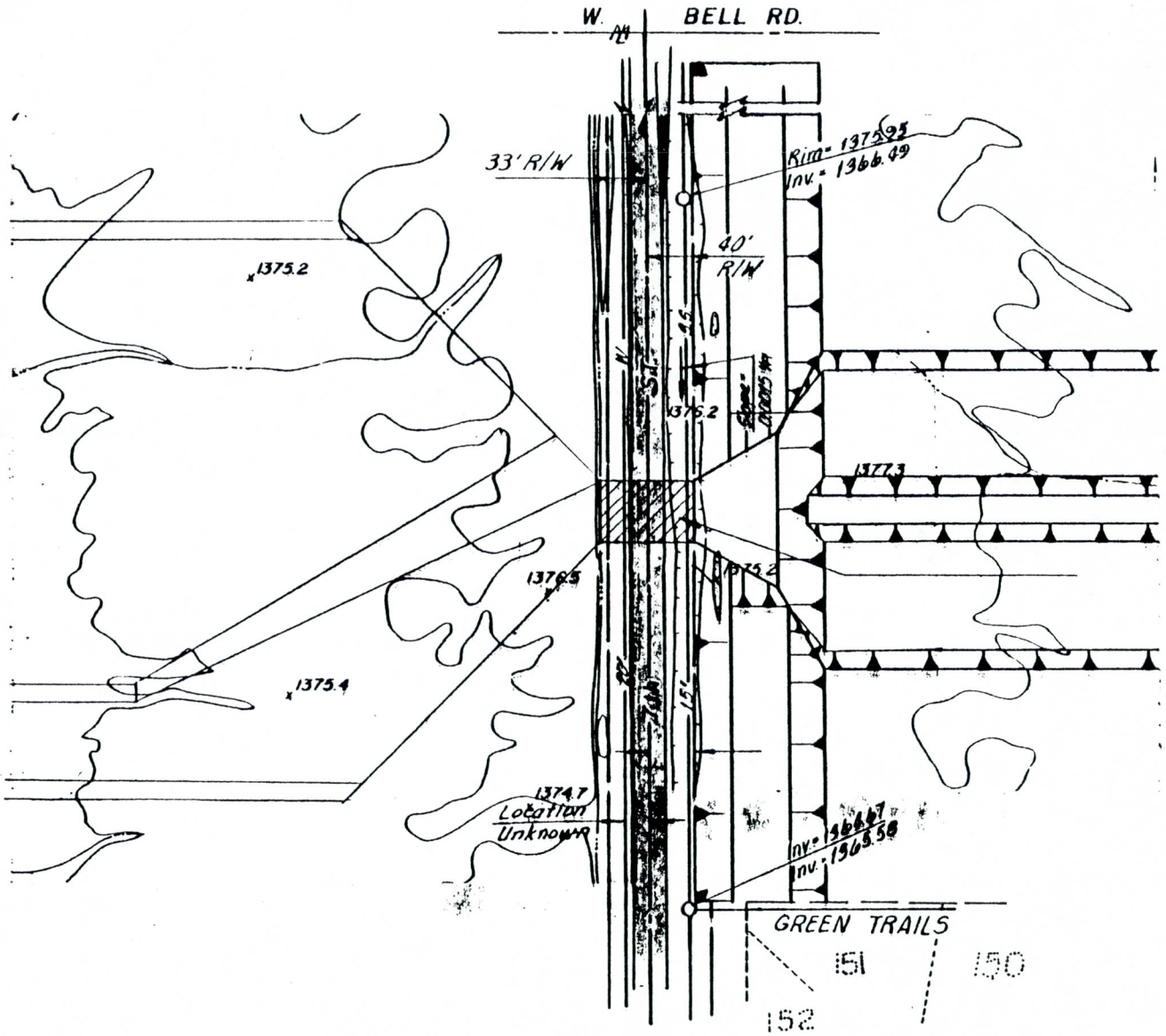
2. Discharge (q) per ft. of channel width

   $q = Q/W_c = 5800/32 = 181$ cfs/ft$_{unobstructed}$

3. Critical depth (d_c) in unobstructed channel from HEC#13 Chart 5 or USCE Chart 610-8

   $d_c \cong 10.1$ for $q = 181$ cfs/ft

   where $d_c = \sqrt[3]{q^2/g}$



N

0' 100' 200'

EAST FORK - 7th ST. CROSSING

SCALE	JOB NO	DATE	

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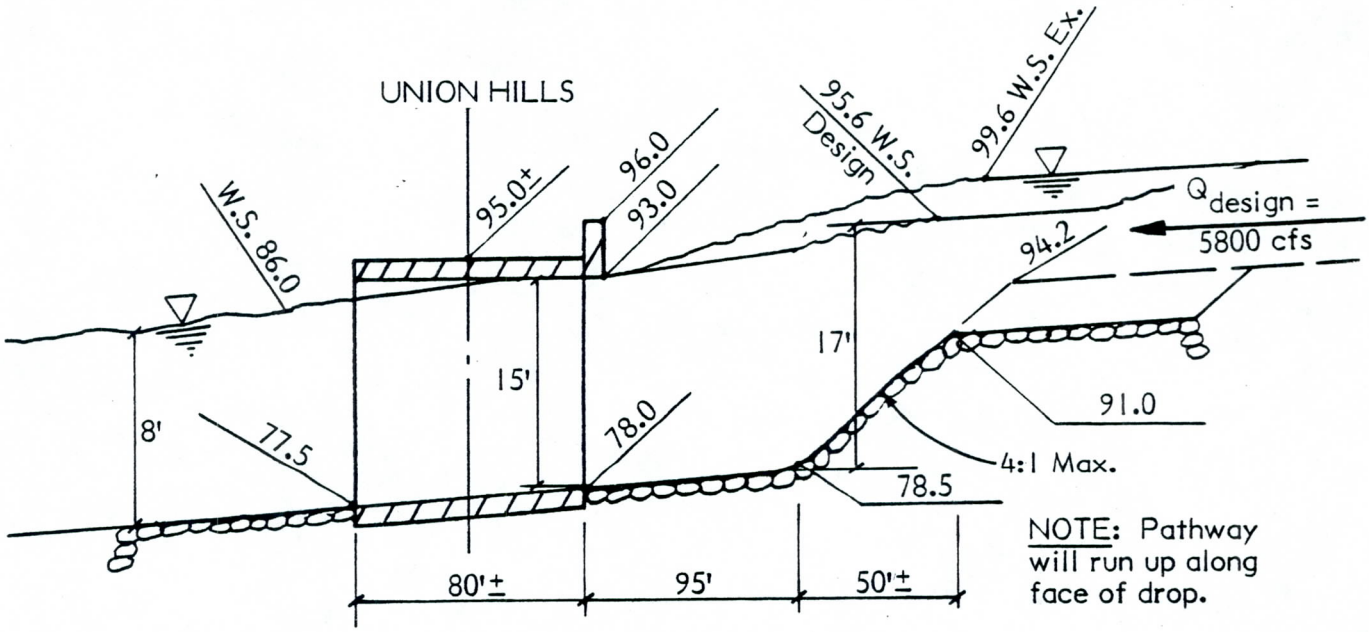
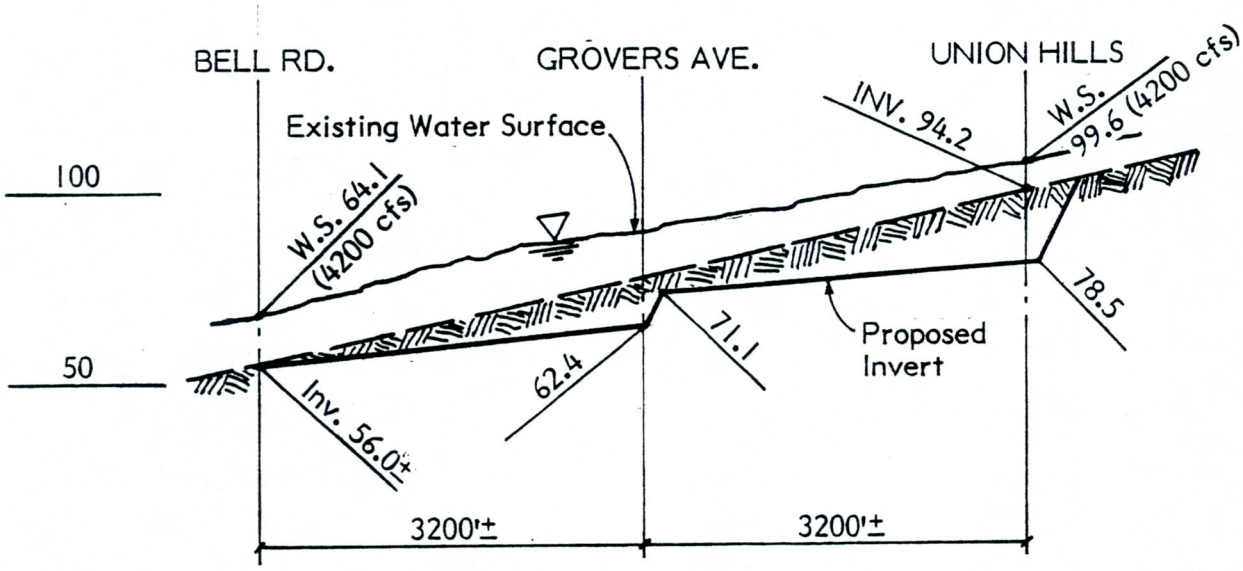
FIGURE B-8



PROFILE OF CROSSING



CHANNEL PROFILE

FIGURE B-9

4. $\lambda = d/d_c = 15/10.1 = 1.485$

5. Flow classification on Chart 010-6/1 intersection of

$\alpha = 0.188$ and $\lambda = 1.485$ is in zone classified as "A" or "B"

Note: This assumes a downstream channel depth of 15 feet. With 8 foot downstream depth, flow may go to Class "B" therefore check both.

6. Upstream depth (d_1)

a) Class A flow - Energy method

$d_1 = d_3 + H_3$ (Chart 010-6/2)

and $H_3 = Xd_c$

$X = 0.146$ for $\alpha = 0.188$ and

$\lambda_3 = \lambda = 1.485$

Note: This assumes the downstream depth is 15 feet which would have to be the case if the flow is Class "A."

$H_3 = 0.146\ (10.1) \cong 1.47$

$d_1 = 15 + 1.47 = 16.47$ say 16.5'

b) If Class "B" flow - Momentum method

$d_1 = \lambda_1 d_c$ (Chart 010-6/3)

$\lambda_1 = 1.66$ for $\alpha = 0.188$

$d_1 = 1.66\ (10.1) = 16.8'$

c) If Class "B" flow - Energy method

$d_1 = \lambda_1 d_c$ (Chart 010-6/4)

$\lambda_1 = 1.63$ for $\alpha = 0.188$

$d_1 = 1.63\ (10.1) = 16.46$ say 16.5'

d) Compute constriction losses by assuming $h = 0.5\ V^2/2g$.

(as recommended by USCE engineering manual "Hydraulic Design of Flood Control Channels")

$V_{constriction} = 5800/15\ (32-6) = 14.9$ fps,

$V_{upstream} \cong 5$ fps

$h_L = 0.5\ (14.9-5)^2/2g = 0.76$ say 0.8

Summary

Method	Dithl
Class A flow - Energy method	17.3'
Class B flow - Momentum method	17.6'
Class B flow - Energy method	17.3'

Use upstream depth = 17.6' for a two bay 15 x 15 culvert. Upstream water surface is therefore 78.0 + 17.6 $\cong$ 95.6 $<$ 99.6, the existing water surface elevation for the current 100-year flow rate of 4200 cfs and $<$ 96.0 the proposed headwall elevation. Drainage along the roadway will be picked up at elevation 96.0 on the approaches to the culvert.

Crest of drop should have capacity for 5800 cfs at a depth of 99.6 - 91.0 = 8.6, say 8 feet.

Assume acts as a submerged broadcrested wier, $Q = CLH^{3/2}$ where C = 3.0

$L_{reqd} = 5800/3(g)^{3/2} \cong 85'$ (minimum)

See Figure B-11.

Will act as a weir if $d_3/d_1 \geq 2/3$*

*King's "Handbook of Hydraulics," 3rd edition, p. 163.

$$d_3/d_1 = (95.6-91)/(99.6-91) =$$

$$= 4.6/8.6 = 0.53 < 0.67$$

Therefore will act as a broadcrested weir.

Actual crest length will equal width of channel = 300 feet.

Figure B-12 is a plan layout of the preceding design information.

Beardsley

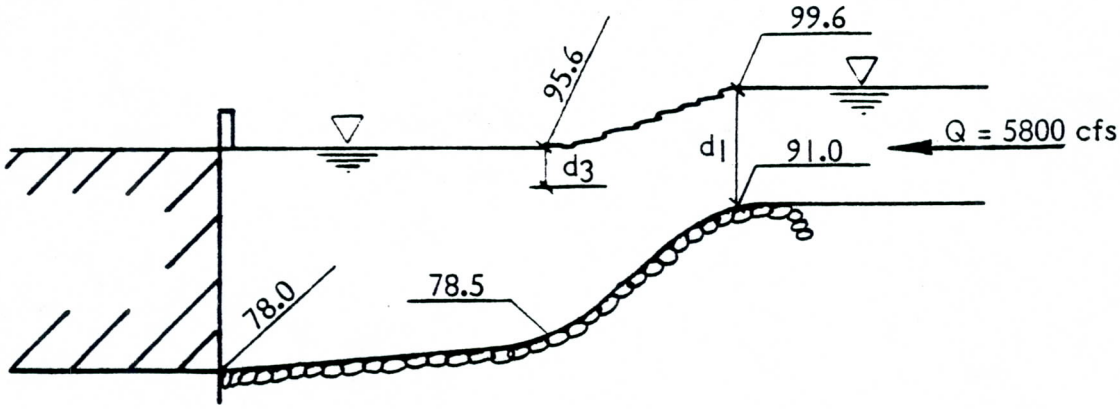
The channel downstream of Beardsley Road will basically follow the existing alignment with excavation of the invert and possible realignment through gravel mining areas. There is approximately 35 feet of drop between Union Hills Drive and Beardsley Road and 10 to 15 feet is needed to maintain a relative stable flattened channel (slope will be set at approximately 0.002). The proposed downstream channel profile is shown in Figure B-13.

Hydraulic Design

The hydraulics are the same as for the Union Hills crossing and the upstream water depth is 17.6 feet for a two bay 15 x 15 culvert. The upstream water surface for the design flow of 5800 cfs is therefore $13.5 + 17.6 \cong 31.1 < 32.1$ (the existing water surface elevation at the current flow rate of 4200 cfs). The crest of the drop will be designed to have an eight foot depth for future channelization upstream.

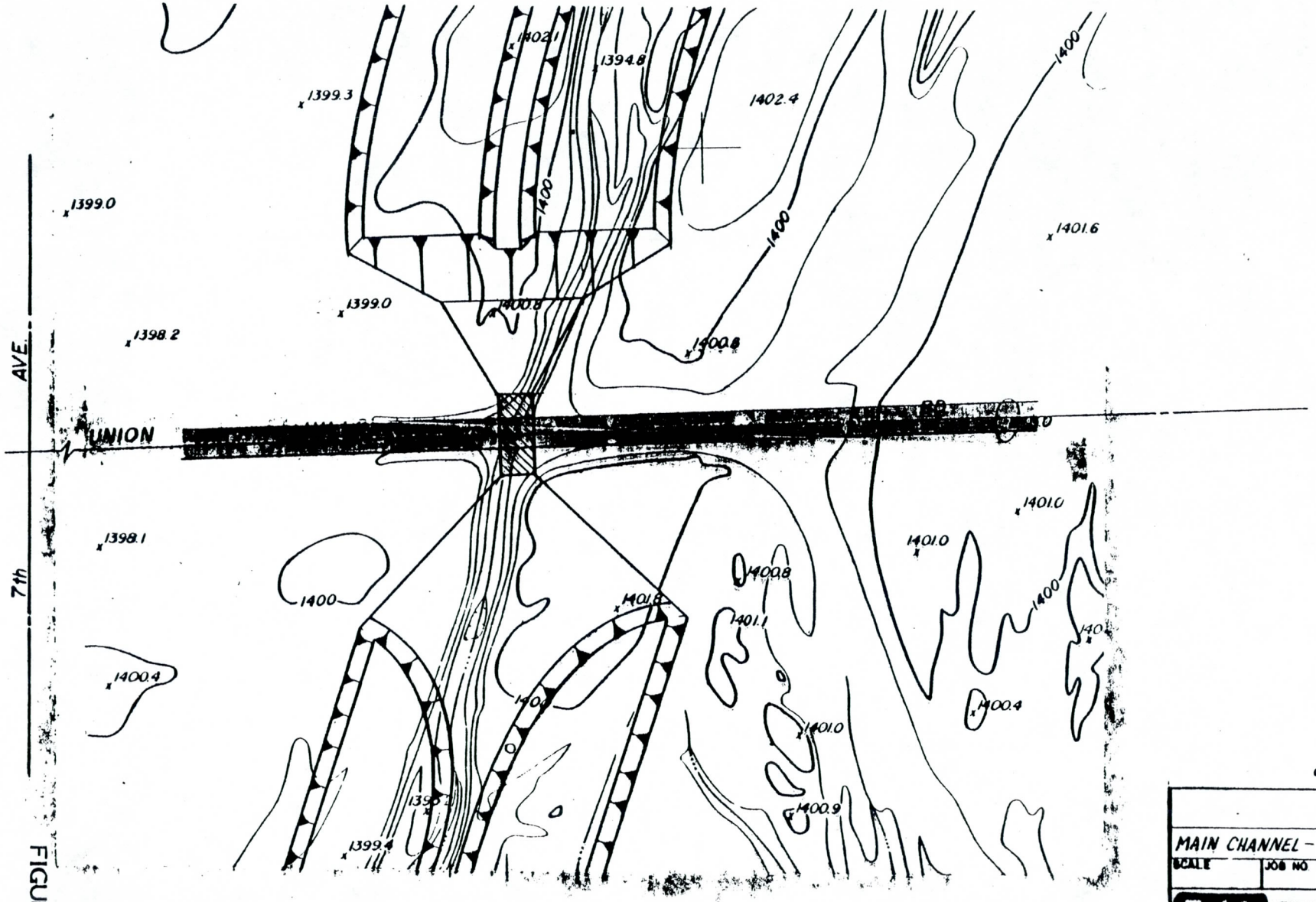
The crest width will match the channel width of approximately 300 feet. Side drainage from the street will be picked up at elevation $31.1 \pm$. See Figure B-14 for inlet profile.

Figure B-15 is a plan layout of the preceding design information.



PROFILE OF UNION HILLS INLET

FIGURE B-11



MAIN CHANNEL – UNION HILLS CROSSING

SCALE	JOB NO	DATE	

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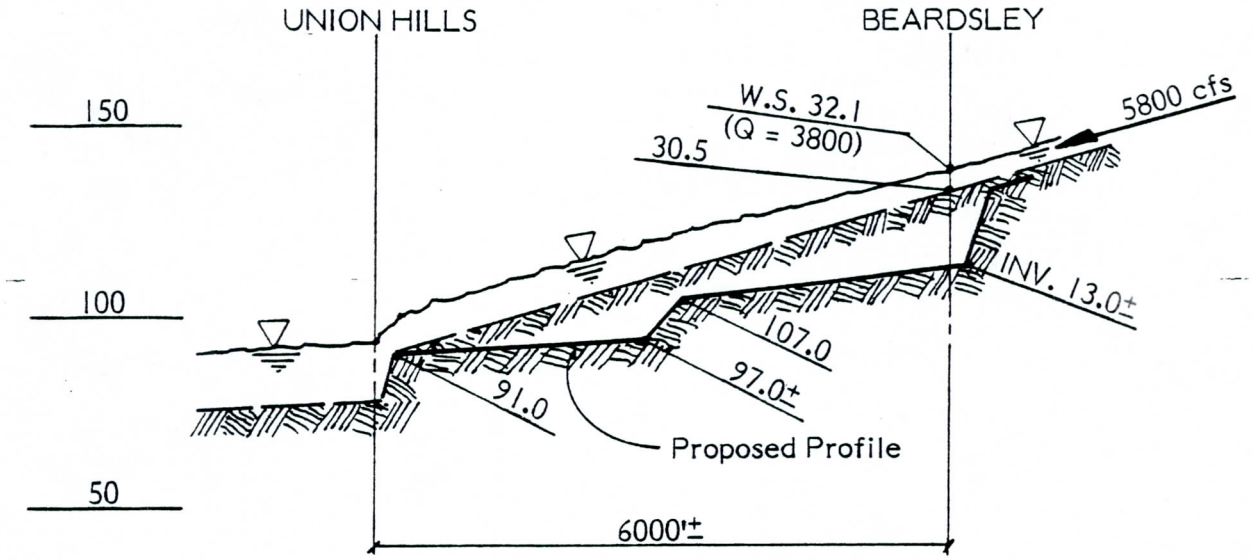
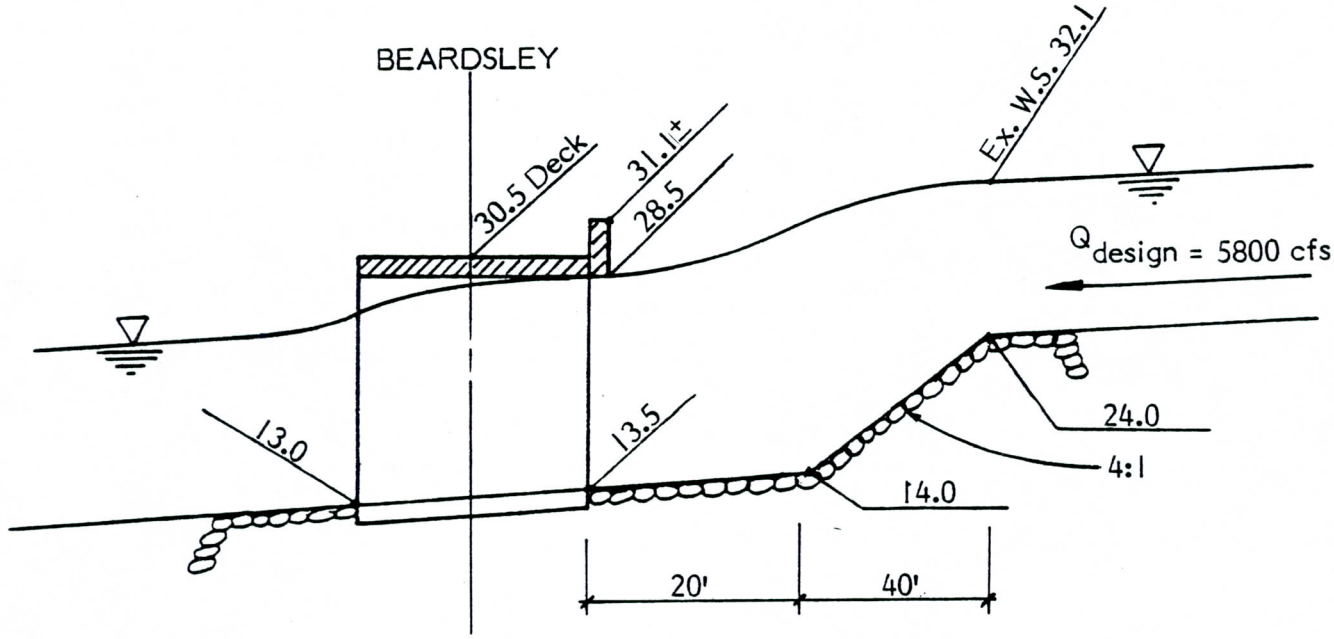
FIGURE B-12

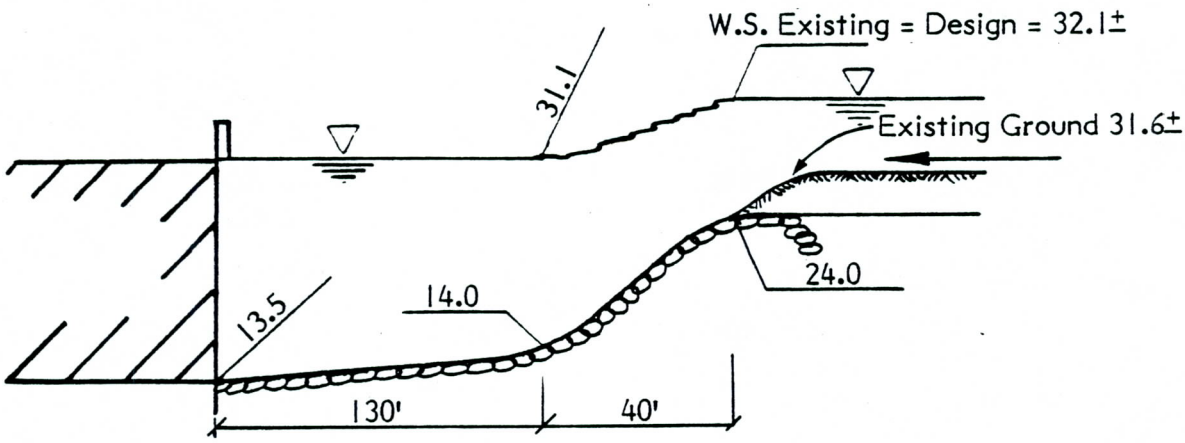


CHANNEL PROFILE



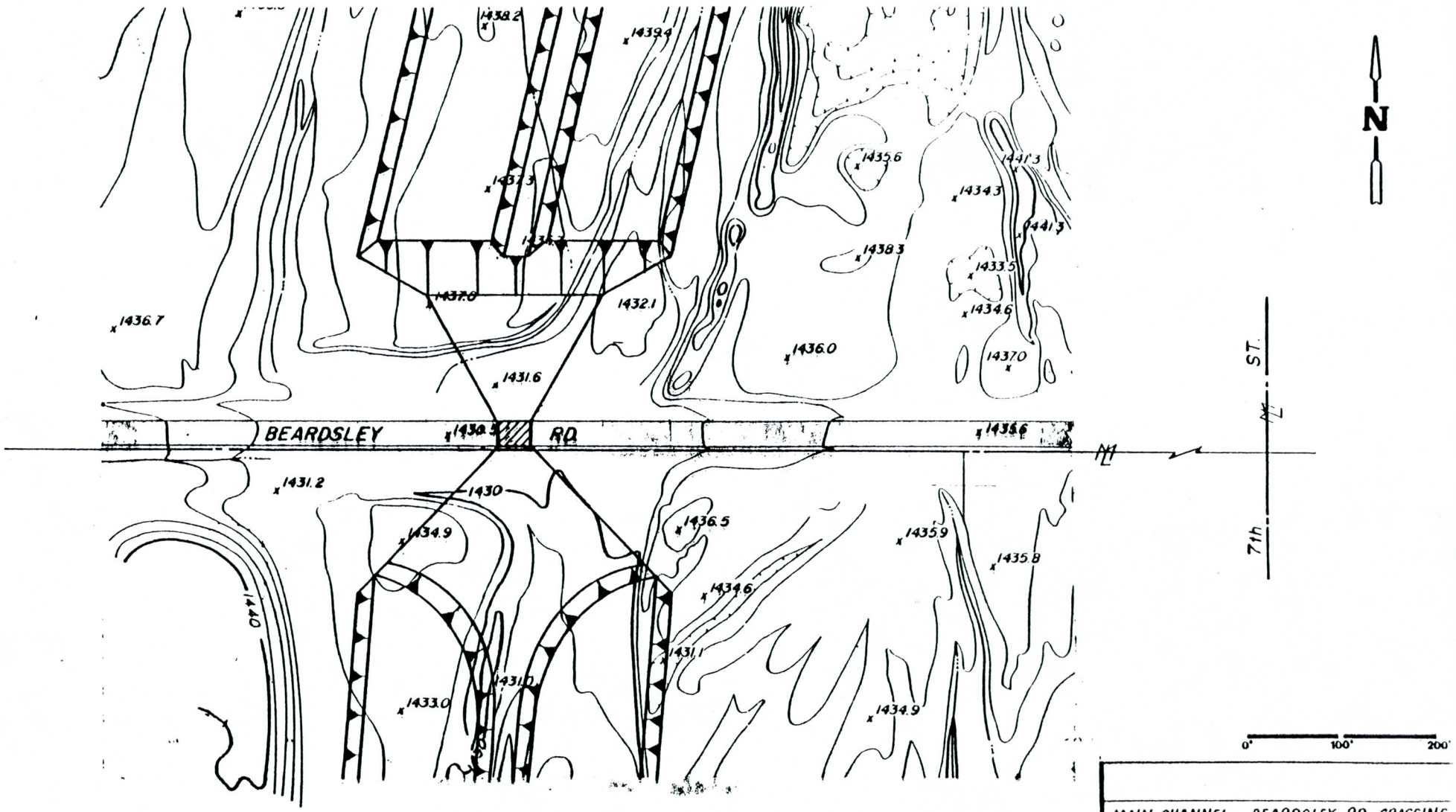
PROFILE OF CROSSING

FIGURE B-13



PROFILE OF BEARDSLEY INLET

FIGURE B-14



MAIN CHANNEL - BEARDSLEY RD. CROSSING

SCALE	JOB NO.	DATE	

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FIGURE B-15

Deer Valley Crossing Design

The Deer Valley Road alignment will be at or very near its present alignment. The design objective, as with other crossings, will be to flatten downstream grades to obtain an entrenched, relatively stable channel and allow a constricted culvert crossing for economy. The downstream control for the crossing is taken as the existing invert on 7th Street where a bridge presently exists.

An earth-lined channel downstream set at a 0.002 slope for stability will result in an invert at Deer Valley suitable for obtaining a constricted channel. The deck height on the culvert could be set relatively high for a pedestrian and equestrian crossing without blocking side drainage. The proposed downstream channel profile is shown as Figure B-16.

Hydraulic Design

Preliminary Size by D.O.T. HEC-#13 August 1972

18° to 33° and 45° wings with beveled inlet edge.

Let $HW = D_{allow} = 159.5 - 74 = 14.5$ say 14'

$HW/D = 1$ and $Q/BD^{3/2} = 3.0$

(from FHA Chart 10, October, 1971)
$Q_{design} = Q_{100} = 5000$ cfs

$$B_{reqd} = \frac{5000}{3(14)^{3/2}} = 32'$$

Compute Bridge Pier Losses by USCE Procedures:

Given: Rectangular channel section round nose piers (see Figure B-17 for cross section)
Channel Discharge (Q) = 5000 cfs
Channel Width (W_c) = 42'
Total Pier Width (W_p) = 2' + 4 (for debris) = 6'
Allowable Depth without bridge piers (d) = 14'
(74 - 59.5 = 14.5 say 14)

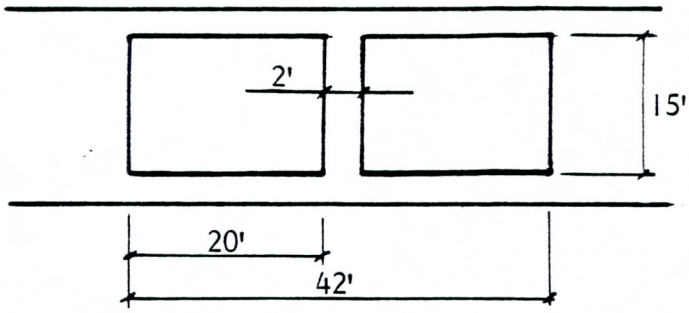


FIGURE B-17
Not to Scale

Compute

1. Horizontal contraction ratio (α)

   $\alpha = W_p/W_c = 6/42 = 0.143$

2. Discharge (q) per ft. of channel width

   $q = Q/W_c = 5000/42 = 119$

3. Critical depth (d_c) in unobstructed channel from HEC #13 Chart 5 or USCE Chart 610-8.

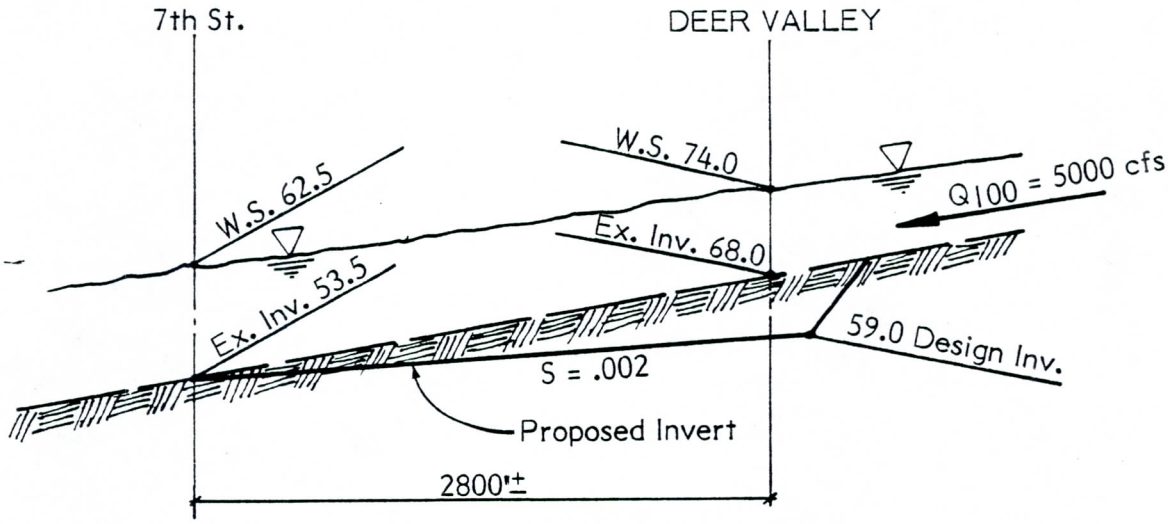
   $d_c = 7.6'$ for $q = 147$

   where $d_c = \sqrt[3]{q^2/2g}$

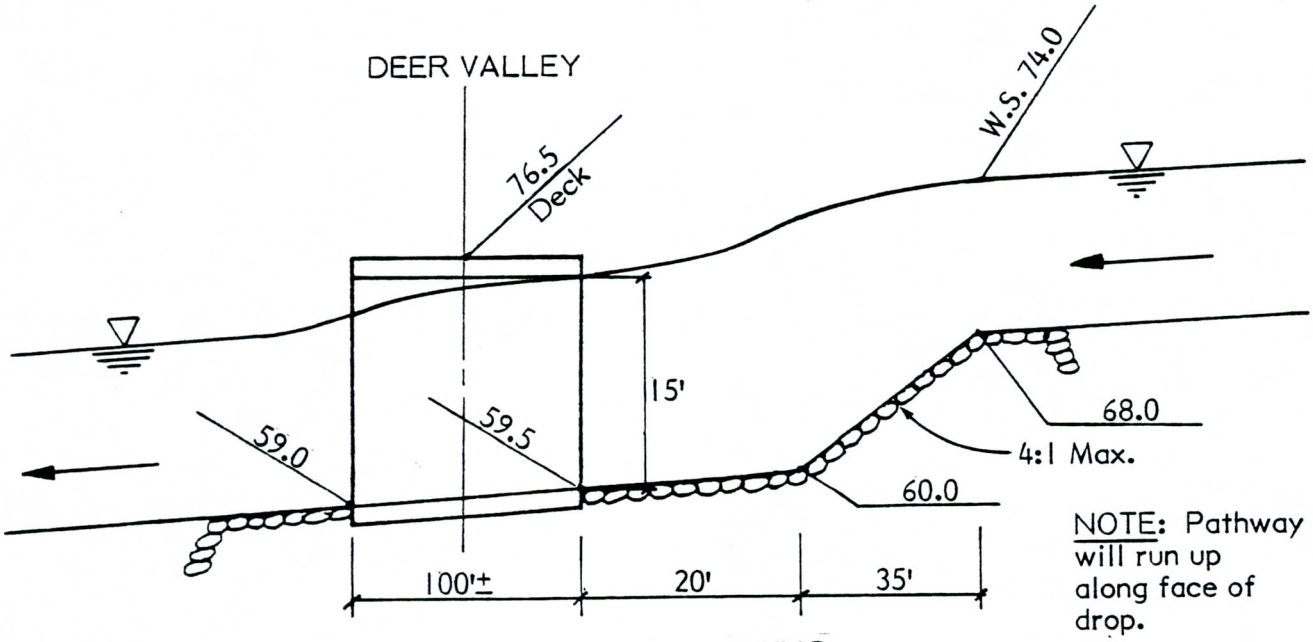
4. $\lambda = d/d_c = 14/7.6 = 1.84$

5. Flow classification on Chart 010-6/1 intersection of

   $\alpha = 0.143$ and $\lambda = 1.84$ is in zone classified as "A"



CHANNEL PROFILE



PROFILE OF CROSSING

FIGURE B-16

Note: This assumes a downstream channel depth of 14 feet with a lower downstream depth flow, may go to Class "B", therefore check both.

6. Upstream depth (d_1)

a) Class A flow - Energy method

$d_1 = d_3 + H_3$ (Chart 010-6/2)

and $H_3 = Xd_c$

for $\alpha = 0.143$ and $\lambda = \lambda_3 = 1.84$

$X = 0.044$

$H_3 = 0.044\ (7.6) = 0.334$

$d_1 = 14 + 0.334 = 14.33$

b) Class B flow - Momentum method

$d_1 = \lambda_1 d_c$ (Chart 010-6/3)

for $\alpha = 0.143$ and $\lambda_1 = 1.56$

and $d_1 = 1.56\ (7.6) = 11.9$

c) Class B flow - Energy method

$d_1 = \lambda_1 d_c$ (Chart 010-6/4)

for $\alpha = 0.143$ and $\lambda_1 = 1.54$

$d_1 = 1.54\ (7.6) = 11.7'$

d) Compute constriction losses by assuming $h = 0.5\ V^2/2g$

(as recommended by USCE engineering manual "Hydraulic Design of Flood Control Channels")

$V_{constriction} = 5000/14(42-6) = 9.9$ fps

$V_{upstream} = 5$ fps

$$h_c = 0.5(9.-5)/2g = 0.08$$

Summary

Method	Dithl
Class A flow - Energy method	14.4'
Class B flow - Momentum method	12.1'
Class B flow - Energy method	11.9'

Use upstream depth = 14.4 for a two bay 15'H x 20'W culvert. Upstream water surface is therefore 59.5 + 14.4 = 73.9 less than 74.0 the existing water surface elevation from the firm study.

The upstream crest should be set to match existing contours unless some additional channelization is desired upstream.

See Figure B-18 for plan layout of preceding design information.

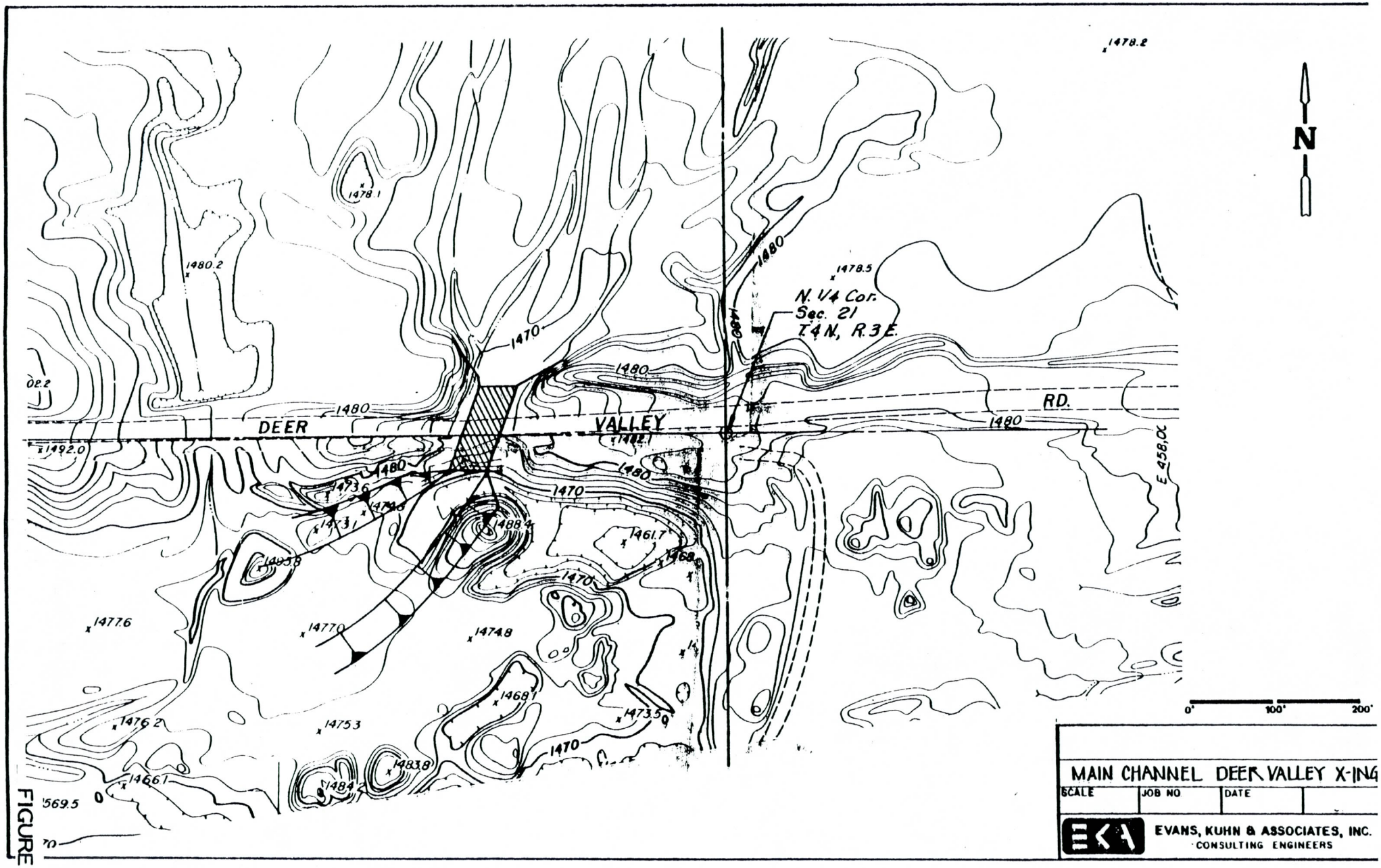

N
DEER VALLEY RD.
N. 1/4 Cor.
Sec. 21
T4N, R3E.
E 458,000
1478.2
1478.1
1480.2
1478.5
1480
1470
1492.0
1482.1
1473.6
1473.1
1488.4
1461.7
1468
1477.6
1477.0
1474.8
1468.1
1473.5
1476.2
1475.3
1483.8
1466.1
1484.2
0'
100'
200'
MAIN CHANNEL DEER VALLEY X-ING
SCALE
JOB NO.
DATE
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FIGURE B-18

APPENDIX B
Part 2
(Copies of Appendix A, Part I References)

HYDRAULIC DESIGN CRITERIA

SHEETS 010-6 TO 010-6/5

OPEN CHANNEL FLOW

BRIDGE PIER LOSSES

Background

1. Methods for computing head losses at bridge piers have been developed by D'Aubuisson, Nagler, Yarnell, Koch and Carstanjen, and others. Each method is based on experimental data for limited flow conditions. Complete agreement between methods is not always obtained. The energy method of Yarnell(4) and the momentum method of Koch and Carstanjen(1) have been widely used in the United States.

Equations for Classes of Flow

2. Three classes of flow conditions, A, B, and C, are encountered in the bridge pier problem. Hydraulic Design Chart 010-6 illustrates the flow condition upstream from, within, and downstream from the bridge section for each class of flow. The energy method of Yarnell is generally used for the solution of Class A flow problems, and is also used for solution of Class B flow. However, the momentum method of Koch and Carstanjen is believed more applicable to Class B flow, and is also applicable for solution of Class C flow.

3. Energy Method, Class A Flow. The Yarnell equation for Class A flow is

$$H_3 = 2K(K + 10\omega - 0.6)(\alpha + 15\alpha^4)\frac{V_3^2}{2g}$$

where

H_3 = drop in water surface, in ft, from upstream to downstream at the contraction

K = experimental pier shape coefficient

ω = ratio of velocity head to depth downstream from the contraction

α = horizontal contraction ratio

V_3 = velocity downstream from the contraction in ft per sec

g = acceleration, gravitational, in ft per sec^2

The values of K determined by Yarnell for different pier shapes are

Pier Shape	K
Semicircular nose and tail	0.90
Twin-cylinder piers with connecting diaphragm	0.95
Twin-cylinder piers without diaphragm	1.05
90 deg triangular nose and tail	1.05
Square nose and tail	1.25

4. Energy Method, Class B Flow. The Yarnell equations for Class B flow are

$$L_B = C_B \frac{V_1^2}{2g}$$

and

$$C_B = 0.50 + K_B(5.5\alpha^3 + 0.08)$$

where

L_B = pier nose loss in ft

C_B = pier nose loss coefficient

V_1 = velocity upstream from the contraction in ft per sec

K_B = experimental pier shape coefficient

The values of K_B determined by Yarnell for different pier shapes are

Pier Shape	K_B
Square nose piers	5
Round nose piers	1

The following equation permits solution of the Yarnell equation for Class B flow by successive approximation

$$d_1 = d_L + L_B$$

where

d_1 = upstream water depth in ft

d_L = the higher depth, in ft, in the unobstructed channel which has flow of equal energy to that required for critical flow within the constricted bridge section

5. Momentum Method, Class B Flow. Koch and Carstanjen applied the momentum principle to flow past bridge piers and verified their results by laboratory investigations. The total upstream momentum minus the momentum loss at the entrance equals the total momentum within the pier section. This momentum quantity is also equal to the total momentum downstream minus the static pressure on the downstream obstructed area. The general momentum equation is

$$m_1 - m_p + \frac{\gamma Q^2}{gA_1^2}(A_1 - A_p) = m_2 + \frac{\gamma Q^2}{gA_2} = m_3 - m_p + \frac{\gamma Q^2}{gA_3}$$

where

Q = discharge in cfs

m_1, m_2, m_3, m_p = total static pressure of water in the upstream section, pier section, downstream section, and on the pier ends, respectively, in lb

A_1, A_p, A_2, A_3 = cross-sectional area of the upstream channel, pier obstruction, channel within the pier section, and downstream channel, respectively, in sq ft

γ = specific weight of water, 62.5 lb/cu ft

6. Graphical Solutions. The U. S. Army Engineer District, Los Angeles(3), modified Yarnell's charts for solution of Class A and Class B flow, and developed a graphical solution for Class B flow by the momentum method. The U. S. Army Engineer District, Chicago (2), simplified the Los Angeles District's graphical solution for Class B flow by the energy method. Hydraulic Design Charts 010-6/2 and 010-6/3, respectively, present the Los Angeles District solutions for Class A flow by the energy method and Class B flow by the momentum method. Chart 010-6/4 presents the Chicago District's solution for Class B flow by the energy method.

Application

7. Classification of Flow. Flow classification can be determined from Chart 010-6/1. The intersection of the computed value of λ (the ratio of the channel depth without piers to the critical depth) and α (the horizontal contraction ratio) determines the flow classification.

8. Class A Flow. Chart 010-6/2 presents a graphical solution of Class A flow for five types of bridge piers. Enter the chart horizontally with a known λ_3 to a known α. Determine the value of X. The head loss through the pier section (H_3) is obtained by multiplying the critical depth in the unobstructed channel by X for round nose piers or by γX for the other pier shapes shown on the chart.

9. Class B Flow. Bridge pier losses by the momentum method can be determined from Chart 010-6/3. For a known value of α, the required ratio of d_1/d_c can be obtained and the upstream depth computed. Chart 010-6/4 permits solution of Class B flow for round and square nose piers by the energy method. This chart is used in the same manner as Chart 010-6/3.

10. Class C Flow. Class C flow is seldom encountered in practical problems. A graphical solution has not been developed, and

analytical solution by the momentum method is necessary.

11. Sample Computation. Chart 010-6/5 is a sample computation illustrating the use of the charts. A borderline flow condition between Class A and Class B is assumed. This permits three solutions to the problem. The most conservative solution is recommended for design purposes.

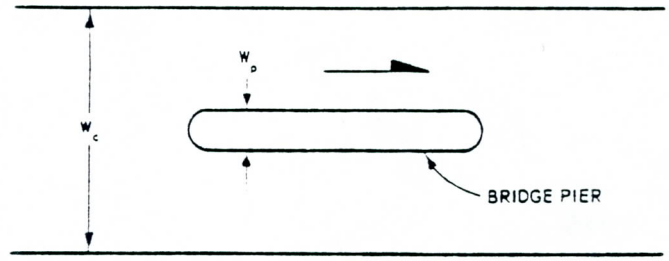
12. References.

(1) Koch, A., Von der Bewegung des Wassers und den dabei auftretenden Kräften, M. Carstanjen, ed. Julius Springer, Berlin, 1926.

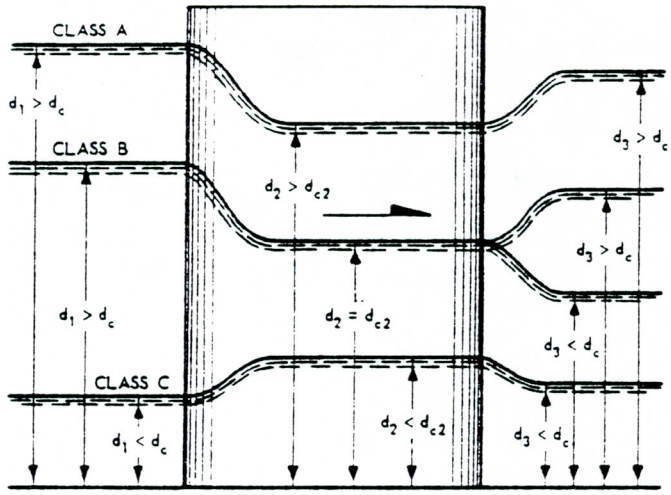
(2) U. S. Army Engineer District, Chicago, CE, letter to U. S. Army Engineer Division, Great Lakes, CE, dated 22 April 1954, subject, "Analysis of Flows in Channels Constricted by Bridge Piers."

(3) U. S. Army Engineer District, Los Angeles, CE, Report on Engineering Aspects, Flood of March 1938, Appendix I, Theoretical and Observed Bridge Pier Losses. Los Angeles, Calif., May 1939.

(4) Yarnell, David L., Bridge Piers as Channel Obstructions. U. S. Department of Agriculture Technical Bulletin No. 442, Washington, D. C., November 1934.



PLAN



ELEVATION

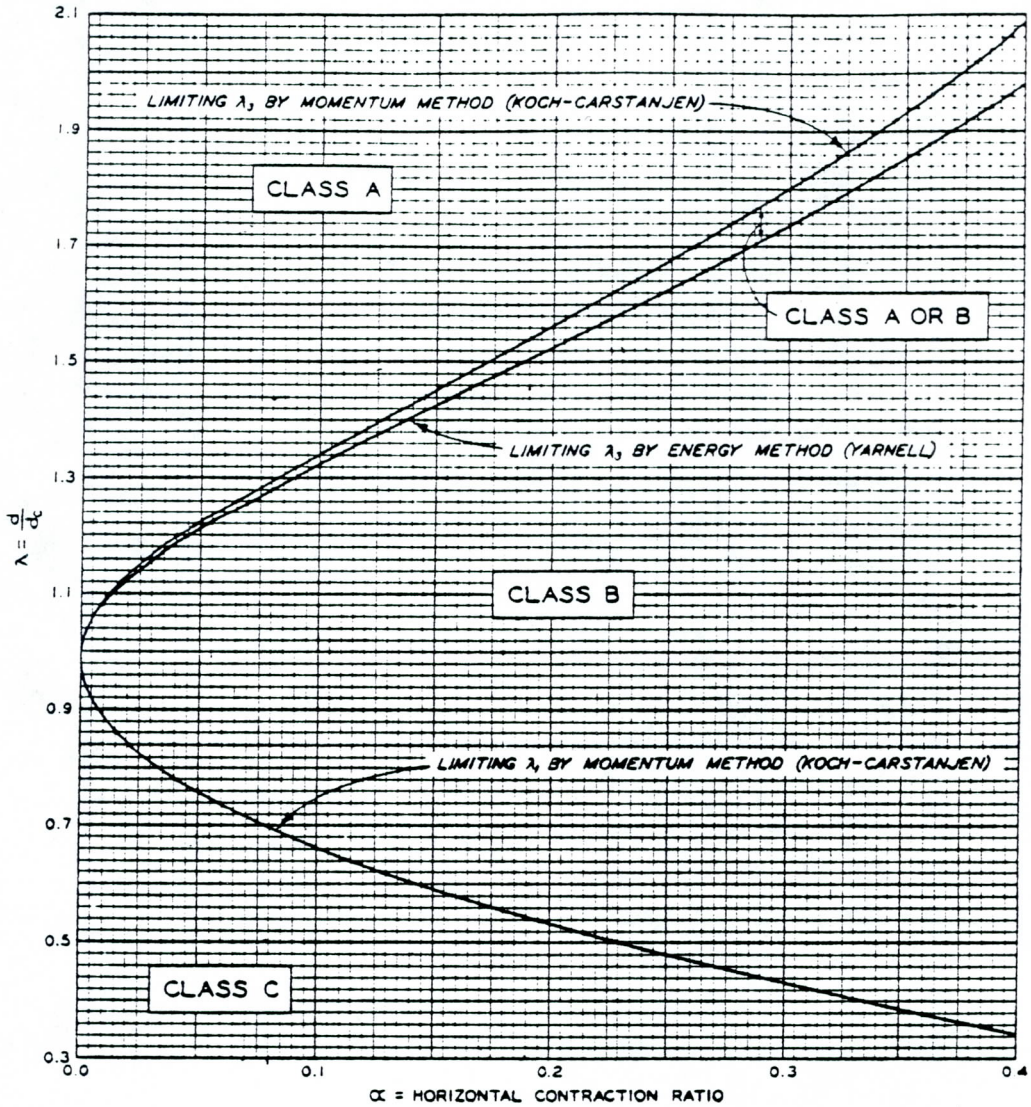
NOTE: $\alpha = W_p/W_c$ = HORIZONTAL CONTRACTION RATIO
W_p = TOTAL PIER WIDTH
W_c = GROSS CHANNEL WIDTH
d_1 = UPSTREAM DEPTH
d_2 = DEPTH WITHIN PIER SECTION
d_3 = DOWNSTREAM DEPTH
d_c = CRITICAL DEPTH WITHIN THE UNOBSTRUCTED CHANNEL SECTION
d_{c2} = CRITICAL DEPTH WITHIN THE PIER SECTION

OPEN CHANNEL FLOW

RECTANGULAR SECTION BRIDGE PIER LOSSES DEFINITION

HYDRAULIC DESIGN CHART 010-6

WES 5-59



EQUATIONS FOR LIMITING λ

λ_3 - ENERGY METHOD (YARNELL)

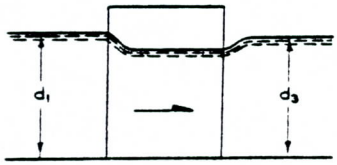
$$\alpha = 1 - \left[\frac{3\lambda_3^2}{2\lambda_3^3+1}\right]^{3/2}$$

λ_3 - MOMENTUM METHOD (KOCH-CARSTANJEN)

$$\alpha = 1 - \left[\frac{3\lambda_3}{(1-\alpha)\lambda_3^3+2}\right]^{3}$$

λ_1 - MOMENTUM METHOD (KOCH-CARSTANJEN)

$$\alpha = 1 - \left[\frac{3\lambda_1}{\lambda_1^3+2}\right]^{3/4}$$



DEFINITION SKETCH

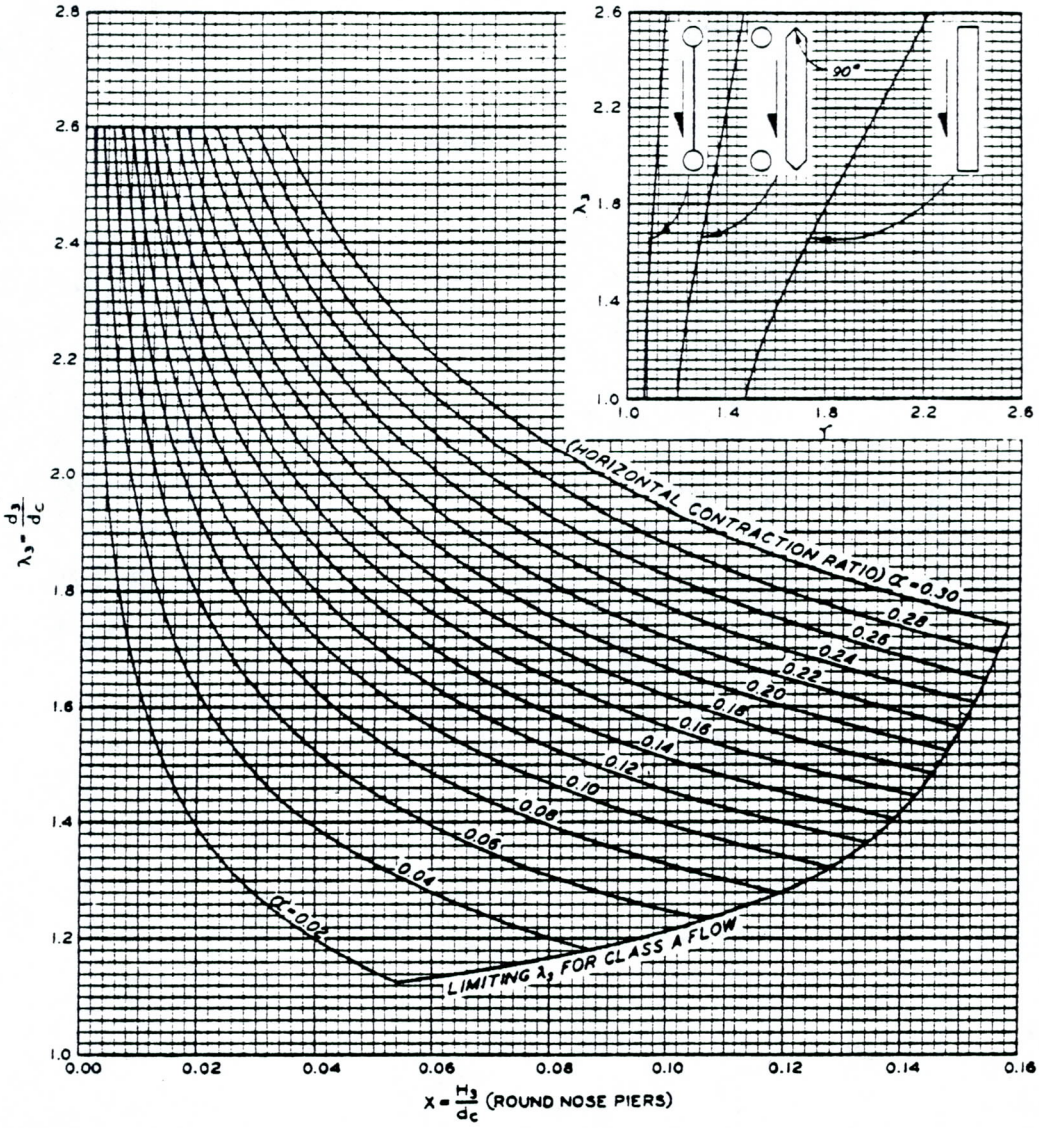
NOTE: $\lambda_1 = d_1/d_c$
$\lambda_3 = d_3/d_c$
d_1 = UPSTREAM WATER DEPTH
d_3 = DOWNSTREAM WATER DEPTH
d_c = CRITICAL DEPTH WITHIN THE UNOBSTRUCTED CHANNEL SECTION
α = HORIZONTAL CONTRACTION RATIO (Σ PIER WIDTHS ÷ CHANNEL WIDTH)
d = DEPTH WITHOUT BRIDGE PIERS

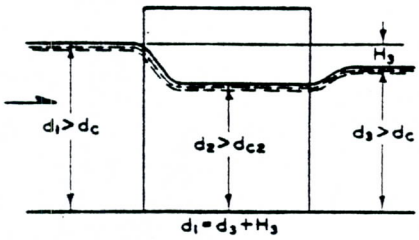
OPEN CHANNEL FLOW

RECTANGULAR SECTION
BRIDGE PIER LOSSES
CLASSIFICATION OF FLOW CONDITIONS

HYDRAULIC DESIGN CHART 010-6/1

PREPARED BY U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION, VICKSBURG, MISSISSIPPI





DEFINITION SKETCH

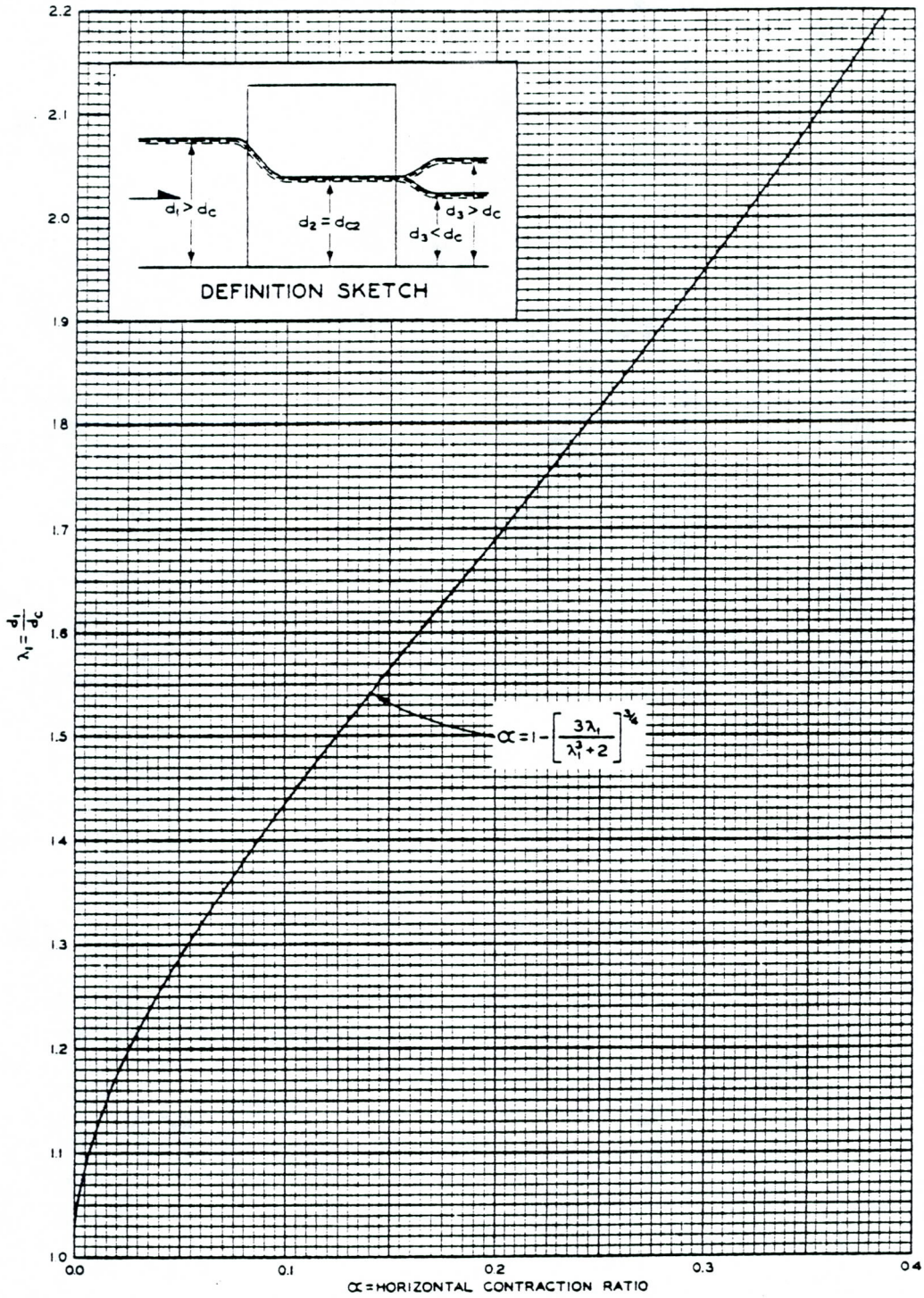
NOTE: d_c = CRITICAL DEPTH WITHIN THE UNOBSTRUCTED CHANNEL SECTION
d_{c2} = CRITICAL DEPTH WITHIN THE PIER SECTION
$H_3 = X d_c$ (ROUND NOSE PIERS)
$H_3 = X d_c \Upsilon$ (INDICATED SHAPES)

OPEN CHANNEL FLOW

RECTANGULAR SECTION
BRIDGE PIER LOSSES
CLASS A FLOW - ENERGY METHOD

HYDRAULIC DESIGN CHART 010-6/2

PREPARED BY U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION, VICKSBURG, MISSISSIPPI



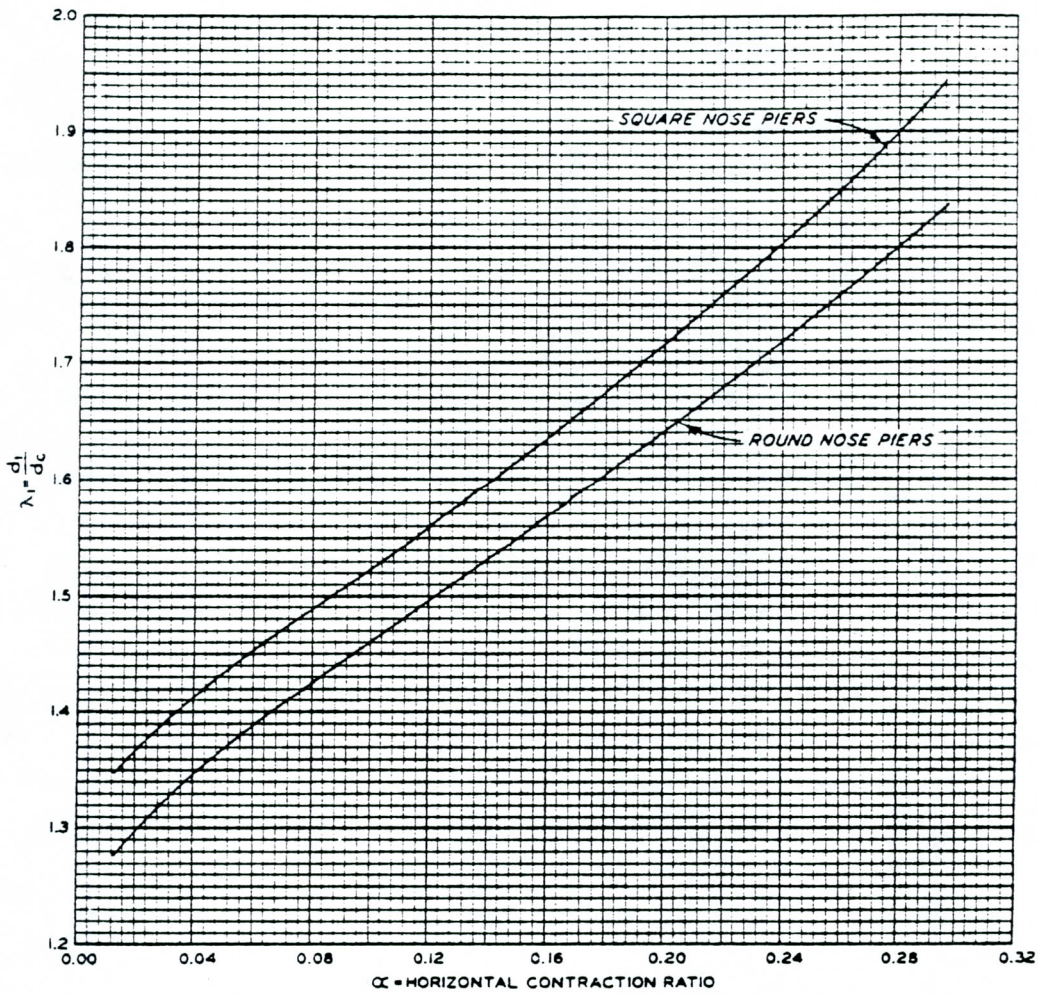
NOTE: $\lambda_1 = d_1/d_c$
d_1 = UPSTREAM WATER DEPTH
d_c = CRITICAL DEPTH WITHIN THE UNOBSTRUCTED CHANNEL SECTION
d_{c2} = CRITICAL DEPTH WITHIN THE PIER SECTION
α = HORIZONTAL CONTRACTION RATIO

OPEN CHANNEL FLOW

RECTANGULAR SECTION
BRIDGE PIER LOSSES
CLASS B FLOW – MOMENTUM METHOD

HYDRAULIC DESIGN CHART 010-6/3

PREPARED BY U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION, VICKSBURG, MISSISSIPPI

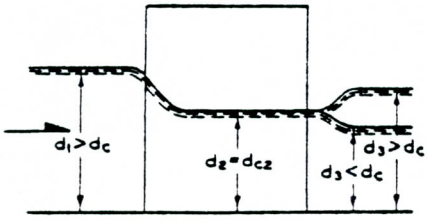


EQUATIONS

$$\frac{1}{(1-\alpha)^{2/3}} = \frac{1}{3\lambda_L^2} + \frac{2\lambda_L}{3}$$

$$\lambda_1 = \lambda_L + \frac{0.5 + K_B(5.5\,\alpha^3 + 0.08)}{2\lambda_1^2}$$

NOTE: λ_1 = d_1/d_c
λ_3 = d_3/d_c
λ_L = LIMITING λ_3 BY ENERGY METHOD
d_1 = UPSTREAM WATER DEPTH
d_3 = DOWNSTREAM WATER DEPTH
d_c = CRITICAL DEPTH WITHIN THE UNOBSTRUCTED CHANNEL SECTION
d_{c2} = CRITICAL DEPTH WITHIN THE PIER SECTION
α = HORIZONTAL CONTRACTION RATIO
K_B = YARNELL PIER-SHAPE COEFFICIENT (1.0 FOR ROUND NOSE) (5.0 FOR SQUARE NOSE)



DEFINITION SKETCH

OPEN CHANNEL FLOW

RECTANGULAR SECTION
BRIDGE PIER LOSSES
CLASS B FLOW - ENERGY METHOD

HYDRAULIC DESIGN CHART 010-6/4

PREPARED BY U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION, VICKSBURG, MISSISSIPPI

HYDRAULIC DESIGN OF FLOOD CONTROL CHANNELS

Department of the Army
Corps of Engineers

1 July 1970
EM 1110-2-1601
Engineer Manual

9. Flow Through Bridges. Bridge piers located in channels result in energy losses in the flow and create disturbances at the bridge section and in the channel sections immediately upstream and downstream. As bridge pier losses materially affect water-surface elevations in the vicinity of the bridge, their careful determination is important. Submergence of bridge members is not desirable.

a. Abutment Losses. Bridge abutments should not extend into the flow area in rapid-flow channels. In tranquil-flow channels they should be so designed that the flow depth between abutments or between the abutment and an intermediate pier is greater than critical depth. The Bureau of Public Roads (BPR)[9] has published design charts for computing backwater for various abutment geometry and degree of contraction. The design procedure and charts developed by BPR are recommended for use in channel designs involving bridge abutments. For preliminary designs and less important structures, a step backwater computation using abrupt expansion and contraction head losses of 1.0 and 0.5, respectively, times the change in velocity head may be used. This method under the same circumstances may be applied to bridge openings containing piers.

APPENDIX C
MAPS

LIST OF MAPS

MAP NUMBER	TITLE
C-1	Existing Land Use
C-2	Zoning
C-3	Land Ownership
C-4	Transportation
C-5	Infrastructure
C-6	Planned Land Use
C-7	Land Use Summary
C-8	Cultural/Biological Resources
C-9	Hydrology/Hydraulics
C-10	Opportunities and Constraints
C-11	Concept Master Plan Alternative A
C-12	Concept Master Plan Alternative B
C-13	Concept Master Plan Alternative C

TABLE I
STUDY TEAM

Area of Responsibility	Team Member(s)
Project Management	Wirth
Opportunities and Constraints	Wirth, EKA, Drake
Alternative Plan Development	Wirth, EKA, Drake
Master Plan Implementation	Wirth, EKA, Drake
Master Plan Development	Wirth, EKA, Drake
Transportation	Wirth, EKA
Land Ownership	Wirth
Recreation	Wirth
Visual Resources	Wirth
Cultural Resources	Wirth
Graphics	Wirth
Report Production	Wirth
Infrastructures	EKA
Topography	EKA
Geology and Soils	EKA
Hydrology	EKA
Hydraulics	EKA
Existing Land Use	Drake
Zoning	Drake
Planned Land Use	Drake, Wirth, EKA
Biological Resources	Smith, Wirth

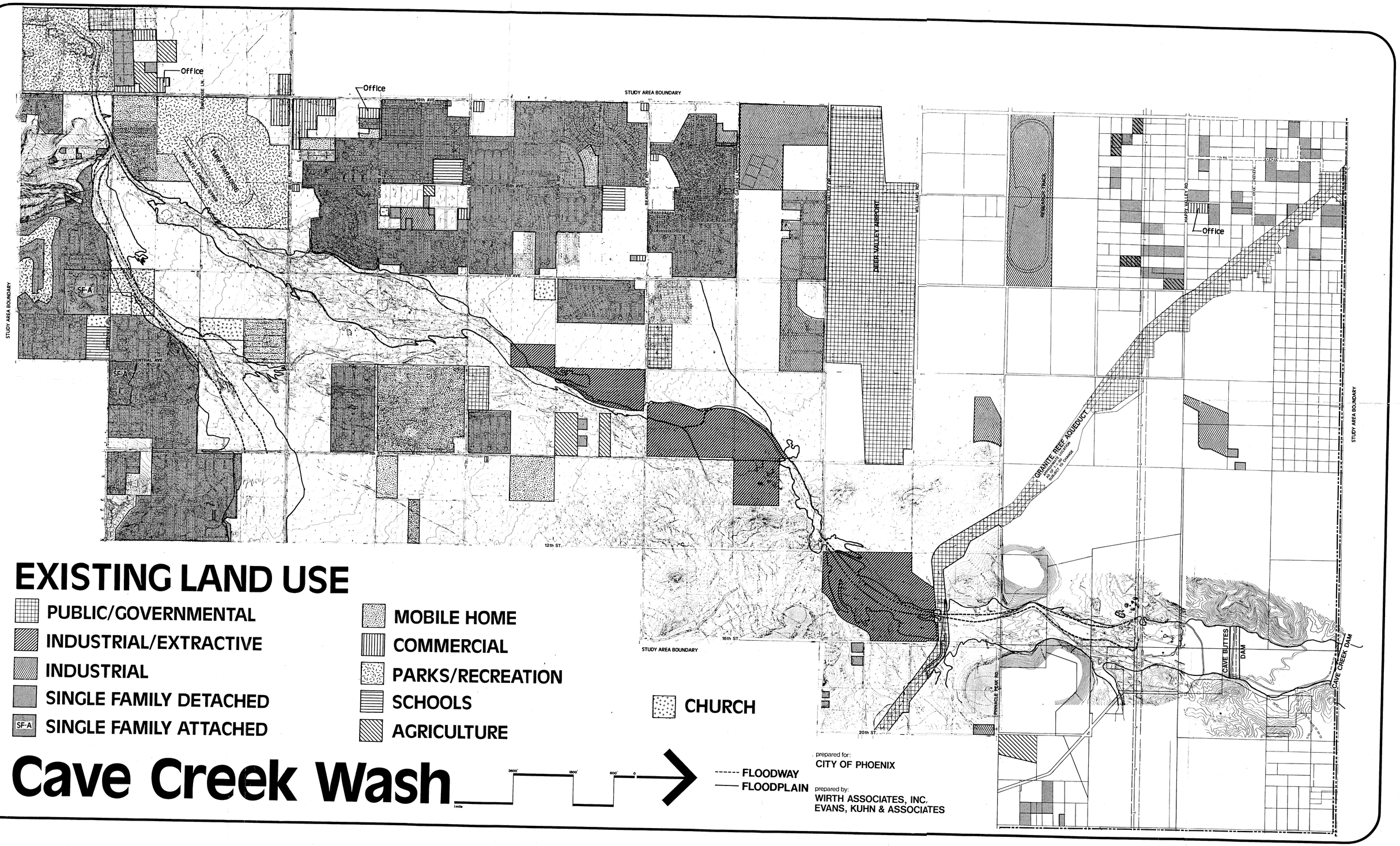

Office
Office
Office
STUDY AREA BOUNDARY
STUDY AREA BOUNDARY
STUDY AREA BOUNDARY
STUDY AREA BOUNDARY
19th AVE.
PARADISE LN.
BELL RD.
PARADISE VALLEY
PARK
PARADISE
GROVER ST.
UNION HILLS DR.
ROSE GARDEN LN.
BEARDSLEY RD.
DEER VALLEY DR.
DEER VALLEY AIRPORT
WILLIAMS RD.
BEARDSLEY TRAIL
HAPPY VALLEY RD.
LAKE PLEASANT RD.
7th AVE.
SF-A
SF-A
SF-A
CENTRAL AVE.
12th ST.
16th ST.
20th ST.
GRANITE REEF AQUEDUCT
AS WRITTEN, SUBJECT TO CHANGE
PINNACLE PEAK RD.
CAVE BUTTES
DAM
CAVE CREEK DAM
EXISTING LAND USE
PUBLIC/GOVERNMENTAL
INDUSTRIAL/EXTRACTIVE
INDUSTRIAL
SINGLE FAMILY DETACHED
SF-A
SINGLE FAMILY ATTACHED
MOBILE HOME
COMMERCIAL
PARKS/RECREATION
SCHOOLS
AGRICULTURE
CHURCH
Cave Creek Wash
3600'
1800'
900'
0
1 mile
FLOODWAY
FLOODPLAIN
prepared for:
CITY OF PHOENIX
prepared by:
WIRTH ASSOCIATES, INC.
EVANS, KUHN & ASSOCIATES

FIGURE C-1

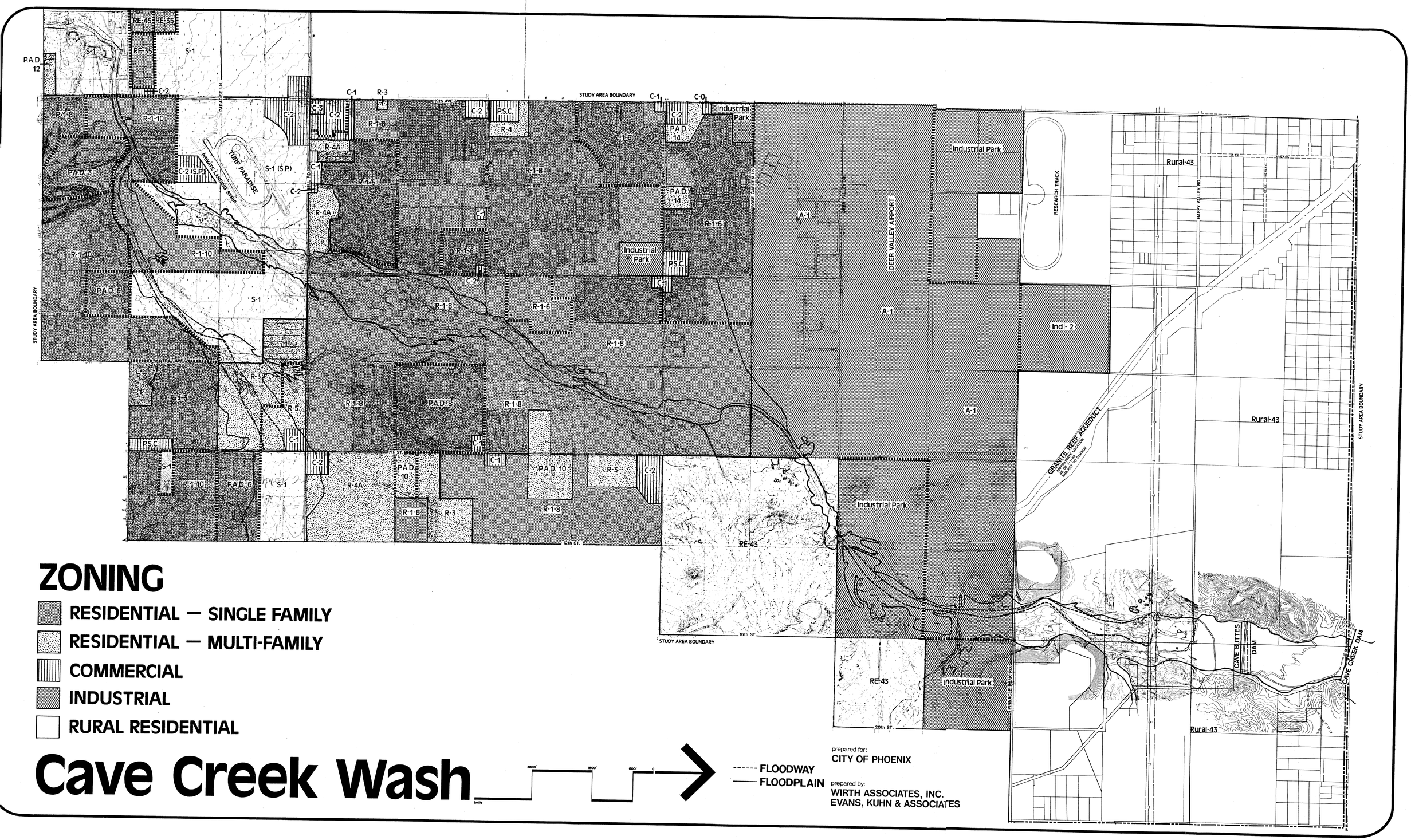

ZONING
RESIDENTIAL — SINGLE FAMILY
RESIDENTIAL — MULTI-FAMILY
COMMERCIAL
INDUSTRIAL
RURAL RESIDENTIAL
Cave Creek Wash
FLOODWAY
FLOODPLAIN
prepared for:
CITY OF PHOENIX
prepared by:
WIRTH ASSOCIATES, INC.
EVANS, KUHN & ASSOCIATES
STUDY AREA BOUNDARY
DEER VALLEY AIRPORT
RESEARCH TRACK
Industrial Park
Rural-43
Ind - 2
A-1
RE-43
GRANITE REEF AQUEDUCT
CAVE BUTTES DAM
CAVE CREEK DAM
TURF PARADISE
PRIVATE LANDING STRIP
PARADISE LN.
19th AVE.
12th ST.
16th ST.
20th ST.
HAPPY VALLEY RD.
PINNACLE PEAK RD.
DEER VALLEY RD.
P.A.D. 12
P.A.D. 3
P.A.D. 6
P.A.D. 8
P.A.D. 10
P.A.D. 14
R-1-8
R-1-10
R-1-6
R-4
R-4A
R-3
R-5
S-1
S-1 (S.P.)
C-2 (S.P.)
C-1
C-2
C-3
C-0
PSC
RE-45
RE-35

FIGURE C-2

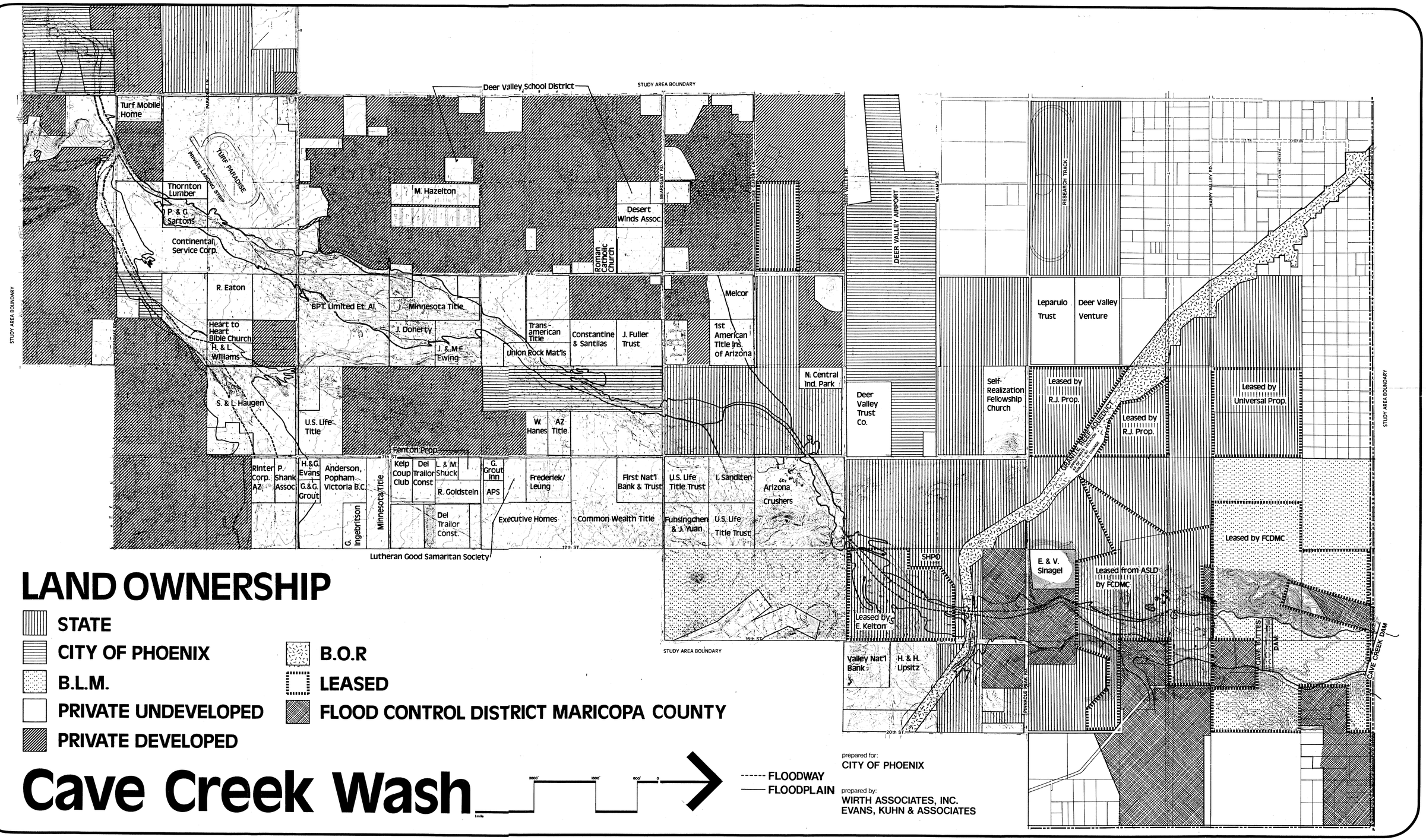

Deer Valley School District
STUDY AREA BOUNDARY
Turf Mobile Home
PARADISE LN.
TURF PARADISE
PRIVATE LANDING STRIP
Thornton Lumber
P. & C. Sartons
Continental Service Corp.
M. Hazelton
Roman Catholic Church
Desert Winds Assoc.
BEARDSLEY RD.
DEER VALLEY DR.
DEER VALLEY AIRPORT
WILLIAMS RD.
RESEARCH TRACK
HAPPY VALLEY RD.
R. Eaton
BPT. Limited Et. Al.
Minnesota Title
J. Doherty
J. & M.E. Ewing
Heart to Heart Bible Church
H. & L. Williams
Trans-american Title
Union Rock Mat'ls
Constantine & Santilas
J. Fuller Trust
Melcor
1st American Title Ins. of Arizona
N. Central Ind. Park
Deer Valley Trust Co.
Leparulo Trust
Deer Valley Venture
Self-Realization Fellowship Church
Leased by R.J. Prop.
Leased by Universal Prop.
S. & L. Haugen
U.S. Life Title
W. Hanes
AZ Title
Fenton Prop.
Rinter Corp. AZ
P. Shank Assoc.
H.&G. Evans
G.&G. Grout
Anderson, Popham Victoria B.C.
G. Ingebritson
Minnesota Title
Kelp Coup Club
Del Trailor Const.
L. & M. Shuck
R. Goldstein
G. Grout Inn
APS
Frederiek/ Leung
First Nat'l Bank & Trust
U.S. Life Title Trust
I. Sanditen
Arizona Crushers
Fuhsingchen & J. Yuan
Del Trailor Const.
Executive Homes
Common Wealth Title
Lutheran Good Samaritan Society
SHPO
E. & V. Sinagel
Leased from ASLD by FCDMC
Leased by FCDMC
Leased by E. Kelton
Valley Nat'l Bank
H. & H. Lipsitz
PINNACLE PEAK RD.
CAVE BUTTES
DAM
CAVE CREEK DAM
LAND OWNERSHIP
STATE
CITY OF PHOENIX
B.L.M.
PRIVATE UNDEVELOPED
PRIVATE DEVELOPED
B.O.R
LEASED
FLOOD CONTROL DISTRICT MARICOPA COUNTY
Cave Creek Wash
3600'
1800'
600'
0
1 mile
FLOODWAY
FLOODPLAIN
prepared for:
CITY OF PHOENIX
prepared by:
WIRTH ASSOCIATES, INC.
EVANS, KUHN & ASSOCIATES

FIGURE C-3

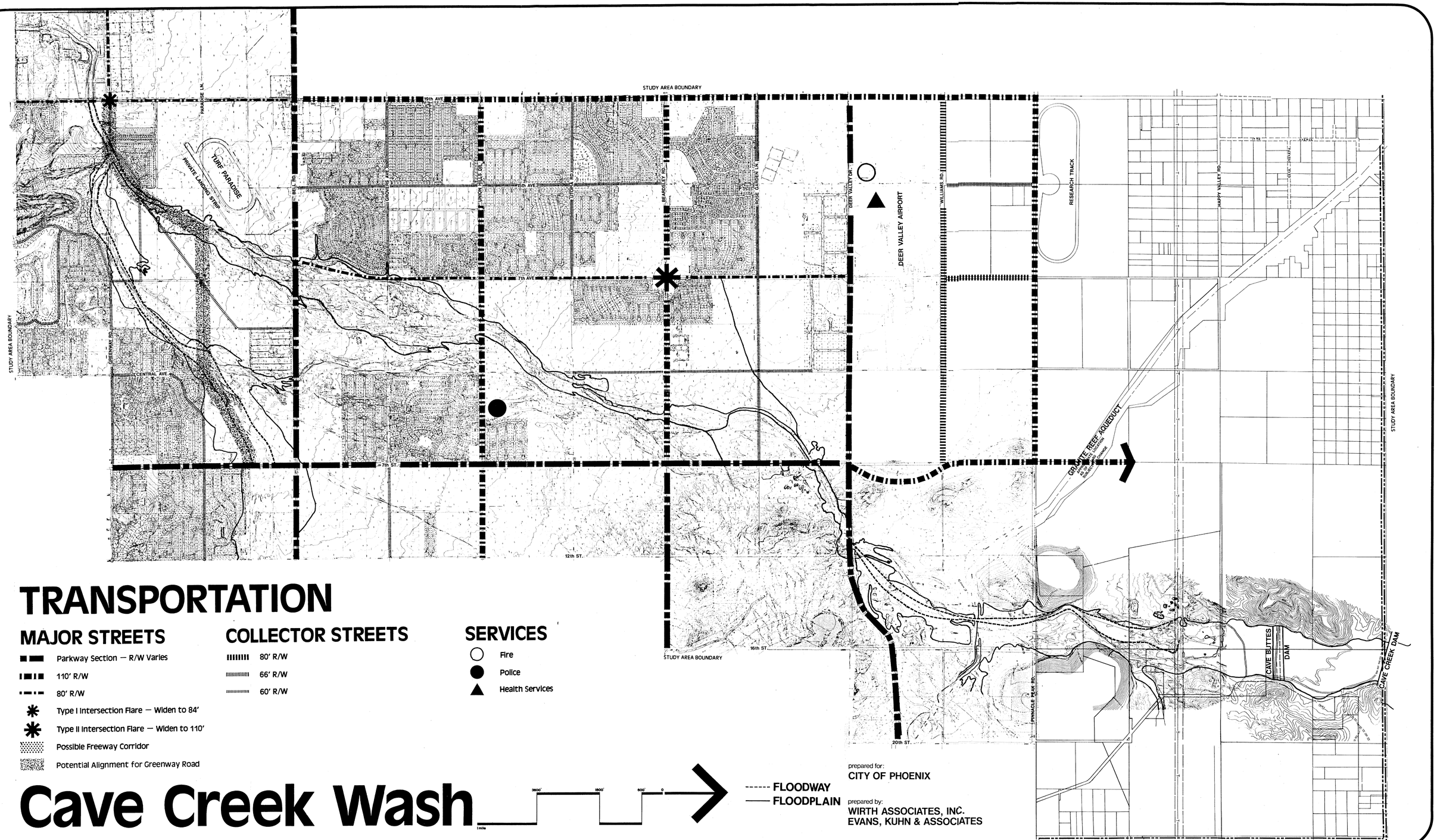
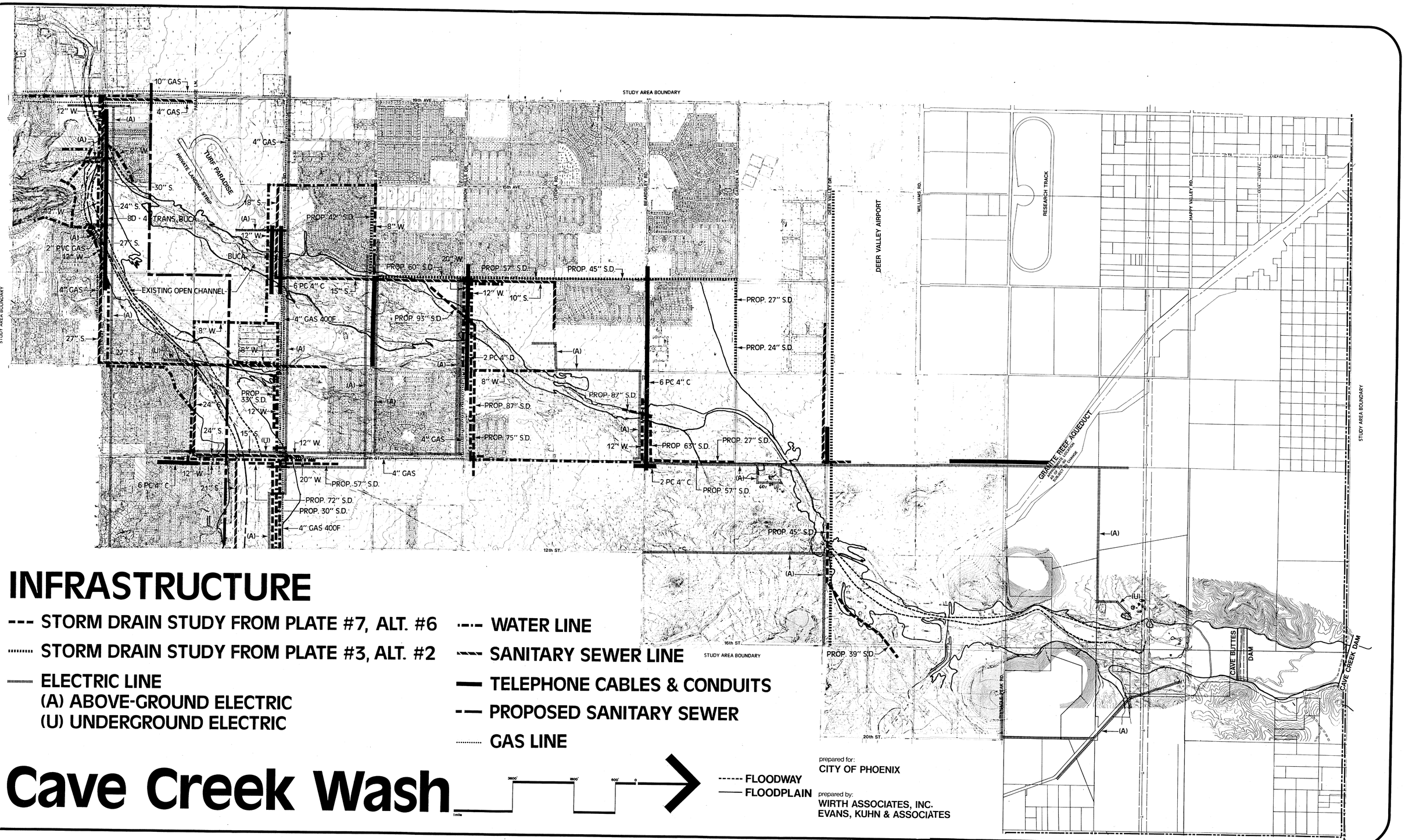

STUDY AREA BOUNDARY
STUDY AREA BOUNDARY
STUDY AREA BOUNDARY
STUDY AREA BOUNDARY
PARADISE LN.
PRIVATE LANDING STRIP
TURF PARADISE
BELL RD.
GREENWAY RD.
CENTRAL AVE.
7th ST.
12th ST.
16th ST.
20th ST.
19th AVE.
15th AVE.
7th AVE.
UNION HILLS DR.
BEARDSLEY RD.
ROSE GARDEN LN.
DEER VALLEY DR.
DEER VALLEY AIRPORT
WILLIAMS RD.
RESEARCH TRACK
HAPPY VALLEY RD.
PINNACLE PEAK RD.
GRANITE REEF AQUEDUCT
CAVE BUTTES DAM
CAVE CREEK DAM
TRANSPORTATION
MAJOR STREETS
Parkway Section — R/W Varies
110' R/W
80' R/W
Type I Intersection Flare — Widen to 84'
Type II Intersection Flare — Widen to 110'
Possible Freeway Corridor
Potential Alignment for Greenway Road
COLLECTOR STREETS
80' R/W
66' R/W
60' R/W
SERVICES
Fire
Police
Health Services
Cave Creek Wash
3600'
1800'
600'
0
1 mile
FLOODWAY
FLOODPLAIN
prepared for:
CITY OF PHOENIX
prepared by:
WIRTH ASSOCIATES, INC.
EVANS, KUHN & ASSOCIATES

FIGURE C-4



INFRASTRUCTURE

--- STORM DRAIN STUDY FROM PLATE #7, ALT. #6

STORM DRAIN STUDY FROM PLATE #3, ALT. #2

ELECTRIC LINE
(A) ABOVE-GROUND ELECTRIC
(U) UNDERGROUND ELECTRIC

WATER LINE

SANITARY SEWER LINE

TELEPHONE CABLES & CONDUITS

PROPOSED SANITARY SEWER

GAS LINE

Cave Creek Wash

3600' 1800' 900' 0
1 mile

FLOODWAY
FLOODPLAIN

prepared for:
CITY OF PHOENIX

prepared by:
WIRTH ASSOCIATES, INC.
EVANS, KUHN & ASSOCIATES

FIGURE C-5

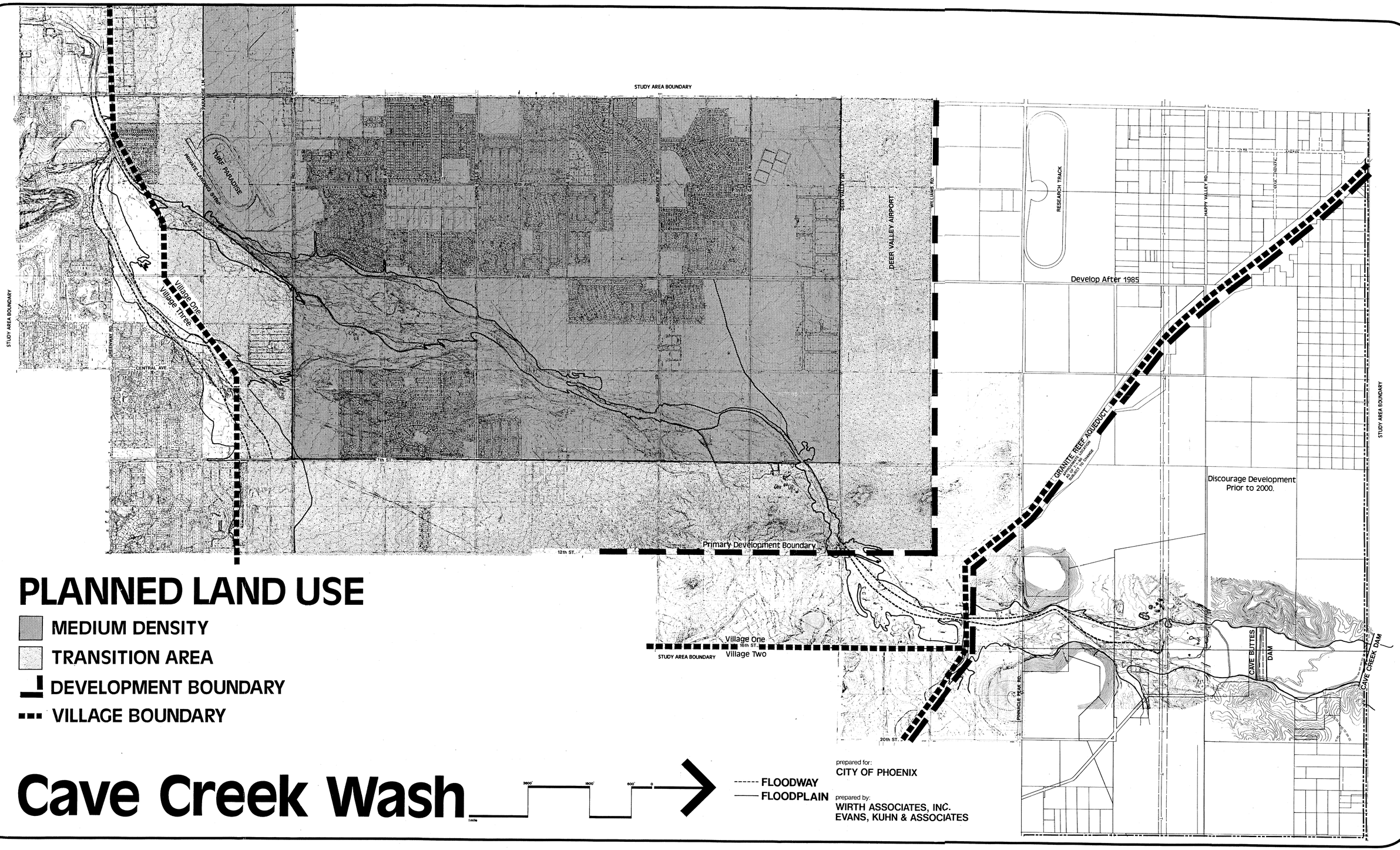

STUDY AREA BOUNDARY
STUDY AREA BOUNDARY
STUDY AREA BOUNDARY
STUDY AREA BOUNDARY
TURF PARADISE
PRIVATE LANDING STRIP
GREENWAY RD.
CENTRAL AVE
7th ST.
12th ST.
16th ST.
20th ST.
DEER VALLEY DR.
WILLIAMS RD.
DEER VALLEY AIRPORT
RESEARCH TRACK
HAPPY VALLEY RD.
GOLF COURSE
PINNACLE PEAK RD.
GRANITE REEF AQUEDUCT
ALIGNMENT LOCATION
SUBJECT TO CHANGE
CAVE BUTTES DAM
CAVE CREEK DAM
Village One
Village Three
Village One
Village Two
Primary Development Boundary
Develop After 1985
Discourage Development Prior to 2000.
PLANNED LAND USE
MEDIUM DENSITY
TRANSITION AREA
DEVELOPMENT BOUNDARY
VILLAGE BOUNDARY
Cave Creek Wash
3600'
1800'
600'
0
1 mile
FLOODWAY
FLOODPLAIN
prepared for:
CITY OF PHOENIX
prepared by:
WIRTH ASSOCIATES, INC.
EVANS, KUHN & ASSOCIATES

FIGURE C-6

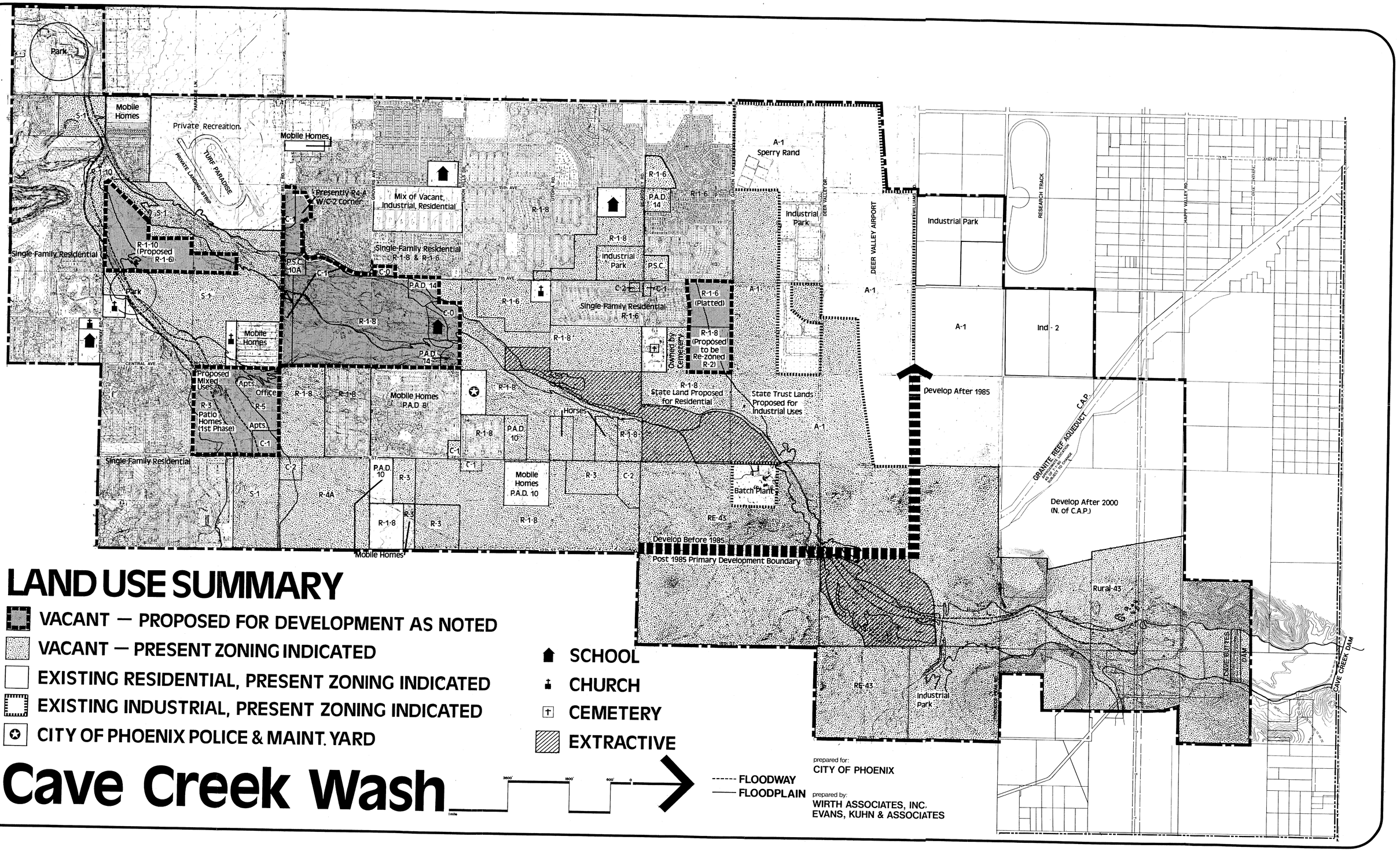

Park
Mobile Homes
Private Recreation
TURF PARADISE
PRIVATE LANDING STRIP
Mobile Homes
Presently R-4-A W/C-2 Corner
Mix of Vacant, Industrial, Residential
Single-Family Residential
R-1-10 (Proposed R-1-6)
P.S.C. 10A
Single-Family Residential R-1-8 & R-1-6
P.A.D. 14
Park
Mobile Homes
Proposed Mixed Uses
Apts.
Office
R-3 Patio Homes (1st Phase)
R-5
Apts.
Single-Family Residential
R-4A
Mobile Homes
Mobile Homes P.A.D. 8
P.A.D. 10
Mobile Homes P.A.D. 10
Horses
Industrial Park
P.S.C.
Single-Family Residential R-1-6
R-1-6 (Platted)
R-1-8 (Proposed to be Re-zoned R-2)
Owned by Cemetery
R-1-8 State Land Proposed for Residential
State Trust Lands Proposed for Industrial Uses
A-1 Sperry Rand
Industrial Park
DEER VALLEY AIRPORT
Batch Plant
RE-43
Develop Before 1985
Post 1985 Primary Development Boundary
Industrial Park
RESEARCH TRACK
A-1
Ind - 2
Develop After 1985
GRANITE REEF AQUEDUCT
C.A.P.
Develop After 2000 (N. of C.A.P.)
Rural-43
CAVE BUTTES DAM
CAVE CREEK DAM
RE-43
Industrial Park
LAND USE SUMMARY
VACANT — PROPOSED FOR DEVELOPMENT AS NOTED
VACANT — PRESENT ZONING INDICATED
EXISTING RESIDENTIAL, PRESENT ZONING INDICATED
EXISTING INDUSTRIAL, PRESENT ZONING INDICATED
CITY OF PHOENIX POLICE & MAINT. YARD
SCHOOL
CHURCH
CEMETERY
EXTRACTIVE
FLOODWAY
FLOODPLAIN
Cave Creek Wash
prepared for:
CITY OF PHOENIX
prepared by:
WIRTH ASSOCIATES, INC.
EVANS, KUHN & ASSOCIATES

FIGURE C-7

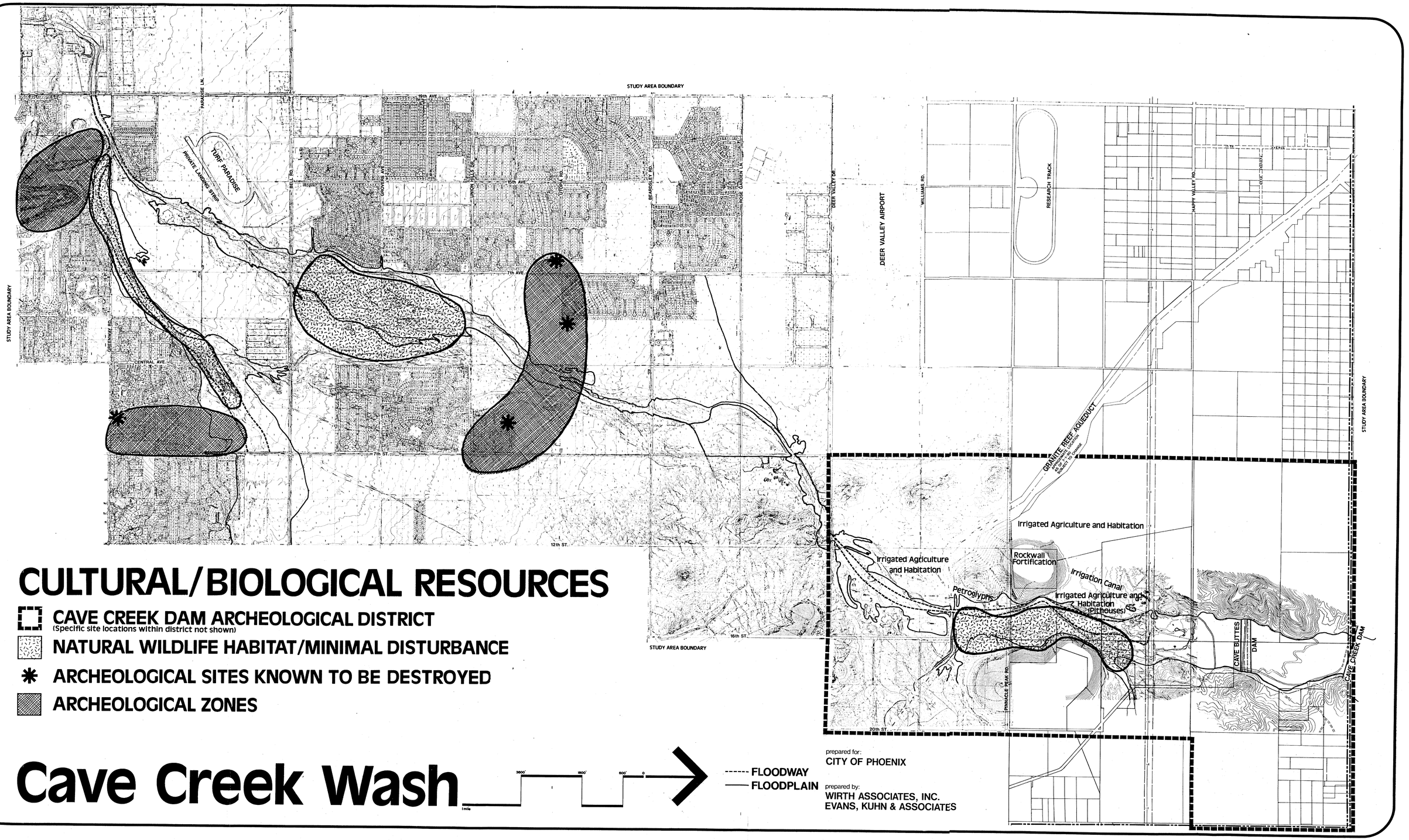
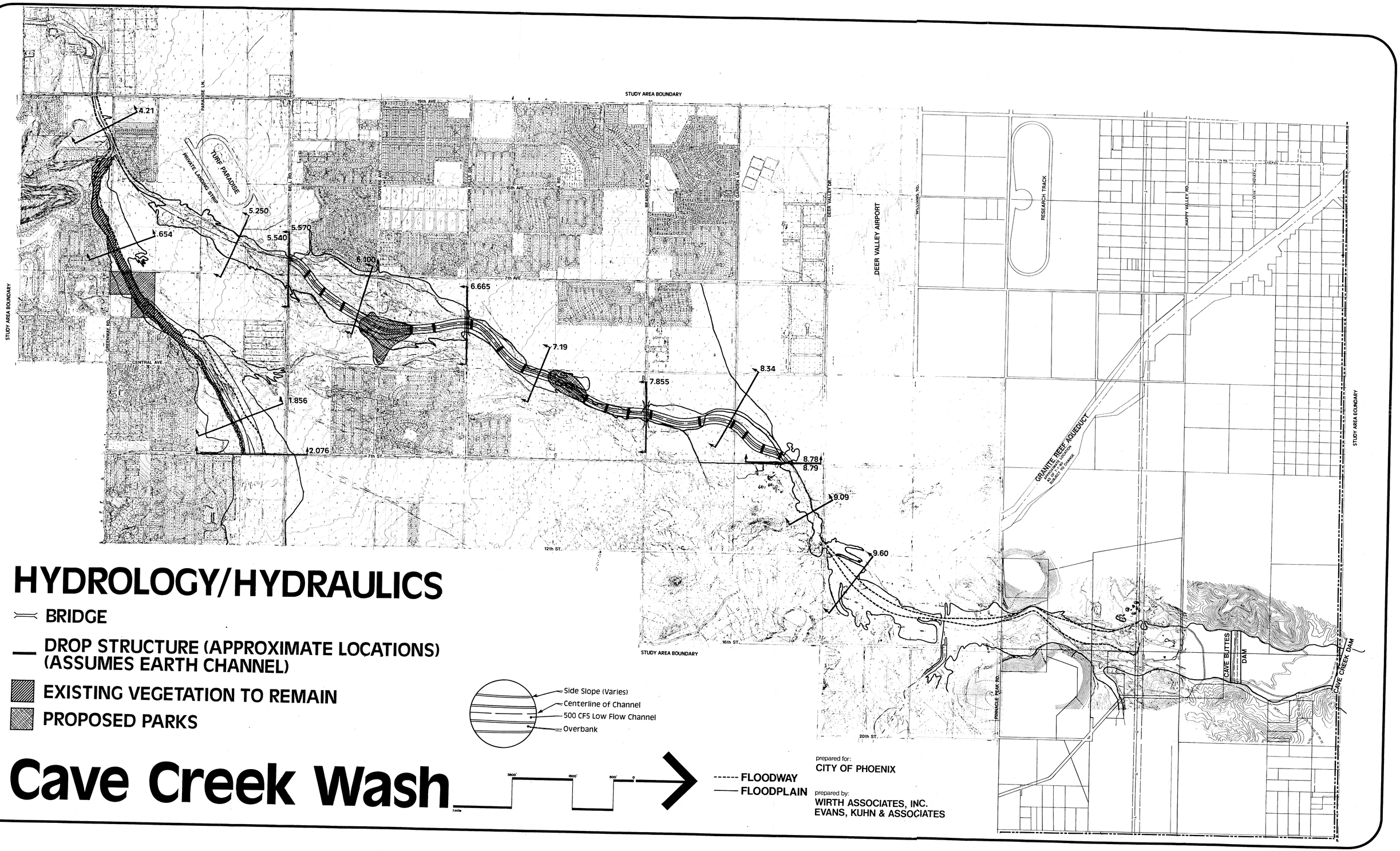

STUDY AREA BOUNDARY
19th AVE.
PARADISE LN.
TURF PARADISE
PRIVATE LANDING STRIP
BELL RD.
GROVERS AVE.
UNION HILLS DR.
TUTONA RD.
BEARDSLEY RD.
ROSE GARDEN LN.
DEER VALLEY DR.
DEER VALLEY AIRPORT
WILLIAMS RD.
RESEARCH TRACK
HAPPY VALLEY RD.
STUDY AREA BOUNDARY
GREENWAY RD.
CENTRAL AVE.
7th AVE.
7th ST.
12th ST.
16th ST.
20th ST.
GRANITE REEF AQUEDUCT
Irrigated Agriculture and Habitation
Rockwall Fortification
Irrigation Canal
Irrigated Agriculture and Habitation (Pithouses)
Petroglyphs
PINNACLE PEAK RD.
CAVE BUTTES DAM
CAVE CREEK DAM
CULTURAL/BIOLOGICAL RESOURCES
CAVE CREEK DAM ARCHEOLOGICAL DISTRICT
(Specific site locations within district not shown)
NATURAL WILDLIFE HABITAT/MINIMAL DISTURBANCE
ARCHEOLOGICAL SITES KNOWN TO BE DESTROYED
ARCHEOLOGICAL ZONES
Cave Creek Wash
3600'
1800'
600'
0
1 mile
FLOODWAY
FLOODPLAIN
prepared for:
CITY OF PHOENIX
prepared by:
WIRTH ASSOCIATES, INC.
EVANS, KUHN & ASSOCIATES

FIGURE C-8



HYDROLOGY/HYDRAULICS

- BRIDGE
- DROP STRUCTURE (APPROXIMATE LOCATIONS) (ASSUMES EARTH CHANNEL)
- EXISTING VEGETATION TO REMAIN
- PROPOSED PARKS

Cave Creek Wash

FIGURE C-9

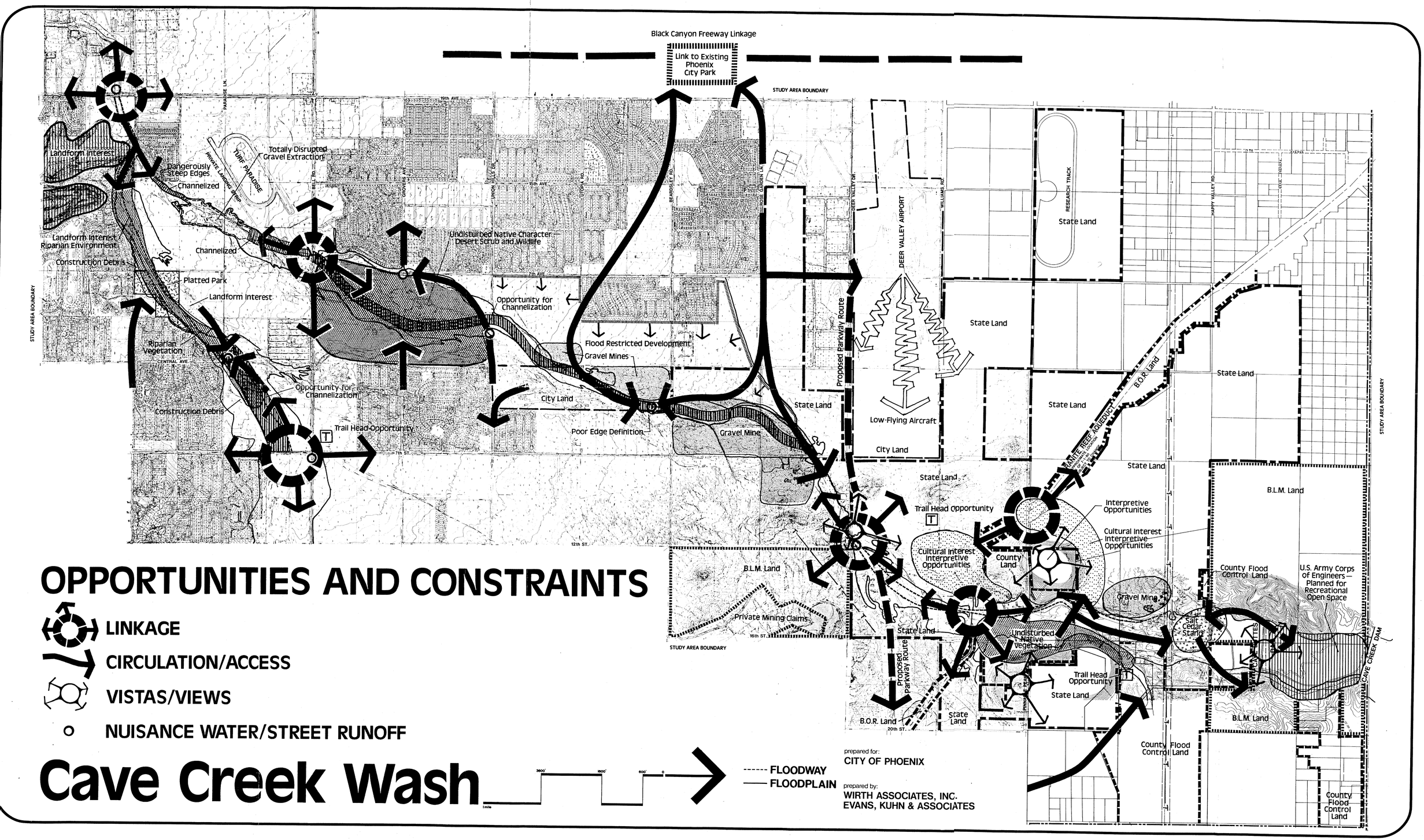

Black Canyon Freeway Linkage
Link to Existing Phoenix City Park
STUDY AREA BOUNDARY
Landform Interest
Dangerously Steep Edges
Channelized
Totally Disrupted Gravel Extraction
TURF PARADISE
PRIVATE LANDING STRIP
PARADISE LN.
BELL RD.
19th AVE.
15th AVE.
Landform Interest Riparian Environment
Construction Debris
Channelized
Platted Park
Landform Interest
Undisturbed Native Character Desert Scrub and Wildlife
Opportunity for Channelization
Flood Restricted Development
Gravel Mines
Riparian Vegetation
CENTRAL AVE.
Opportunity for Channelization
Construction Debris
Trail Head Opportunity
7th ST.
City Land
Poor Edge Definition
Gravel Mine
State Land
Proposed Parkway Route
DEER VALLEY AIRPORT
Low-Flying Aircraft
City Land
State Land
Trail Head Opportunity
Interpretive Opportunities
Cultural Interest Interpretive Opportunities
Cultural Interest Interpretive Opportunities
County Land
B.L.M. Land
Private Mining Claims
16th ST.
12th ST.
STUDY AREA BOUNDARY
State Land
Undisturbed Native Vegetation
Proposed Parkway Route
B.O.R. Land
20th ST.
State Land
Trail Head Opportunity
State Land
RESEARCH TRACK
State Land
State Land
State Land
State Land
B.O.R. Land
SANTA FE REEF AQUEDUCT
B.L.M. Land
County Flood Control Land
U.S. Army Corps of Engineers— Planned for Recreational Open Space
Gravel Mine
Salt Cedar Stand
CAVE CREEK DAM
B.L.M. Land
County Flood Control Land
County Flood Control Land
HAPPY VALLEY RD.
STUDY AREA BOUNDARY
STUDY AREA BOUNDARY
OPPORTUNITIES AND CONSTRAINTS
LINKAGE
CIRCULATION/ACCESS
VISTAS/VIEWS
NUISANCE WATER/STREET RUNOFF
Cave Creek Wash
3600'
1800'
600'
0
1 mile
FLOODWAY
FLOODPLAIN
prepared for:
CITY OF PHOENIX
prepared by:
WIRTH ASSOCIATES, INC.
EVANS, KUHN & ASSOCIATES

FIGURE C-10

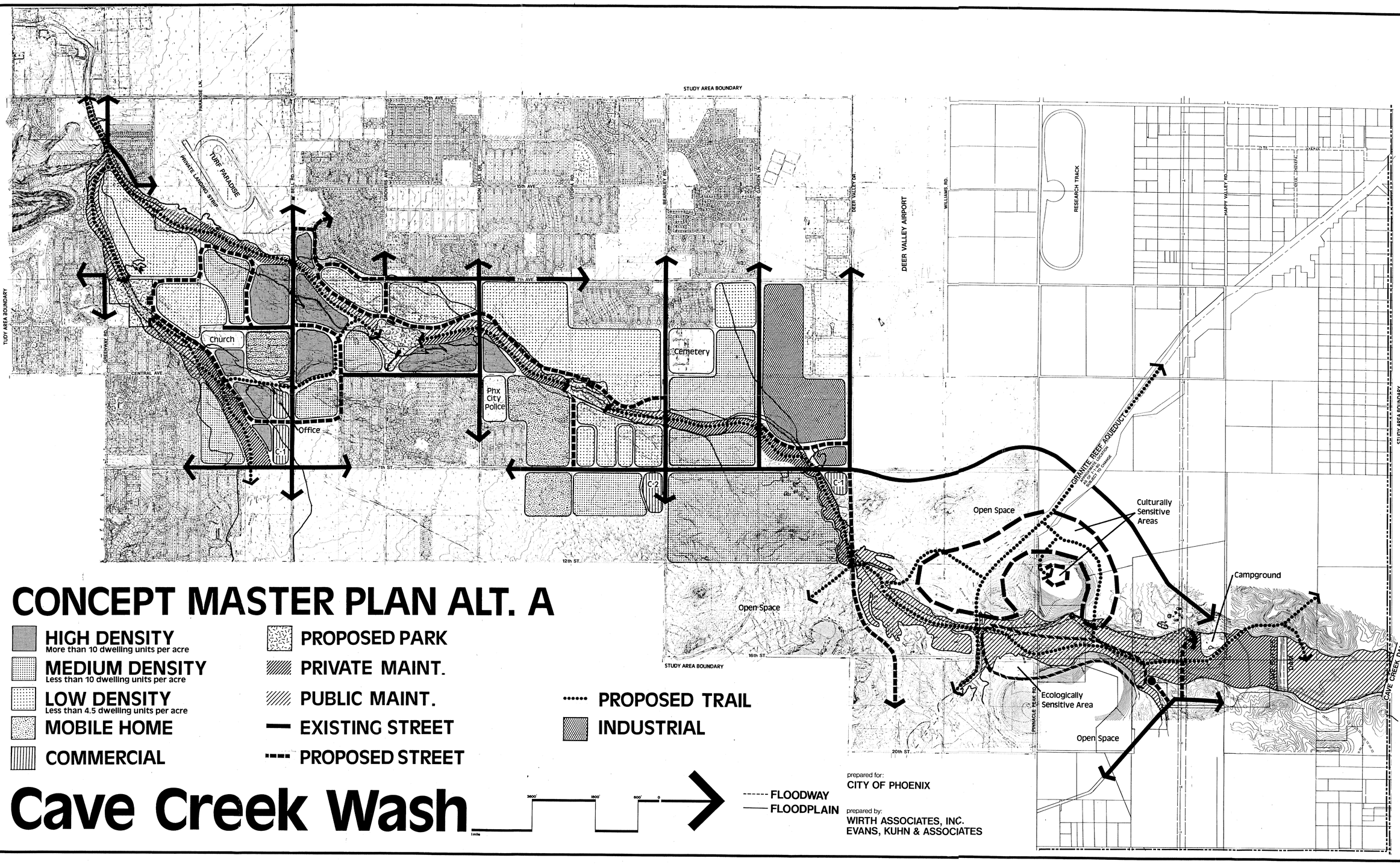

STUDY AREA BOUNDARY
19th AVE.
15th AVE.
7th AVE.
PARADISE LN.
TURF PARADISE
PRIVATE LANDING STRIP
ROSE GARDEN LN.
DEER VALLEY DR.
DEER VALLEY AIRPORT
WILLIAMS RD.
RESEARCH TRACK
HAPPY VALLEY RD.
TUDY AREA BOUNDARY
GREENWAY RD.
CENTRAL AVE.
church
Office
Phx City Police
Cemetery
7th ST.
12th ST.
16th ST.
20th ST.
STUDY AREA BOUNDARY
Open Space
Open Space
GRANITE REEF AQUEDUCT
Culturally Sensitive Areas
Campground
Ecologically Sensitive Area
Open Space
PINNACLE PEAK RD.
CAVE CREEK DAM
STUDY AREA BOUNDARY
CONCEPT MASTER PLAN ALT. A
HIGH DENSITY
More than 10 dwelling units per acre
MEDIUM DENSITY
Less than 10 dwelling units per acre
LOW DENSITY
Less than 4.5 dwelling units per acre
MOBILE HOME
COMMERCIAL
PROPOSED PARK
PRIVATE MAINT.
PUBLIC MAINT.
EXISTING STREET
PROPOSED STREET
PROPOSED TRAIL
INDUSTRIAL
Cave Creek Wash
3600'
1800'
600'
0
1 mile
FLOODWAY
FLOODPLAIN
prepared for:
CITY OF PHOENIX
prepared by:
WIRTH ASSOCIATES, INC.
EVANS, KUHN & ASSOCIATES

FIGURE C-11

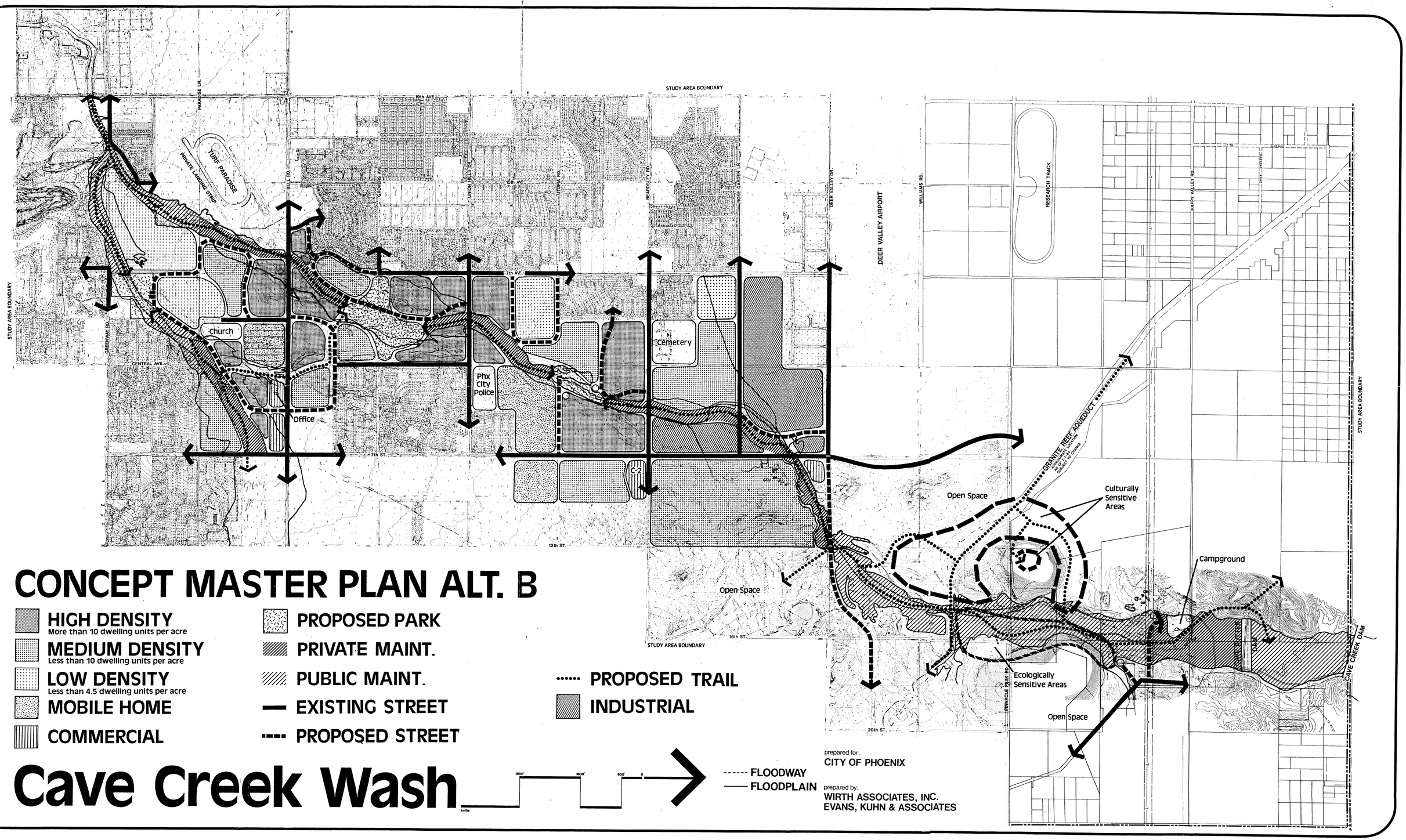

STUDY AREA BOUNDARY
19th AVE.
PARADISE LN.
TURF PARADISE
PRIVATE LANDING STRIP
BELL RD.
15th AVE.
UNION HILLS DR.
BEARDSLEY RD.
ROSE GARDEN LN.
DEER VALLEY DR.
DEER VALLEY AIRPORT
WILLIAMS RD.
RESEARCH TRACK
HAPPY VALLEY RD.
STUDY AREA BOUNDARY
GREENWAY RD.
CENTRAL AVE.
church
Office
7th AVE.
Phx City Police
cemetery
7th ST.
C-2
12th ST.
GRANITE REEF AQUEDUCT
Open Space
Culturally Sensitive Areas
Campground
Open Space
16th ST.
STUDY AREA BOUNDARY
PINNACLE PEAK RD.
Ecologically Sensitive Areas
Open Space
20th ST.
CAVE BUTTES
DAM
CAVE CREEK DAM
CONCEPT MASTER PLAN ALT. B
HIGH DENSITY
More than 10 dwelling units per acre
MEDIUM DENSITY
Less than 10 dwelling units per acre
LOW DENSITY
Less than 4.5 dwelling units per acre
MOBILE HOME
COMMERCIAL
PROPOSED PARK
PRIVATE MAINT.
PUBLIC MAINT.
EXISTING STREET
PROPOSED STREET
PROPOSED TRAIL
INDUSTRIAL
Cave Creek Wash
3600'
1800'
600'
0
1 mile
FLOODWAY
FLOODPLAIN
prepared for:
CITY OF PHOENIX
prepared by:
WIRTH ASSOCIATES, INC.
EVANS, KUHN & ASSOCIATES

FIGURE C-12

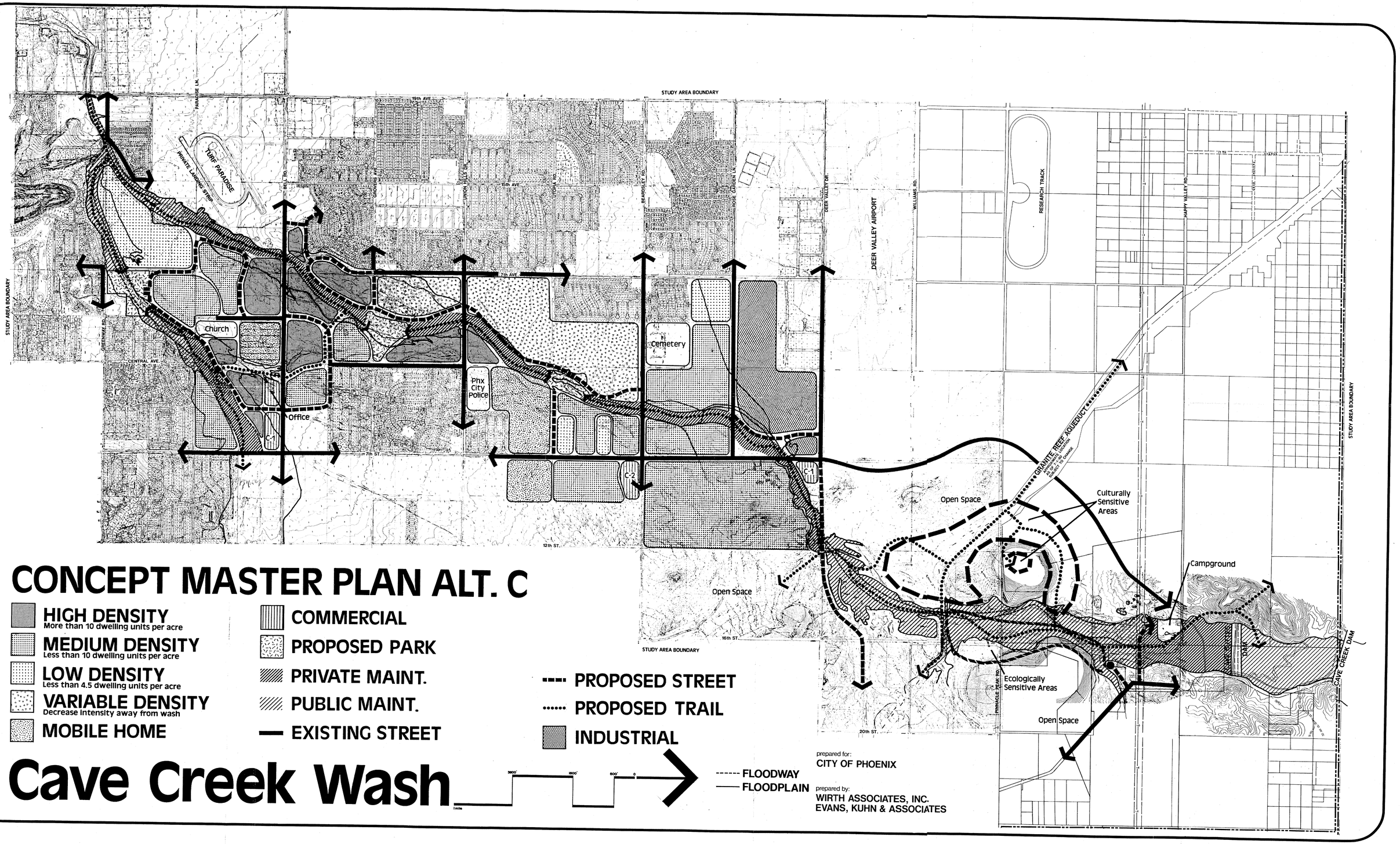

STUDY AREA BOUNDARY
19th AVE.
PARADISE LN.
PRIVATE LANDING STRIP
TURF PARADISE
BELL RD.
GOODES AVE.
UNION HILLS RD.
19th AVE.
JUDGE RD.
BEARDSLEY RD.
ROCK CANYON LN.
DEER VALLEY DR.
DEER VALLEY AIRPORT
WILLIAMS RD.
RESEARCH TRACK
HAPPY VALLEY RD.
SKYLINE DR.
STUDY AREA BOUNDARY
SHEA BLVD.
CENTRAL AVE.
Church
Office
C-1
7th ST.
Phx City Police
Cemetery
C-2
C-1
12th ST.
7th AVE.
GRANITE REEF AQUEDUCT
ALIGNMENT LOCATION SUBJECT TO CHANGE
Open Space
Culturally Sensitive Areas
Campground
Open Space
16th ST.
STUDY AREA BOUNDARY
PINNACLE PEAK RD.
Ecologically Sensitive Areas
Open Space
20th ST.
LAKE PLEASANT DAM
CAVE CREEK DAM
STUDY AREA BOUNDARY
CONCEPT MASTER PLAN ALT. C
HIGH DENSITY
More than 10 dwelling units per acre
MEDIUM DENSITY
Less than 10 dwelling units per acre
LOW DENSITY
Less than 4.5 dwelling units per acre
VARIABLE DENSITY
Decrease intensity away from wash
MOBILE HOME
COMMERCIAL
PROPOSED PARK
PRIVATE MAINT.
PUBLIC MAINT.
EXISTING STREET
PROPOSED STREET
PROPOSED TRAIL
INDUSTRIAL
Cave Creek Wash
3900'
1800'
600'
0
1 mile
FLOODWAY
FLOODPLAIN
prepared for:
CITY OF PHOENIX
prepared by:
WIRTH ASSOCIATES, INC.
EVANS, KUHN & ASSOCIATES

FIGURE C-13