The City of Glendale, Arizona

Storm Water Management Plan

By

Camp Dresser & McKee Inc.

Jointly Funded
by the
City of Glendale
and
Flood Control District of Maricopa County

January 1986

CITY OF GLENDALE

5850 West Glendale Avenue
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January 2, 1986

Letter of Introduction

Glendale Storm Water Management Plan

Dear Reader:

The City of Glendale contracted with Camp Dresser & McKee, Inc. to create this Storm Water Management Plan. The plan has been jointly funded by the City and the Flood Control District of Maricopa County to resolve drainage planning issues in the study area.

Camp Dresser & McKee, Inc. (CDM) has worked diligently to complete the Study in close coordination with the technical review team. CDM and the review team must be commended for the final work product and the professional completion of the Study as presented.

This Plan incorporates consideration of regional drainage issues as a result of the joint efforts of the Flood Control District and the City of Glendale. While this product stands alone by discussing local drainage solutions, these solutions have been influenced by the regional aspects of resolving drainage problems that are area wide.

Regional coordination is further enhanced through a separate Glendale-Peoria Area Drainage Master Study that is jointly funded by the Flood Control District and the Cities of Glendale and Peoria.

The City would like to take this opportunity to express our gratitude to the Flood Control District for participating in the funding and the technical review of the plan. Additionally it is appropriate that we thank Salt River Project for also providing technical review representation.

Finally, the City thanks the participants in the review process listed below.

Sincerely,

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Section One

Introduction

1. Introduction

BACKGROUND

The City of Glendale, Arizona, while located in an arid region, does experience occasional significant storms. The City does not currently have a drainage system that is adequate to handle these flows, which are a nuisance and cause considerable inconvenience during moderate storms and can cause property damage during major storms.

In order to solve these problems, the City sought to develop a Stormwater Management Plan that would allow the rational implementation of the necessary facilities. The City selected Camp Dresser & McKee Inc. (CDM) to develop this plan.

GOALS

Before an effective Stormwater Management Plan could be developed, it was necessary to determine the goals of the plan and to establish guidelines that would be followed in developing it.

The primary goal of the Stormwater Management Plan is the reduction of existing flooding problems. The plan also seeks to mitigate future flooding problems that may be experienced in the City due to changes in land use. The plan is intended to be flexible so that it can be implemented in stages, and so that it can be readily modified to respond to urbanization patterns different from those assumed for the purpose of this study.

SCOPE OF STUDY

The process of developing the Stormwater Management Plan was divided into the following tasks:

Task 1	Acquire and Review Basic Data
Task 2	Prepare Study Area Map
Task 3	Define Stormwater Model/Hardware
Task 4	Model the Existing Storm Drainage System
Task 5	Prepare Conceptual Storm Drainage Alternatives
Task 6	Hydraulic Analysis of Alternatives
Task 7	Cost-Effectiveness Evaluation of Alternatives
Task 8	Prepare Master Storm Drainage Plan
Task 9	Prepare a Capital Improvement Program
Task 10	Implement Stormwater Model on City's Computer System

This document represents the completion of Tasks 1 through 10 listed above.

Section Two

Study Area

2. Study Area

The City of Glendale is located in the center of Maricopa County, in south-central Arizona. The City is bounded on the southeast by the City of Phoenix and on the northwest by the Cities of Peoria and El Mirage. The study area addressed by the Stormwater Management Plan is defined by the following boundaries: to the north, Pinnacle Peak Road; to the east, 51st and 43rd Avenues; to the south, Camelback Road; and along the western perimeter, New River, Northern Avenue, 67th Avenue, the Arizona Canal, and New River again at the northwestern corner (See Figure 1).

LAND USE

Glendale was originally a trade and service center for the rich agricultural area lying west of the City of Phoenix. Glendale's population remained relatively constant until after World War II, at which time a large population influx occurred due to the conversion of farmland to residential tracts. Between 1970 and 1980, the population increased by 176 percent. The 1980 population of Glendale was 96,988, and the 1985 population is estimated to be 130,000. According to the City of Glendale Plan 1980-2005, additional population growth of 50 to 100 percent is expected by the year 2000.

The General Plan also indicates that land use in the City is distributed among the following categories, with approximate percentages for each: agriculture (48%); residential development (24%); undeveloped land (17%); schools and parks (6%); commercial enterprises (3%); and industry (2%). Growth is anticipated in residential, commercial, and industrial development while agricultural use is expected to decline.

TOPOGRAPHY

Glendale is situated in the basin of New River, which originates in the New River Mountains north and east of the City.

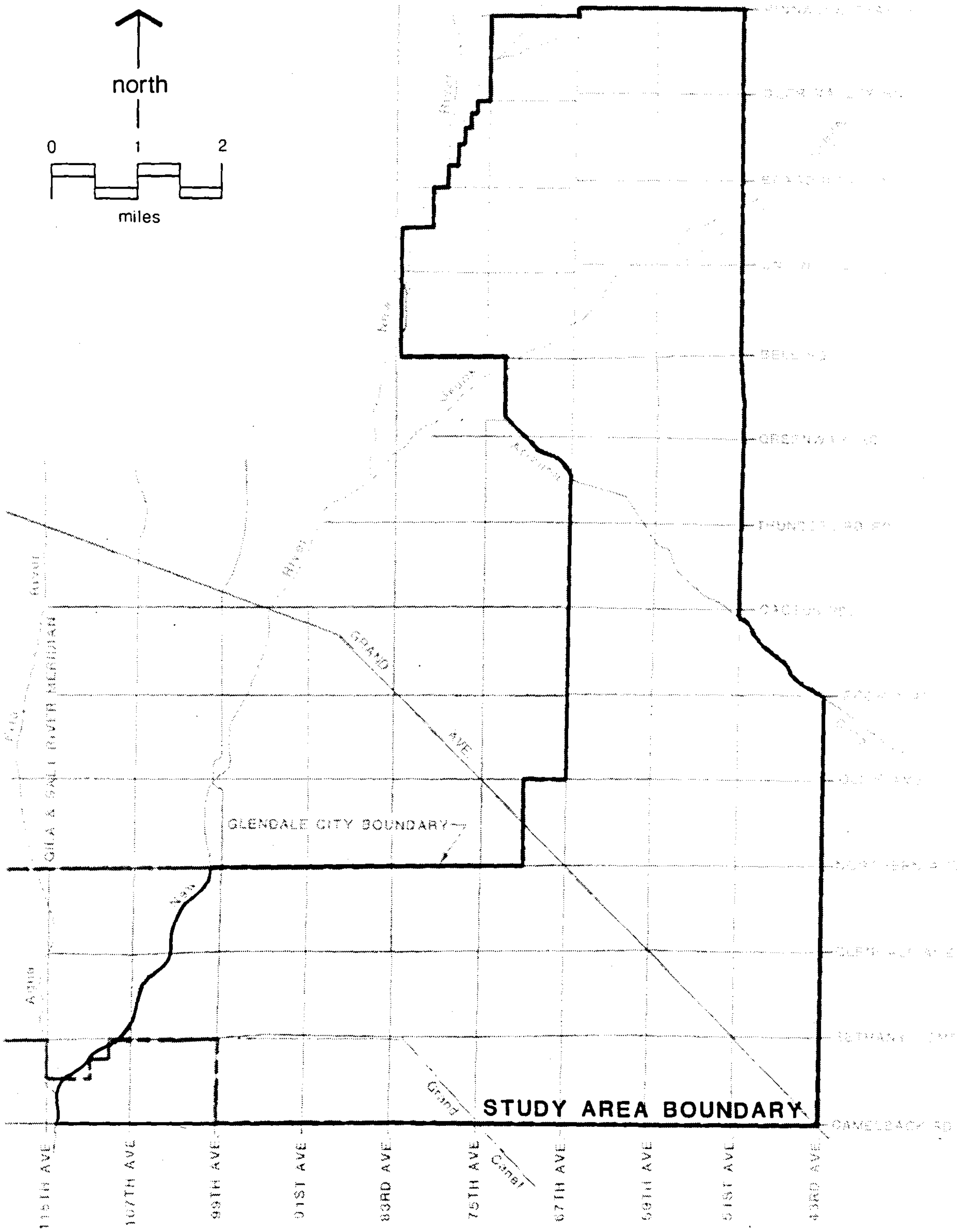


FIGURE 1

STUDY AREA

The primary watercourses in the area include the Agua Fria River, New River, and Skunk Creek. The Agua Fria River starts in the mountains of central Arizona near Prescott, and flows south more than 100 miles before joining the Gila River 15 miles west of Phoenix. New River, a tributary of the Agua Fria River, flows generally southwesterly until it joins the Agua Fria River west of Glendale. Skunk Creek is a major tributary of New River which starts in the New River Mountains and flows generally southwest until it joins New River west of Glendale. Apart from the major rivers in the area, natural drainage was previously provided by poorly defined washes flowing across the alluvial fan. However, when valley land was converted to agricultural uses, these small washes were generally obliterated.

The terrain in the City of Glendale is flat, with a gradual slope of about 4.5 feet per 1,000 towards the southwest and about 3 feet per 1,000 along the principal streets, which run north and south or east and west in a rectangular grid.

GEOLOGY

The geology in the Glendale area consists of a basement complex predominantly of Precambian schistose and massive metaigneous rocks with lesser amounts of gneiss and quartzite. These are overlain with and intruded by igneous rocks consisting of granites, rhyolite, andesite, flows of vesicular basalt, tuff, and tuffaceous agglomerate. The valleys in this area are filled with alluvium derived from the same general material of which the bedrock is composed. Older alluvium is found on the side slopes of the valleys and underlying more recent deposits in the valleys, and consists of well-cemented residual soil and debris, mostly sand and silty sand. Recent alluvium is found in valley areas near streambed channels, and consists of uncemented silts, sands, gravels, cobbles, and boulders. The total depth of the alluvium is estimated to be 1,000 to 1,200 feet in the Glendale area. The groundwater table is about 250 to 300 feet below the surface.

SOIL CHARACTERISTICS

Major soil types found in the City of Glendale have been mapped by the United States Department of Agriculture Soil Conservation Service (SCS). Generally, these soils are loams, sandy loams, and clay loams. A hydrologic group classification has been determined for soils by the SCS to indicate the general potential of various soils to generate runoff from rainfall. The following definitions of hydrologic soil groups are used:

Group A (Low runoff potential). Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission.

Group B Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well, to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

Group C Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

Group D (High runoff potential). Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

The soil types found within the City generally belong to the B hydrologic soil group, which have a moderately low runoff potential. Some soils belonging to the A and D soil groups are also found within the City.

For the analysis of the stormwater system, infiltration rates were used as a parameter rather than the hydrologic soil group. Figure 2 shows the general pattern of infiltration rates within the City (Soil Survey of Maricopa County, 1977).

RAINFALL

Rain storms that occur in the Glendale area are generally one of three types, as indicated by the U. S. Army Corps of Engineers (Design Memorandum No. 2, 1982). These storms are described below:

- General Winter Storms. These storms originate from the north Pacific Ocean, and can occur from late October through May, although they are most common from December through early March. These storms frequently last several days and spread generally light to moderate precipitation over large areas. Although these storms are generally of low intensity, combined with snowmelt from the mountains, their large areal extent and long duration, these storms can produce high peak flows on the large rivers in the area.

- General Summer Storms. These storms generally originate from the southeast or south and are often associated with tropical storms or hurricanes. The storms can occur from late June through mid-October, but are most frequent from August through early October. They usually last from 1 to 3 days, and produce locally heavy precipitation for many areas within a widespread area of light to moderate rain.

- Local Storms. These convective storms are generally referred to as thunderstorms or cloudbursts and consist of heavy downpours of rain over relatively small areas for short periods of time. They are most prevalent during the summer months of July to September. The runoff from these storms generally has a high peak and low volume, and can result in serious flash floods.

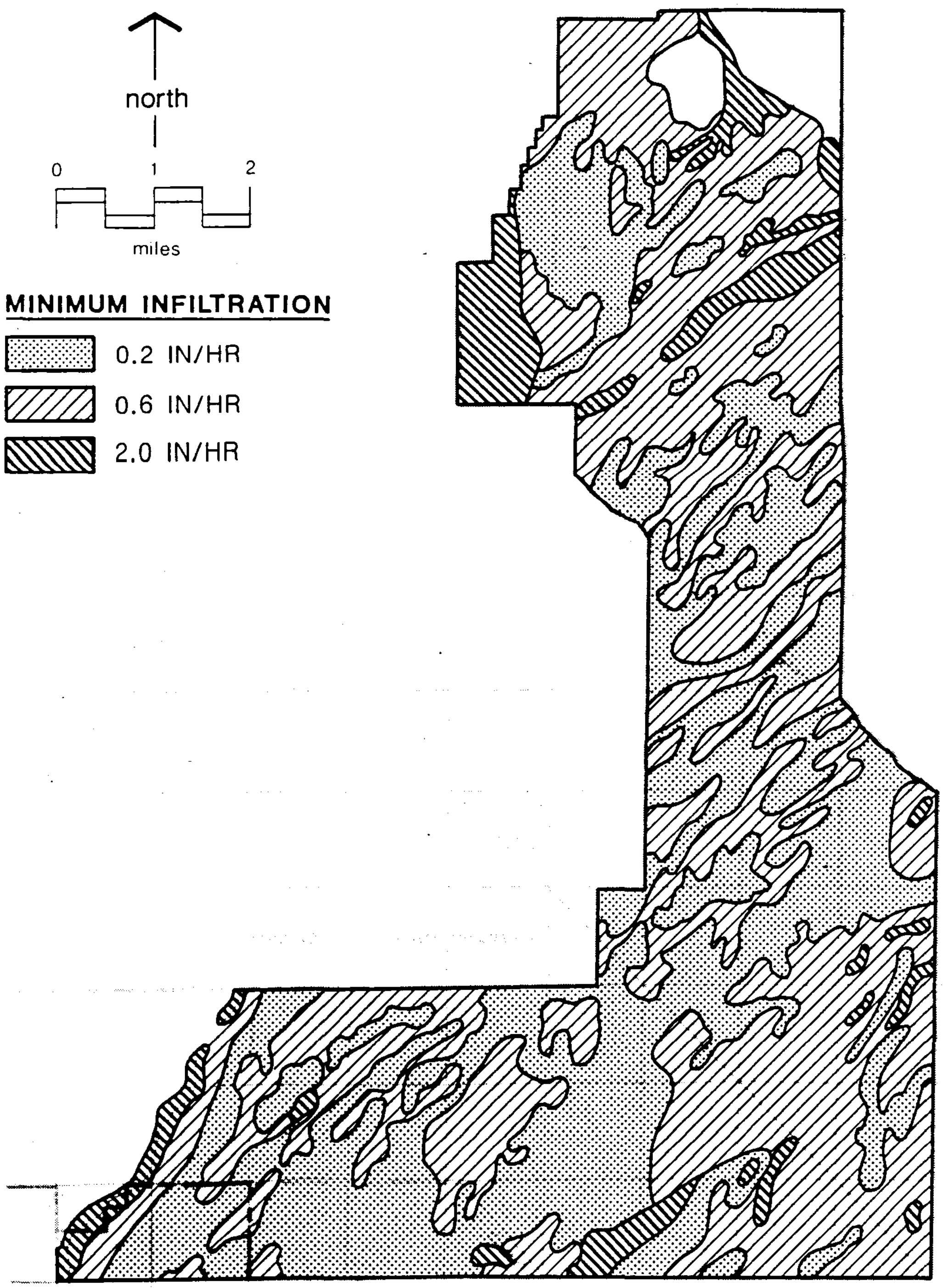


FIGURE 2

GENERAL PATTERN OF INFILTRATION RATES

Section Three

Storm Drainage System

3. Storm Drainage System

EXISTING SYSTEM

Glendale's existing storm drainage system, including the Salt River Project (SRP) facilities, is shown on Figure 3. For the most part, storm runoff is carried in the streets themselves, and the flows generally follow the natural gradient of the land towards the south and west. For runoff originating in the northern part of the City, the railroad parallel to State Highway 93 (Grand Avenue) running northwest to southeast forms a barrier to this natural drainage pattern due to the low embankment which was created. Flows can cross the railroad at a few points, primarily at 59th Avenue and Glendale, and 51st Avenue, but the capacity of these crossings is limited.

As a part of the construction of State Highway 93 through Glendale, the Arizona Department of Transportation (ADOT) constructed a number of storm drains. These drains were installed in six different segments, extending from Thomas Road and Grand Avenue on the south to Butler Drive and Grand Avenue on the north. The drains range in size from 18- to 36-inch diameter pipe. The system was only designed to accommodate storm runoff within and adjacent to Grand Avenue, and has a relatively small capacity.

In the central downtown area, there are a number of storm drainage pipes, most of which drain to the ADOT Grand Avenue drainage system.

Other storm drain inlets in the downtown area are used to convey water to irrigation pipes and canals of the SRP system supply lines or drain lines. The City maintains these drain inlets, and in some cases also maintains drain lines where they have been abandoned by the SRP.

The Arizona Canal Diversion Channel (ACDC) is a proposed drainage structure to be located just upstream and nearly parallel to the Arizona Canal. Reach 1, from 75th Avenue and Skunk Creek to 53rd Avenue, is currently under construction. The ACDC will extend about 17.3 miles from Cudia City

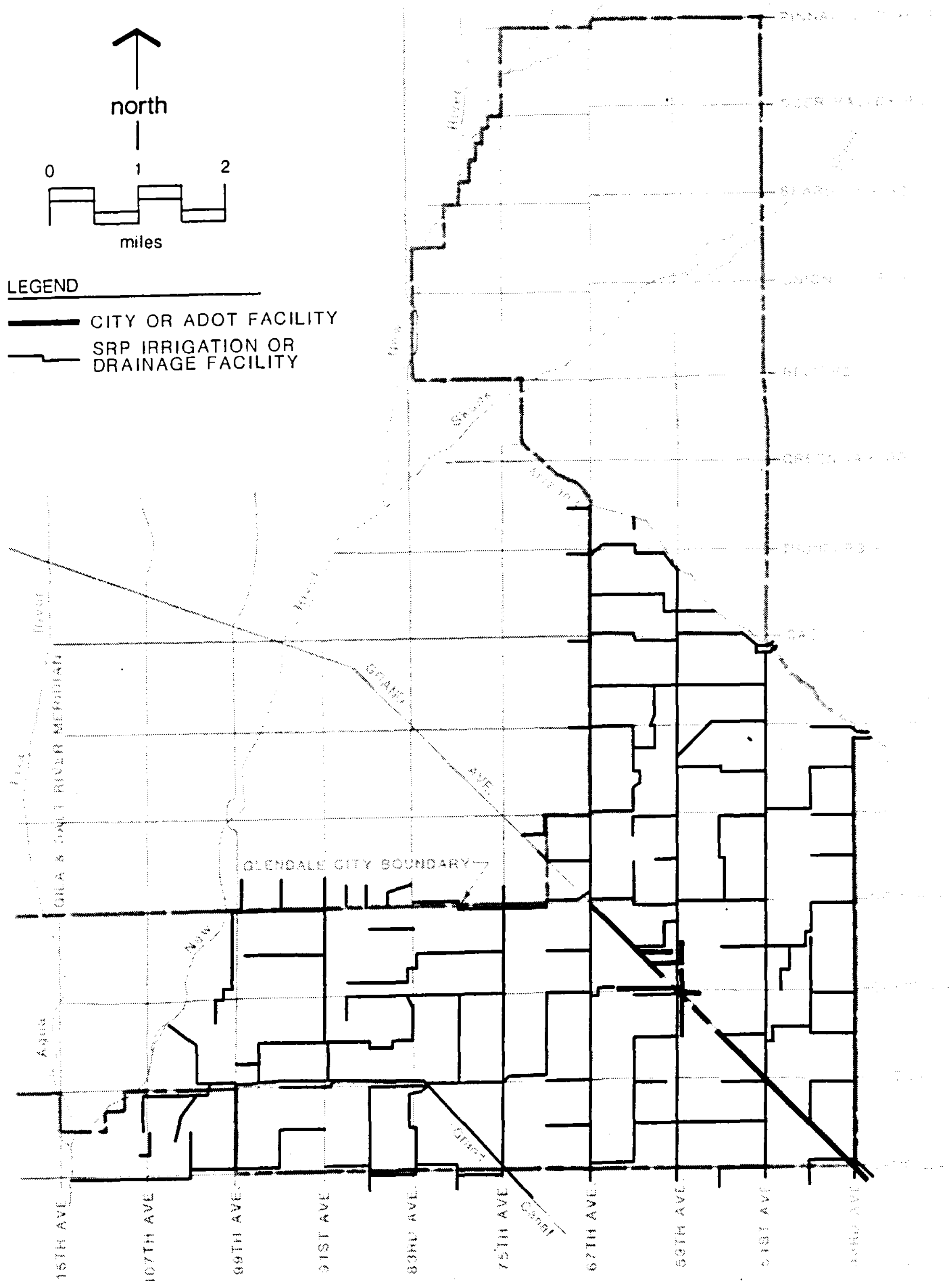


FIGURE 3

EXISTING STORM DRAINAGE SYSTEM

Wash at the upstream end, and will discharge into Skunk Creek. The channel will be concrete-lined and rectangular or trapezoidal, or unlined trapezoidal for various portions of its length. The tops of the channel walls will be at existing ground level, so that side inflow can spill directly into the channel. In areas adjacent to the channel where ponding occurs, pipe inlets will be provided.

The Grand Canal, the primary supply canal for irrigation waters in southwestern Glendale, also receives a limited amount of drainage waters. These drainage waters, which are conveyed in irrigation laterals or drainage ditches, enter the Grand Canal at locations where the Canal is below the natural ground level.

EXISTING DRAINAGE PROBLEMS

The inadequacy of the current drainage system causes a number of problems under existing conditions during intense storms. These problems consist primarily of flooding of streets and intersections and subsequent traffic disruption, as well as ponding of water in ditches and gutters at many locations in the City.

The flooding problems are most severe where the shallow flood flows are interrupted by natural or manmade barriers, which cause ponding of water. This occurs on the north side of Grand Avenue, where the downtown commerical district is particularly affected, and on the north side of the Grand Canal.

A number of intersections in the City also have dip crossings where a shallow gutter along one street extends across an intersecting street to allow passage of stormwater. The flow of traffic at these crossings can be restricted when stormwater flow is high.

With increased development, street flooding has worsened to the point where it is a severe nuisance on the threshold of causing damage to structures and their contents in some areas.

Some flooding occurs because of water that enters Glendale from surrounding areas. In the northern part of Glendale, stormwater enters the City from Phoenix along 51st Avenue. Most of this water flows west on Thunderbird Road and into the ACDC. This is a severe problem making Thunderbird Road impassable, causing property damage, and critically reducing access to the Thunderbird Samaritan Hospital. The remaining stormwater continues south on 51st Avenue and enters the ACDC at Cactus Road.

Flooding problems have also occurred along the Grand Canal, which causes water to pond where the canal is higher than the surrounding ground. Stormwater entering the canal can also cause the canal to overflow.

In the past, considerable water has entered the Arizona Canal during storm periods, causing it to overflow in the Glendale area. When the adjoining drainage channel (ACDC) is completed, this problem will be eliminated because the drainage channel has been designed to carry flows to accommodate the estimated 100-year future peak flow.

RETENTION AND DETENTION BASINS

Retention and detention basins are devices that can be used to reduce the peak storm runoff from urban areas; both types of facilities can store runoff during storms and then release the runoff gradually after the storm passes. Retention basins differ from detention basins as follows: The retention basin has no outlet, and water leaves only by evaporation or percolation into the ground. Stormwater entering the retention basin does not normally enter the storm drain system unless the retention basin overflows. The detention basin, on the other hand, has a small outlet, and flow returns to the downstream drainage system at a low rate. The size of the downstream pipes and ditches can be reduced below what would be required without detention.

The use of retention/detention basins is a relatively new concept for the City of Glendale, having been used only within the last 2 or 3 years. The City now owns and maintains several retention basins, which are used also as city parks. Two of these basins are located at Montarra Park, near

Peoria and 65th Avenues, and at Sunnyside Park, at 63rd and Cholla Street. The City has found that water in these basins tends to percolate very slowly, allowing standing water to remain in the basin for long periods. Occasionally, the City has used portable pumps to drain the basins by pumping water into the street. Dry wells are in the design stages to facilitate percolation and reduce retention time in parks.

In addition to the City-operated retention basins, there are a number of privately owned retention basins. At the present time, developers in the City are required to install retention basins for new development. Parking lots have typically been used as retention facilities for commercial developments. Problems have been experienced with landscaping and filling activities in these areas with small retention basins, thereby reducing or eliminating the retention storage. The present policy is to use larger retention sites that serve all or major portions of developments.

Section Four

Stormwater Modeling

4. Stormwater Modeling

NEED FOR A STORMWATER MODEL

The development of a Stormwater Management Plan for the City of Glendale required the determination of peak flows and runoff hydrographs for each of the subdrainage areas in the City, and the use of a computerized runoff simulation model was chosen as the most desirable method for obtaining this information. Statistical or manual computation methods were not felt to be appropriate for developing runoff hydrographs for the following reasons: historical runoff measurements are not available; flow patterns in the area are quite complex; and land uses in the area have changed rapidly from rural to suburban, to urban.

The computerized model more easily permits the evaluation of existing stormwater conditions and the determination, through simulation, of the response of the storm drainage system to various corrective actions. Various runoff models were investigated for possible use in the project, including the Stormwater Management Model (SWMM) developed by the Environmental Protection Agency, the HEC-1 Model developed by the Corps of Engineers, and the Illinois Urban Drainage Area Simulator (ILLUDAS) Model developed by the Illinois State Water Survey.

The SWMM Model was felt to be the most appropriate tool for developing the runoff hydrographs because of its capabilities for simulating runoff and routing subsequent hydrographs for both rural and urban areas.

APPLICATION OF SWMM MODEL

The SWMM Model simulates the runoff pattern from a specific storm event by applying a rainfall pattern to the watershed area and calculating the path of the water based on the physical characteristics of the watershed.

Input data for the SWMM Model is developed for each of the subdrainage areas. The drainage area, slope, and width of each subarea is estimated from topographic maps. The amount of impervious area is estimated from land use maps, applying appropriate factors for each land use type. Infiltration rates are estimated from soils maps of the area and known characteristics of the various soil types. Roughness values and surface storage parameters are estimated from site visits.

Each of the subareas is connected to a pipe segment for which the pipe size, slope, and Manning's roughness coefficient is input. Connection to downstream pipe segments is shown, and branch pipes are also indicated so that runoff hydrographs can be combined at appropriate locations.

For future land use conditions, appropriate changes to the imperviousness and infiltration rate parameters are made based on the estimated changes in land use types.

The proposed pipe improvements are simulated with the SWMM Model by changing the pipe size as appropriate.

HYDROLOGIC CRITERIA

Stormwater facilities in Glendale must be in conformance with the current City drainage regulations. These regulations are set forth in Chapter 17A of the City Code, which was adopted in 1984.

These regulations require that residential subdivisions and commercial and industrial areas retain all stormwater from a 10-year, 2-hour storm. Local streets must be constructed to carry the runoff from a 10-year storm between the curbs. Major and minor arterial streets (section and mid-section line streets) must be constructed to carry the runoff from a 100-year storm within the right-of-way.

No additional hydrologic guidelines have been established for the design of stormwater facilities in the City of Glendale. In the past, the design of most facilities has been based upon the rational method or the SCS TR-55 procedures.

For the Glendale Stormwater Management Plan, local storm conditions (as defined in Section 2) were found to be most appropriate for use in calculating the peak flow which was used to determine the required size of facilities. The design rainfall that was used in the SWMM model was determined by examining historical rainfall data and reviewing methods currently used by other cities and agencies near Glendale.

Many cities and agencies in the area use the rainfall intensity-duration-frequency relation developed for Phoenix as the basis for determining the peak design rainfall. These curves are prepared using methods of the U.S. Weather Bureau and rainfall data prepared by the Weather Bureau for the Soil Conservation Service in March 1967, and revised slightly in June 1975 to reflect new Weather Bureau information. A review of these curves indicated that they were reasonable for use in the Glendale study area.

The SWMM model requires the use of an entire rainfall pattern for a storm, rather than just the peak rainfall value. Various methods were investigated for constructing a design storm from the intensity-duration-frequency curves. When these curves are used for simple calculation of peak runoff rates, a time of concentration for the watershed is determined and the average rainfall intensity for that time period is taken from the curves using the desired storm frequency. This method estimates the peak runoff rate, but does not give a representative runoff volume for a storm of the desired frequency, since the actual storm occurs over a longer period of time than the time of concentration. In order to accurately represent the hydrograph in the SWMM model, longer duration rainfall intensities are considered in addition to peak rainfall intensities.

While the rainfall intensity curves indicate rainfall magnitude, they do not show the relative placement of the peak rainfall within the storm, which is an important factor in determining the capacity of storage facilities. In order to locate the peak rainfall, the actual rainfall records for a number of the major local storms were plotted to determine a common pattern. It was observed that the most intense rainfall in these storms occurred fairly consistently within the first hour of the storm. Therefore, to best represent this condition, it was determined that design storms should have the peak rainfall at the beginning of the storm.

Using the Phoenix intensity-duration-frequency curve, average rainfall intensities were read for 15-minute intervals ranging from 15 minutes to 6 hours duration. The average intensities were then converted into incremental intensities for each 15-minute period. Results of these tabulations are shown in the Appendix.

Section Five

Alternative Stormwater Plans

5. Alternative Stormwater Plans

BACKGROUND AND CONCEPTS

The development of alternative stormwater plans required that consideration be given to existing facilities within the study areas. From the review of available data, existing drainage facilities were tabulated and included in a study area map. Field inspections were conducted as necessary to verify the location of pipelines, ditches, watershed boundaries, and other drainage features. These data were compiled to ensure that the alternative stormwater plans would not conflict with existing water and sewer lines. Other existing features, such as SRP irrigation and drainage facilities and the Santa Fe Railroad along Grand Avenue, were given consideration during the development of alternative stormwater plans. It was felt that the proposed alternatives should mimimize any disruption to existing facilities and to current agriculture in the area.

In determining the types of stormwater systems that should be considered, it was felt that an underground pipe drain system would be preferable to an open ditch system because pipes can provide greater safety. As land within the City rapidly becomes urbanized, ditches would be used only on an interim basis in areas where the immediate installation of pipes could not be justified (such as sparsely populated rural areas).

The pipes were routed to follow the natural land slope towards the southwest as much as possible and aligned with the rectangular grid of streets in order to eliminate the need to obtain additional rights-of-way. In some cases, the 1/4 section streets were used due to utility crowding on major streets. The pipes were also routed so that the entire length of pipe drain to its outlet would be within the City of Glendale, rather than cross the City boundary. For this reason, all stormwater from land south of the Arizona Canal was assumed to be carried at least as far south as Northern Avenue, and then west to New River.

The pipe network layout for each alternative has been developed to a resolution of 1/2 mile, which will serve watershed areas of 160 acres each. This minimum level of detail was considered appropriate for a city-wide stormwater management plan, with major drainage facilities located along section and half-section boundaries.

STUDY AREAS

For the purpose of developing alternative stormwater plans, the City was divided into these four main areas:

A. Camelback Road to Northern Avenue.

B. Northern Avenue to ACDC.

C. ACDC to Skunk Creek.

D. North of Skunk Creek.

These areas, as shown on Figure 4, were selected based primarily on existing drainage patterns. Area A, which includes most of the land area currently developed within the City, drains westerly to New River downstream of its confluence with Skunk Creek. Area B is situated immediately to the north of Area A and also drains to New River downstream of the Skunk Creek confluence. Area B was considered separately, however, to facilitate evaluation of alternative discharge routes to New River, either directly to the west or to the south through Area A. Drainage in Area C is toward the south to the ACDC, which forms the drainage barrier between Areas B and C. Most of Area D drains to Skunk Creek, which forms the drainage barrier between Areas C and D. The extreme western portion of Area D drains to New River upstream of its confluence with Skunk Creek.

Areas A and B - Camelback Road to ACDC

For the purposes of this discussion, the alternatives considered for Areas A and B are described jointly. This is done because storm runoff from Area B is routed through Area A in some of the alternatives considered.

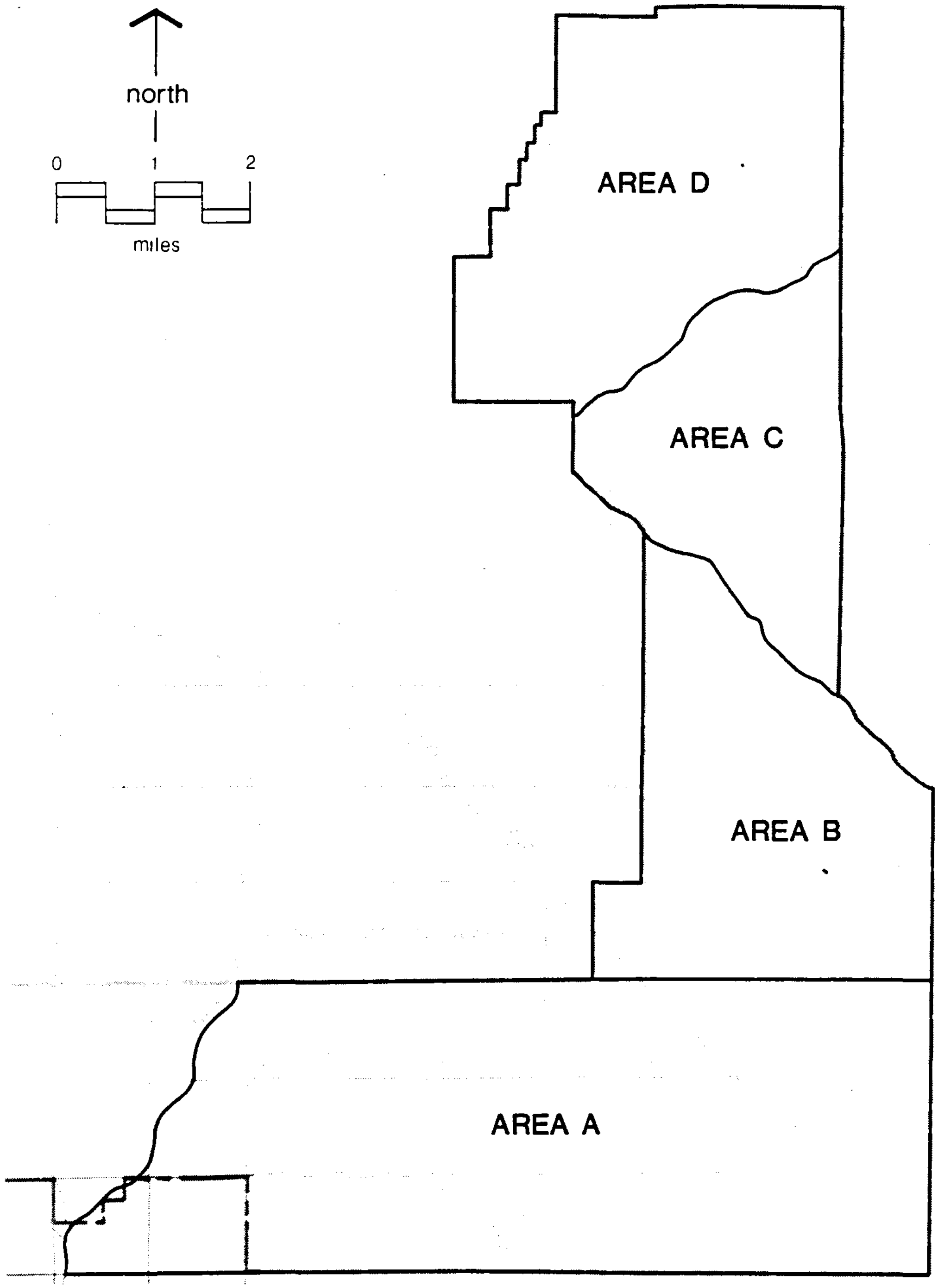


FIGURE 4
STORMWATER AREAS

A total of five alternative drainage systems were considered for Areas A and B, which are identified as Alternatives 1, 1A, 2, 3, and 4. The specific pipe network layout for each alternative is described below and illustrated on Figures 5 through 9.

For all alternatives, drainage from Area B is collected along 51st, 59th and 67th Avenues, routed southerly to Northern Avenue, and then westerly to Grand Avenue. This establishes the Northern - 67th - Grand Avenue intersection as the common drainage outlet point from Area B.

Alternative 1

For this alternative, drainage from Area B is routed directly west along Northern Avenue to New River. Drainage from most of Area A is collected along Camelback Road, and is then conveyed westerly to New River.

Alternative 1A

Runoff from Area B is first routed 1/2-mile south along 67th Avenue and is then directed westerly to New River along Orangewood Avenue, an alignment midway between Northern and Glendale Avenues. This alternate discharge route was selected to avoid utilities located along Northern Avenue. Runoff from the portion of Area A east of 75th Avenue is collected along Camelback Road and conveyed westerly, as in Alternative 1. However, runoff is then routed northwesterly along the Grand Canal and finally westerly along Bethany Home Road to New River. This alternate discharge route from Area A was selected to avoid crossing of the Grand Canal. This route also avoided installation of a major pipe beneath Camelback Road east of 75th Avenue, thus reducing interference with existing utilities.

Alternative 2

For this alternative, runoff from Area B is routed directly south to Camelback Road. Drainage from most of Area A is collected along Camelback Road and conveyed westerly to New River, as in Alternative 1. Therefore, for this alternative, runoff from nearly all of Areas A and B drains to a single major collector along Camelback Road which discharges to New River.

Alternative 3

Runoff from Area B is routed to New River parallel to Northern Avenue and offset 1/2-mile to the south, as in Alternative 1A. Runoff from most of Area A is collected along an alignment parallel to Camelback Road and offset 1/2-mile to the north. This discharge route for Area A was selected to avoid installation of a major drainage pipe beneath the entire length of Camelback Road, thus reducing interference with existing utilities.

Alternative 4

Runoff from most of Area A is routed to New River parallel to Camelback Road and offset 1/2-mile to the north, as in Alternative 3. Runoff from Area B is routed south along 67th Avenue, west between Glendale Avenue and Bethany Home Road, and finally south along 83rd Avenue to the main drainage collector in Area A. This indirect flow path from Area B, rather than the direct path south along 67th Avenue as in Alternative 2, was selected to minimize the size of the main drainage collector needed to cross the Grand Canal.

Area C - ACDC to Skunk Creek

Two alternative drainage systems were considered for Area C, which are identified as Alternatives 5 and 6. The specific pipe network layout for each alternative is described below and illustrated on Figures 10 and 11.

Alternative 5

For this alternative, all runoff from Area C is routed south to ACDC.

Alternative 6

For this alternative, runoff from Area C south of Bell Road is routed south to ACDC. However, runoff from Area C north of Bell Road is routed westerly to Skunk Creek.

Area D - North of Skunk Creek

The area north of Skunk Creek consists of three parts: the proposed Arrowhead Ranch, the lands north of Arrowhead Ranch, and the lands south of Union Hills Drive (See Figure 12). Arrowhead Ranch will have an independent stormwater system that will carry some runoff westerly to New River and some southerly to Skunk Creek. Stormwater from the lands north of Arrowhead Ranch will flow southwesterly to a levee around Arrowhead Ranch, at which point a portion will be directed westerly to New River and the remainder southerly to Skunk Creek. Stormwaters from the lands south of Union Hills Drive will flow in roadside ditches to New River and Skunk Creek.

Since the proposed drainage facilities for Arrowhead Ranch will be entirely within Arrowhead Ranch, and stormwater from the other two parts of Area D are currently accommodated, or will be accommodated as part of land development projects, no further improvements were considered in Area D as part of the stormwater plan.

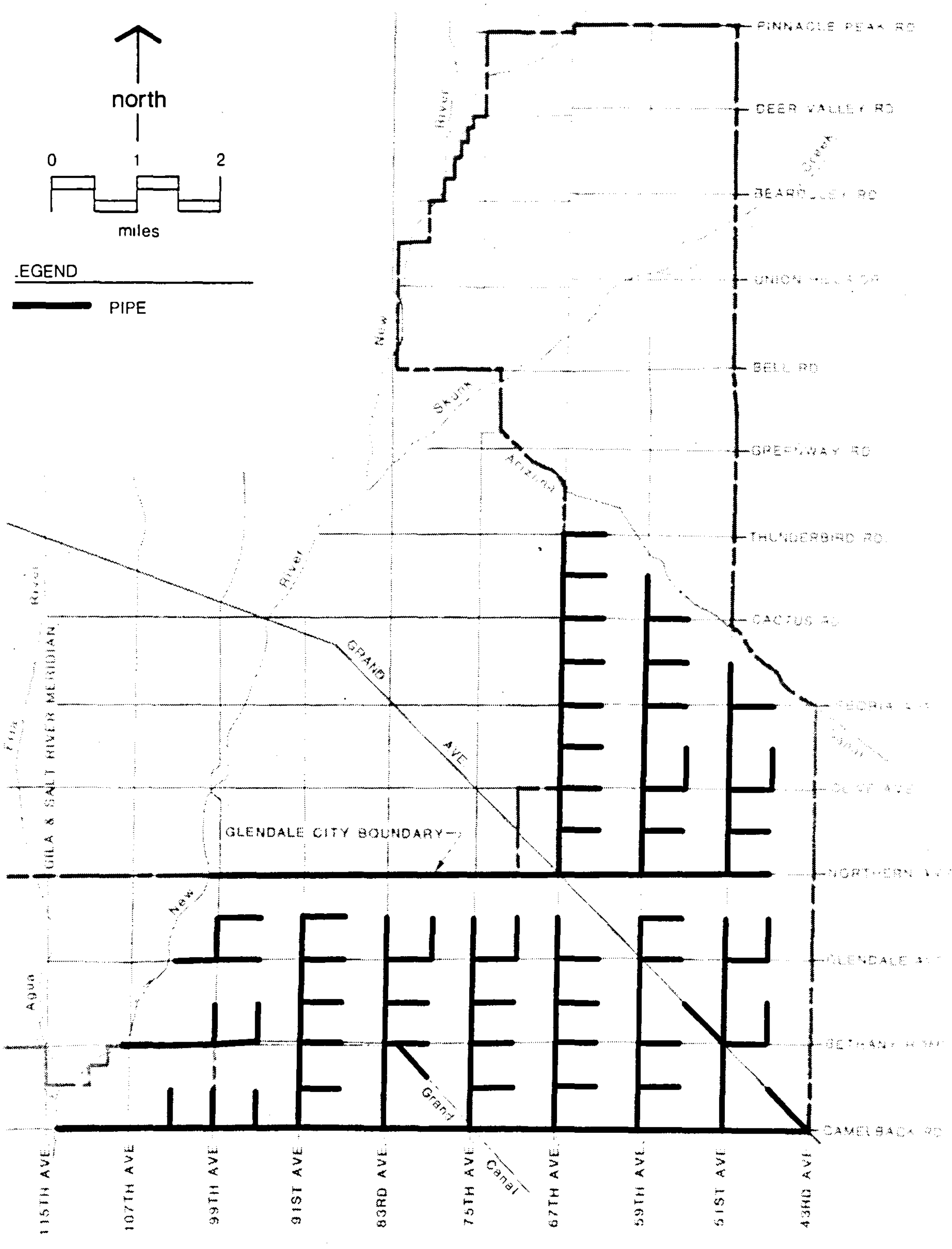


FIGURE 5

ALTERNATIVE 1

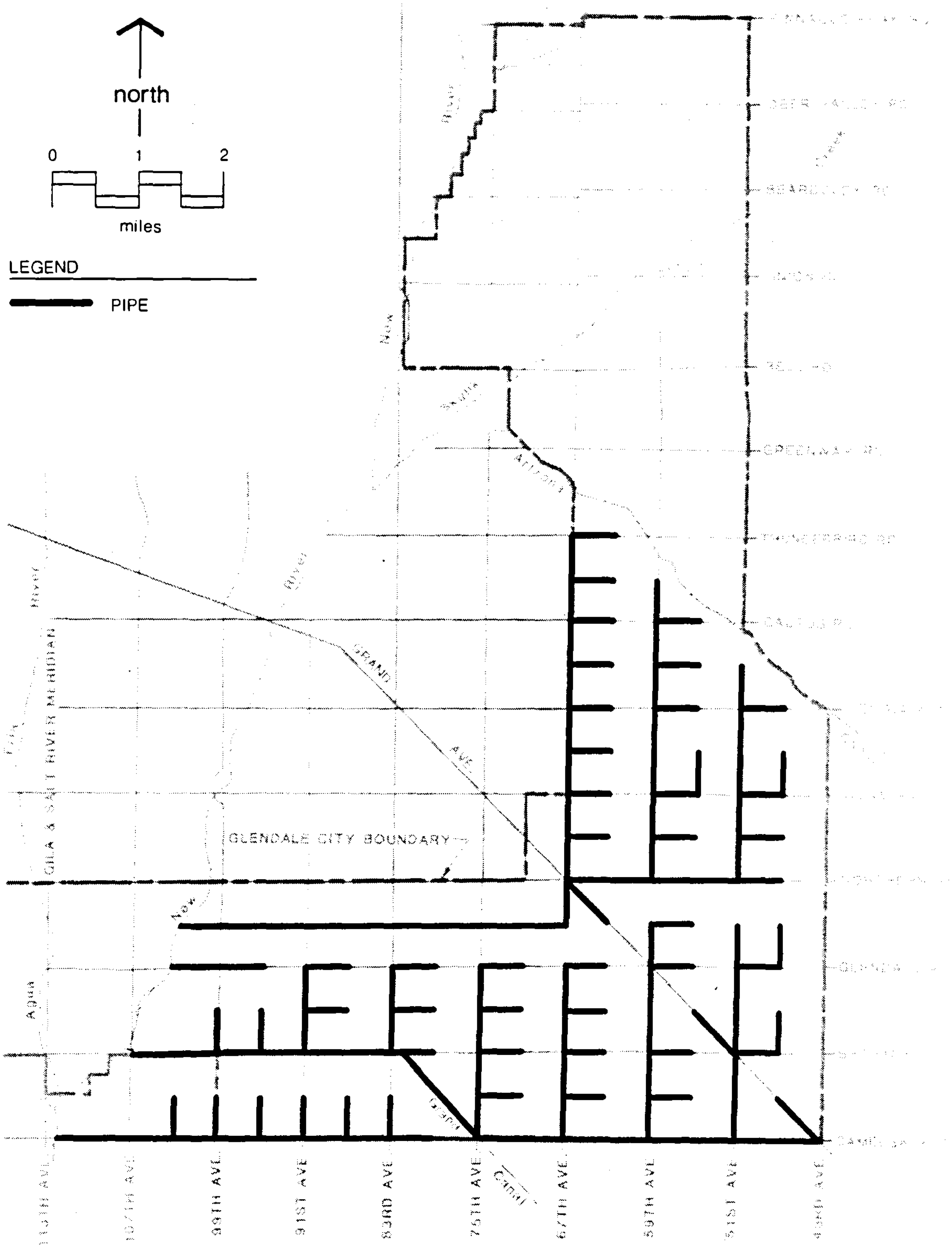


FIGURE 6

ALTERNATIVE 1-A

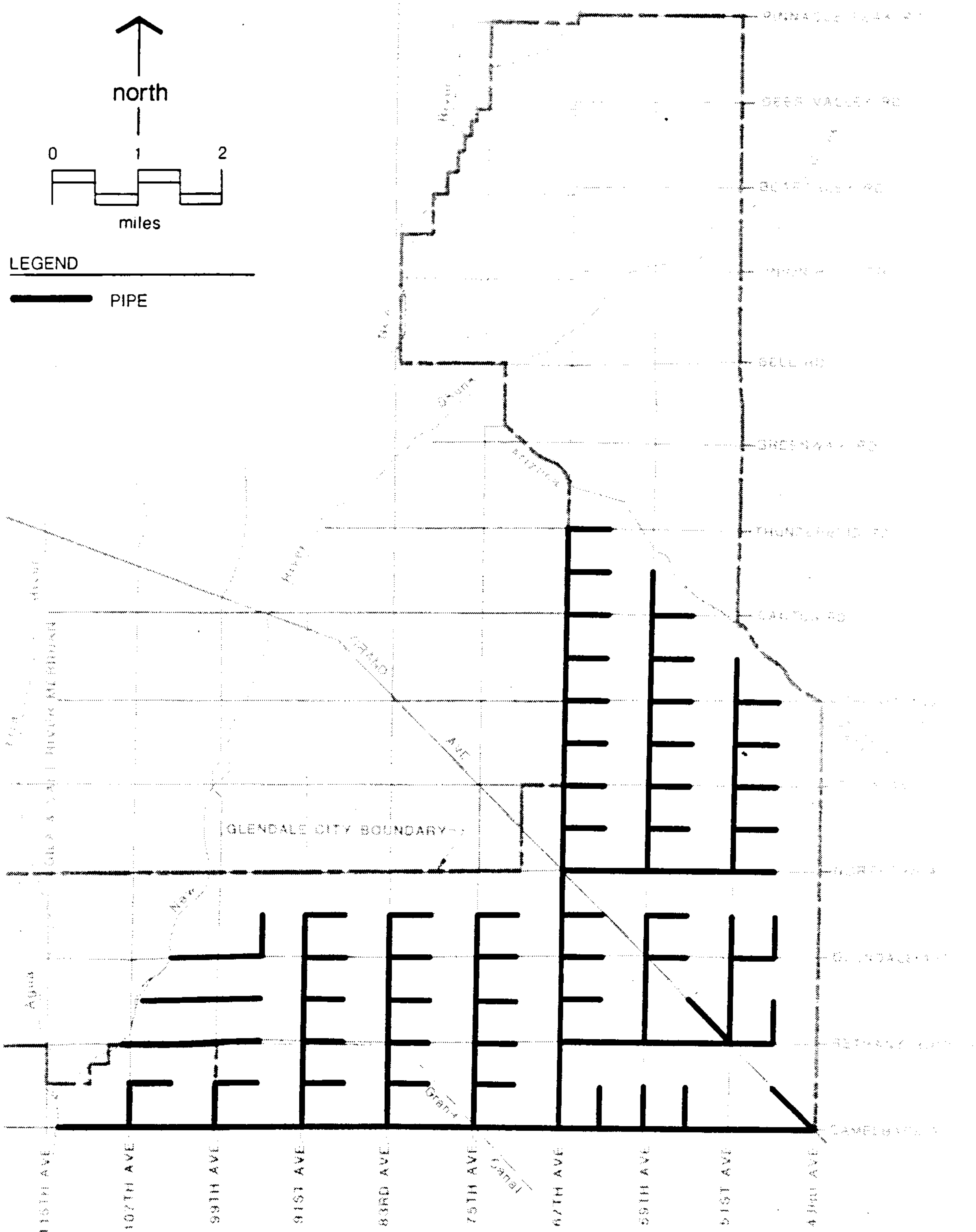


FIGURE 7

ALTERNATIVE 2

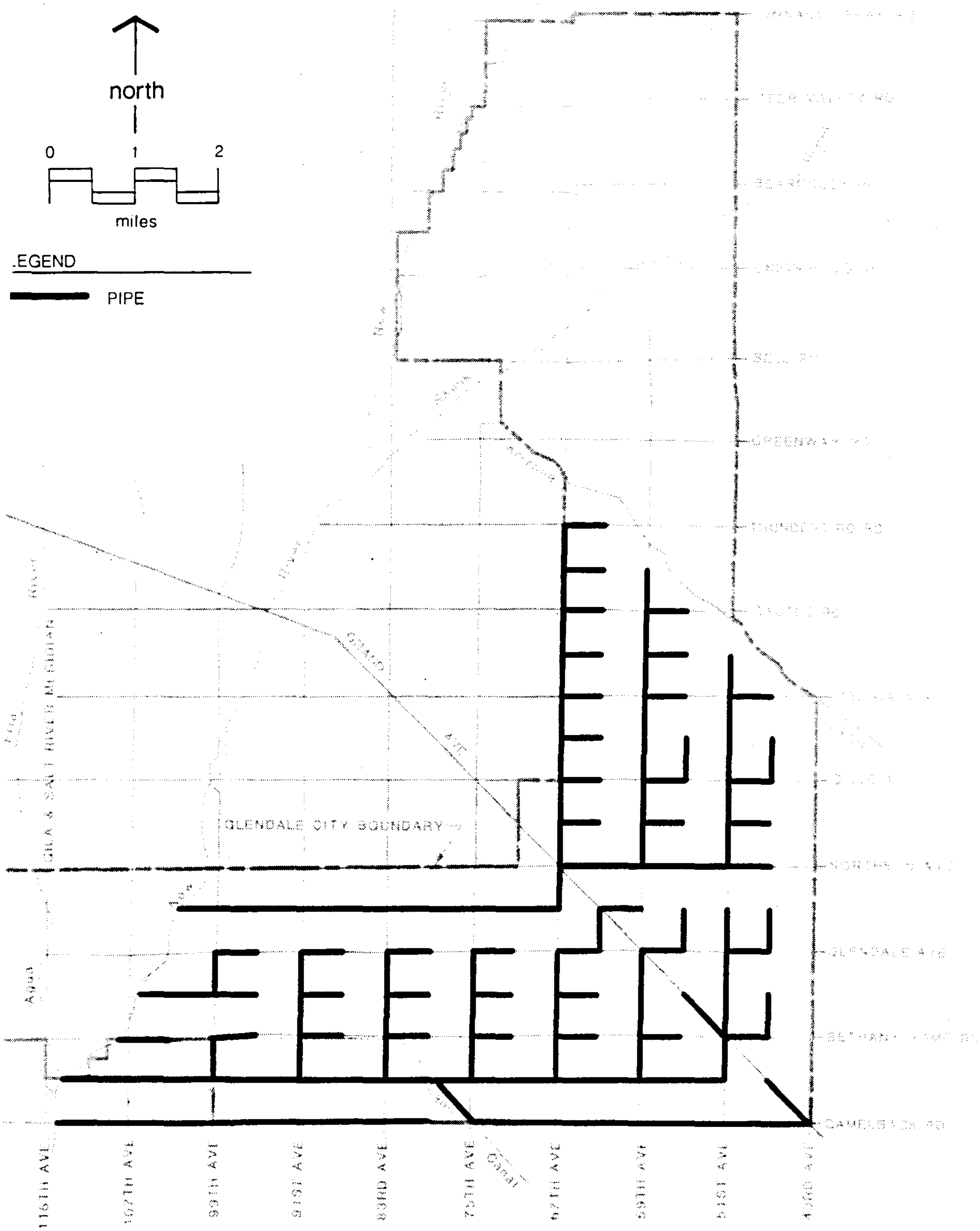


FIGURE 8

ALTERNATIVE 3

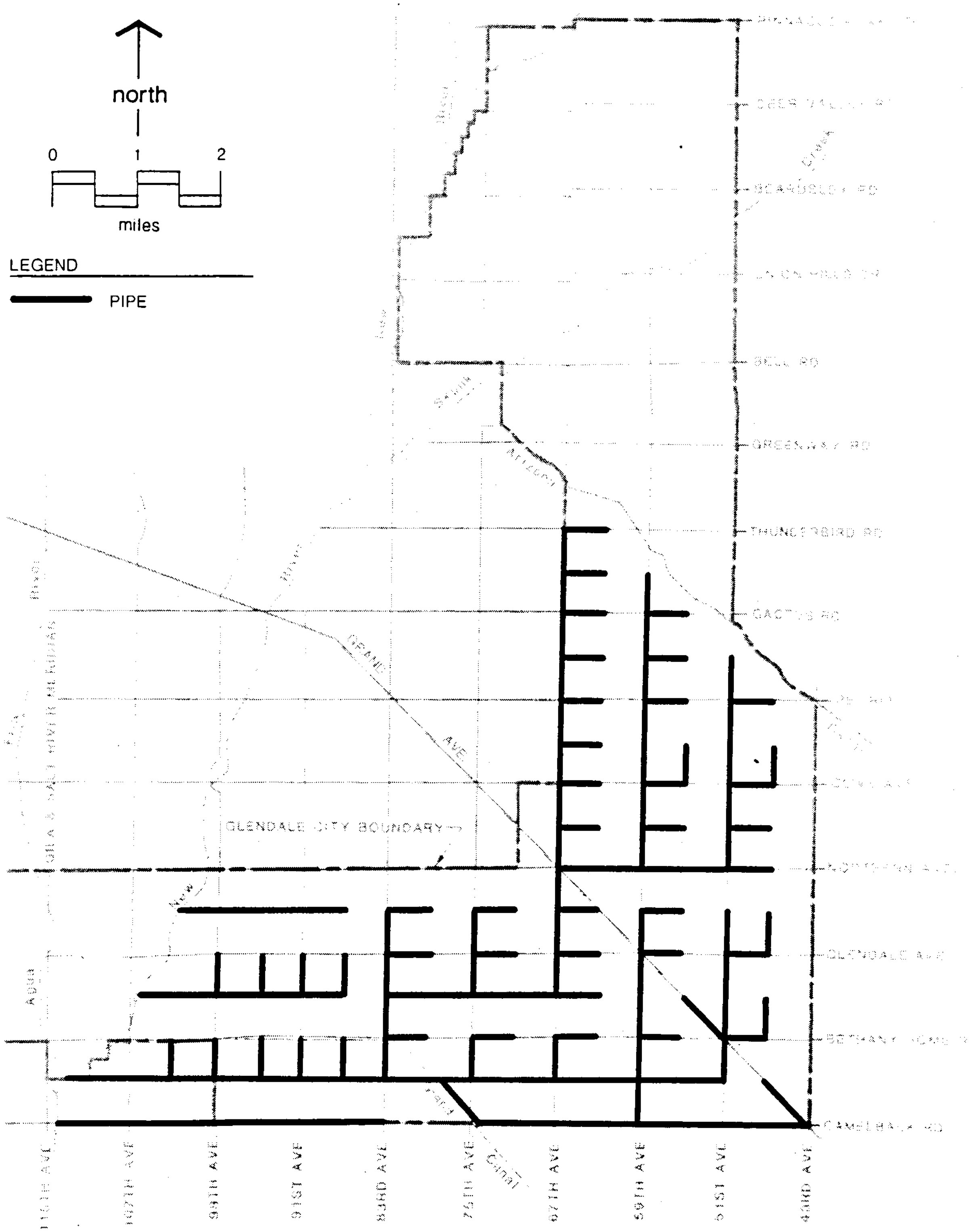


FIGURE 9

ALTERNATIVE 4

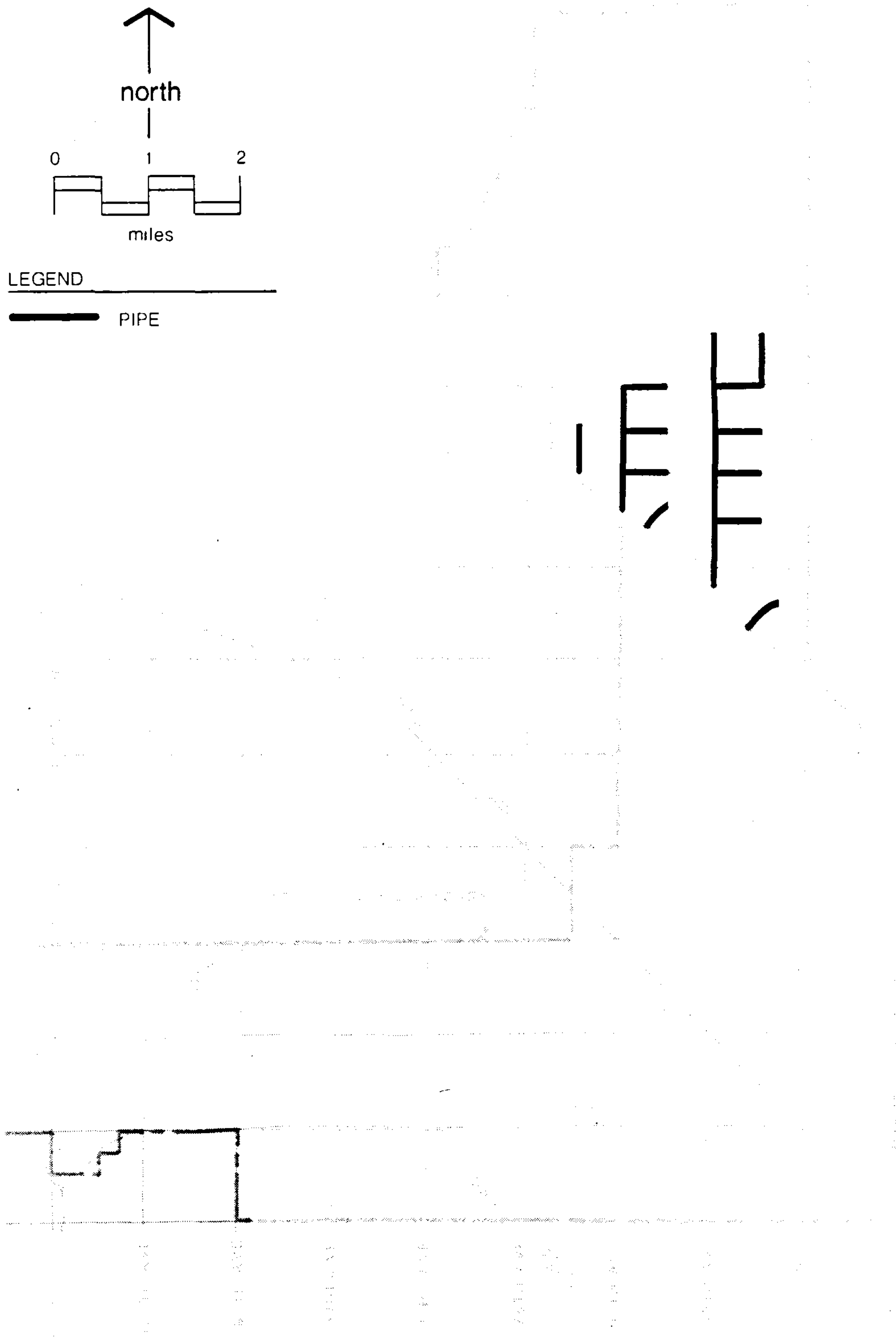


FIGURE 10
ALTERNATIVE 5

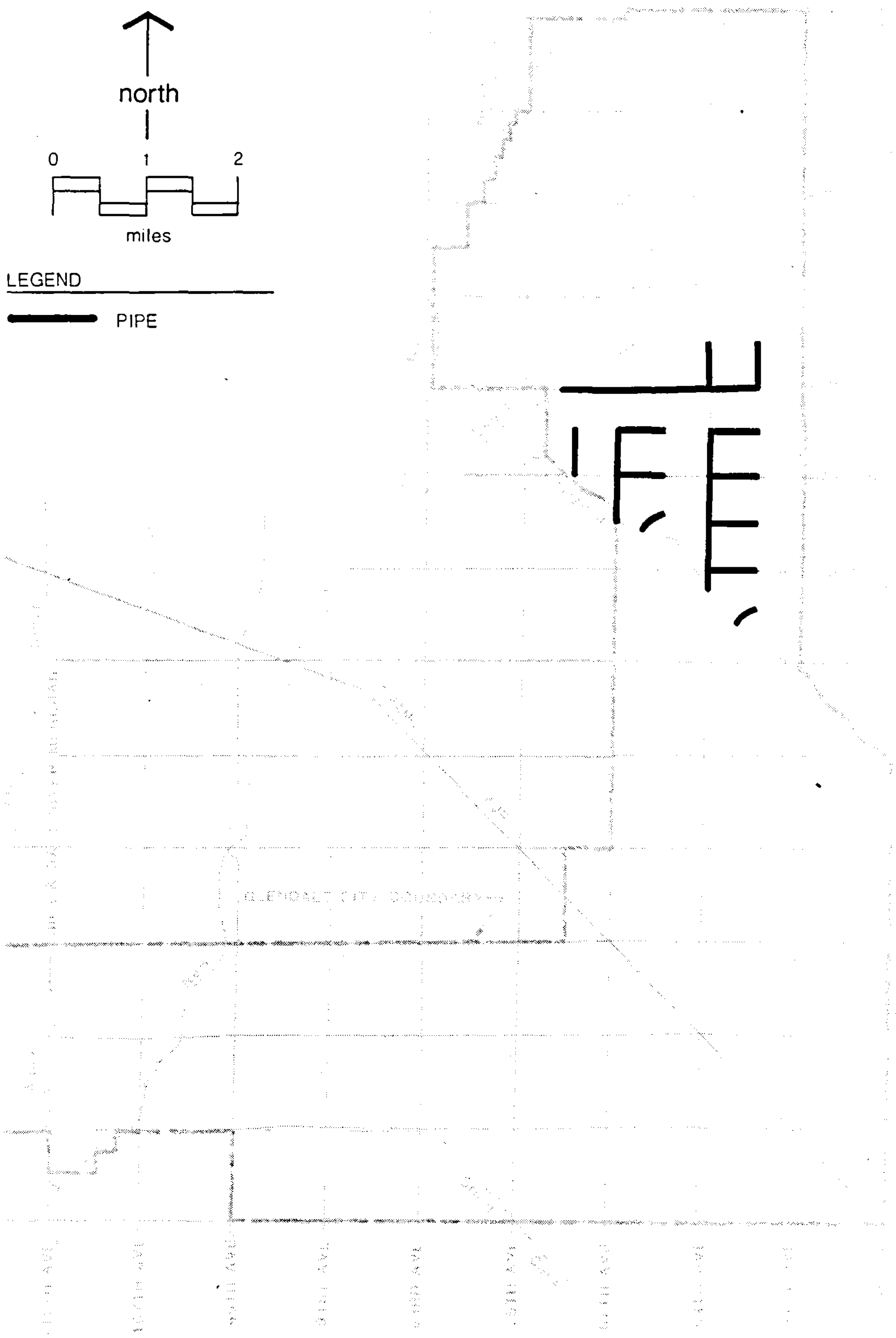


FIGURE 11

ALTERNATIVE 6

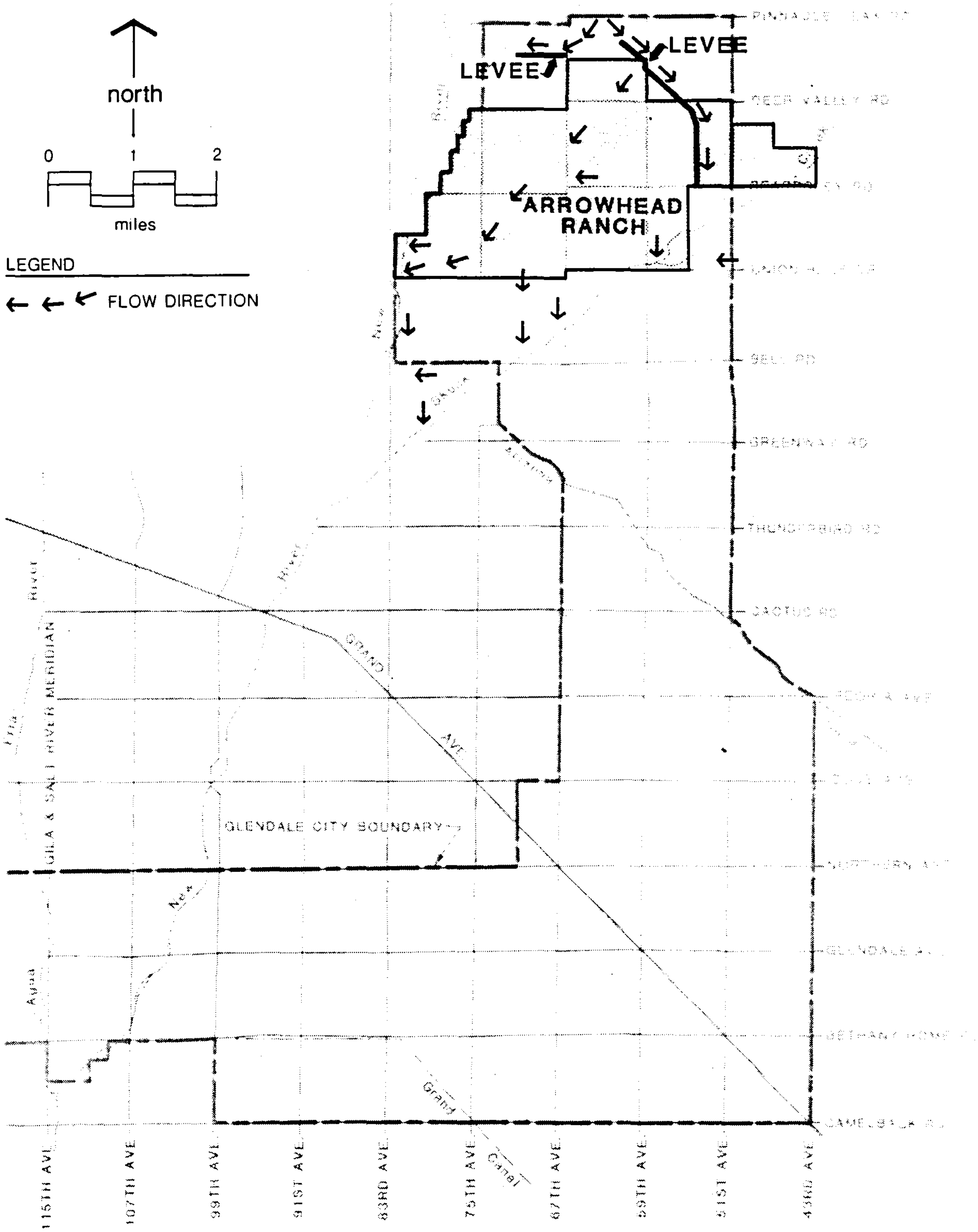


FIGURE 12

FLOW DIRECTIONS NORTH OF SKUNK CREEK

Section Six

Evaluation of Alternatives

6. Evaluation of Alternatives

EVALUATION PROCEDURE

The evaluation of alternative stormwater plans requires consideration of the following parameters:

1. Drainage system configuration.
2. Volumes of detention storage.
3. Levels of flood protection.

From the preceding section, five drainage system configurations were identified for Areas A and B, and two configurations for Area C. Hence, a total of 10 combinations of drainage system configurations exist for the entire study area. Each system must also be evaluated for various amounts of detention storage and levels of flood protection. If it is assumed that each system is evaluated for three amounts of detention storage at two levels of flood protection, a total of 60 alternative stormwater plans must be evaluated.

A two-step evaluation procedure was adopted in order to reduce the number of alternative stormwater plans that must be evaluated. First, the drainage system configurations for all areas were examined in relation to four criteria to determine the recommended drainage configuration. These criteria were: capital cost, compatibility with existing or planned facilities, acceptability to the public, and environmental impacts. Second, the costs of this system were evaluated (1) for various amounts of detention storage, and (2) for levels of flood protection to determine the recommended stormwater plan.

EVALUATION OF DRAINAGE SYSTEM CONFIGURATIONS

In order to compare and evaluate the various drainage system configurations, an evaluation matrix procedure was employed, based on the following criteria:

1. Capital Cost

   An estimate of capital cost was made for each drainage system configuration.

2. Compatibility and Disruption

   An estimate was made of the compatibility of the drainage system configuration with other projects and plans. The factors considered were disruption of existing roads and utilities during construction of the system.

3. Acceptability to the Public

   An assessment was made of how the public would react to each drainage system configuration.

4. Environmental Factors

   The relative impact that implementation of the drainage system configuration would have on the quantity and quality of water in the receiving channel, as well as the effects on wildlife, aquatic life, and vegetation, were evaluated.

The evaluation of each criterion, as it applied to the various drainage system configurations, was done on the basis of a positive, negative, or neutral rating. Positive (+) indicates that the alternative would have a favorable (least negative) impact upon the element being rated. Negative (-) indicates that the alternative would have an unfavorable (most negative) impact upon the element, and neutral (0) indicates that the alternative would not significantly affect the element.

This rating was intended to evaluate each project only in relation to the other alternative projects. The rating factor is not intended to have a meaning in relation to projects in other locations.

The results of the evaluation procedure for the drainage system configurations are presented in Table 1. For Areas A and B, Alternative 1A received the highest overall rating for the following reasons: (1) it had the lowest cost of the five alternatives; (2) it made use of the alignment of the Grand Canal, an existing facility; and (3) it would cause the least disruption of the five alternatives, and therefore be most acceptable to the public. Alternatives 2 and 4 were rated as negative because they would require the construction of very large conduits, which would be more expensive and more disruptive to traffic and local businesses. The environmental impacts of all the alternatives were judged to be neutral because each system would be underground, and therefore would not have any significant positive or negative effects on the environment. For Area C, Alternative 5 received the higher overall rating because it had a lower cost than Alternative 6 and a greater area would drain to the ACDC. Because the ACDC will be a well built and maintained channel, outfalls to this structure may perform better than those going directly to the river where bank erosion and debris may affect the stormwater system.

EVALUATION OF DETENTION STORAGE

Alternative detention facilities were considered for use with the recommended drainage system configuration. In general, detention basins were assumed to be located at existing City parks or other vacant City land as much as possible. Where no City-owned land was located in close proximity to the required site, suitable undeveloped land was chosen to avoid displacing any existing structures or facilities.

Detention facilities were considered preferable to retention facilities because detention storage would interfere less with alternative uses, such as park recreation activities. In addition, it was felt that with a small-sized outlet, the downstream pipes would probably be the same size for both detention and retention facilities, but that detention facilities would provide more storage, and therefore be more beneficial in multiple storm conditions.

TABLE 1

EVALUATION MATRIX

	Area A and B					Area C	
Alternative	1	1A	2	3	4	5	6
Evaluation Criteria							
1. Capital Costs	0	+	-	0	-	+	0
2. Compatibility and Disruption	+	+	-	+	-	+	+
3. Acceptability to the Public	0	+	-	0	-	+	0
4. Environmental Factor	0	0	0	0	0	0	0
Overall Evaluation	0	+	-	0	-	+	0

+ = favorable
0 = neutral
- = unfavorable

A separate evaluation was conducted to determine the amount of detention storage to be provided with the recommended drainage system configuration. To perform this analysis, various amounts of detention storage for the drainage system were postulated. Using the SWMM Model, the system was re-evaluated to compute the reduction in size of downstream pipe facilities required as a result of detention storage.

EVALUATION OF LEVEL OF PROTECTION

As an integral part of this evaluation, the level of protection that was to be provided had to be considered. It is generally not feasible to eliminate all possible damages from all possible floods. Even if protection is provided against a 100-year flood (defined as a flood flow which, on the average, is expected to be equaled or exceeded once in every 100-year period), it is possible to have a 200- or 1,000-year flood which will exceed the design capacity. Therefore, an element of risk enters into the development of any flood control plan. The risk of flood damage can be lowered by providing a greater level of protection (designing for the 100-year flood instead of the 50-year flood). However, this lower risk is achieved at the additional cost of constructing larger facilities. The decision about what level of protection should be provided depends on the resources available to implement the plan. Generally, the resources allocated should be fewer than or equal to the benefits realized to the community by the plan.

In order to determine the recommended amount of detention storage and level of protection, various systems utilizing Alternatives 1A and 5 were formulated, the required facilities were sized, and construction costs were estimated. The stormwater systems evaluated in this manner included two different levels of protection (design capacity for both 2- and 10-year frequency storms), and three different combinations of drain conveyance facilities and detention facilities (no detention facilities and large-sized drains; minimum detention facilities and moderate-sized drains; more detention facilities and small-sized drains). The results of this cost analysis are shown in Table 2, and include 20 percent for engineering, legal, and administration plus 20 percent for contingencies. In this evaluation, the "minimum detention" option contained about 2/3 as much detention storage volume as the "detention" option. This study of stormwater conveyance and detention facilities was not an extensive evaluation of all combinations, but does appear to be leading toward an optimal combination.

From this information and discussions with the City, it was determined that the increase in benefits provided by facilities with 10-year protection justify the increased cost of these facilities. Therefore, the implementation of drainage system that could safely handle the 10-year storm flow was established as a desirable level of protection, which can be most economically provided using a considerable amount of detention storage.

It would be possible to provide greater levels of protection in different areas of the stormwater system. However, this would have to be justified on an individual analysis of the cost and benefits in a particular area.

For example, an oversized crossing of the railroad might be justified on the basis that flooding tends to be worse in a specific area and affects a high value commercial district.

TABLE 2

EVALUATION OF DETENTION STORAGE AND LEVEL OF PROTECTION

		Preliminary Costs in Millions of Dollars					
		No Detention		Minimum Detention		Detention	
Area		2-yr	10-yr	2-yr	10-yr	2-yr	10-yr
A	Camelback Road to Northern Avenue	95	136	*	109	*	94
B	Northern Avenue to ACDC	53	83	34	53	*	45
C	ACDC to Skunk Creek	11	15	10	14	10	13
D	North of Skunk Creek[1]	*	*	*	*	*	*
	Subtotals	159	234	*	176	*	152

*Items not calculated.

[1]Area D was not evaluated for detention storage and level of protection because most of it lies within the Arrowhead Ranch properties, which will have an independent stormwater system.

Section Seven

Recommended Plan

7. Recommended Plan

GENERAL CHARACTERISTICS OF THE PLAN

The City of Glendale currently experiences some serious flooding problems, primarily due to the limited stormwater facilities which are available. Most of these problems result from the high peak flow rates that occur during intense local thunderstorms.

In order to eliminate these problems, an extensive stormwater system will have to be installed in the City. The general characteristics of the system are listed below:

1. The system would be an underground pipe and box culvert system which would provide greater safety than an open ditch system.

2. The system would follow the rectangular grid street pattern in order to facilitate access and avoid additional right-of-way requirements.

3. The system would be contained within the City limits.

4. Detention or retention facilities are advised in order to reduce the total cost of the system. Detention facilities are preferred because they would interfere less with alternative uses, such as park recreation activities. Both types of facilities can provide the additional benefit of groundwater recharging if the site is suitable and the facility is properly designed for this purpose.

5. The system should provide protection against the 10-year flood. It was determined that this level of protection would produce a good balance between cost of the system and benefits yielded.

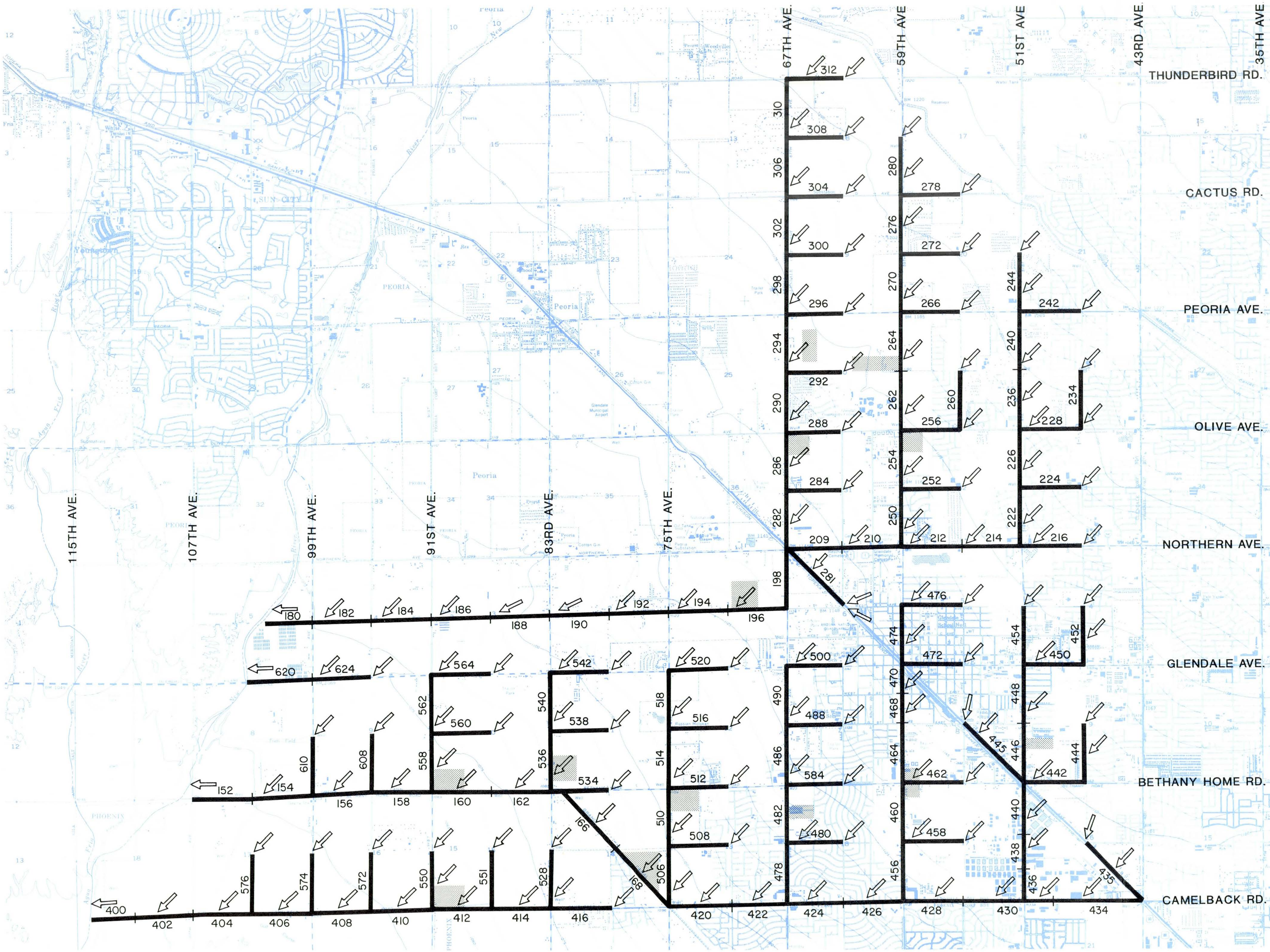
A number of alternative pipe systems were developed and evaluated. Of these, Alternative 1A for lands south of ACDC was determined to be the best because of its low cost, use of existing rights-of-way, and the low level of disruption it will cause. Alternative 5 was determined to be the best alternative for the lands between ACDC and Skunk Creek.

A more detailed analysis of these alternatives was performed in order to obtain more precise sizes for pipes and detention basins. All conveyance facilities in the recommended plan are indicated as pipes. However, for pipes larger than 7 to 8 feet in diameter, box culverts of equivalent capacity will probably be less costly to construct.

In preparing this plan, the future development that will occur within the City was accounted for, assuming that current drainage regulations will be applied. Since these regulations require that on-site retention be provided for a 10-year storm in newly developed areas, reductions in effective areas were made to account for these changes. To reflect streets and other miscellaneous areas that would not drain to the retention basin, 15 percent of the area to be developed was assumed to be tributary to the stormwater system.

The design criteria used for formulating the alternatives is shown in the Appendix.

Table 3 shows the estimated size of the required pipes for the recommended plan, and Figures 13 and 14 illustrate the layout of the recommended plan. For purposes of comparison, a table listing pipe sizes that would be needed without detention facilities has been included in the Appendix.



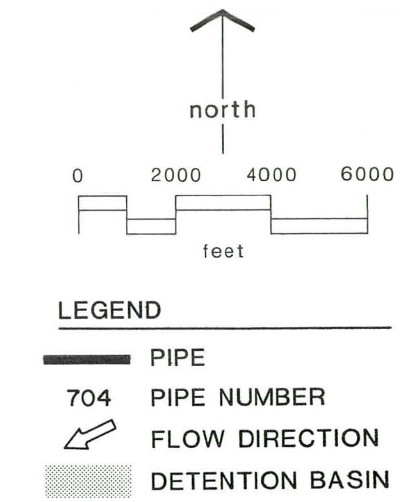


FIGURE 13
RECOMMENDED PLAN
SOUTH OF ARIZONA CANAL

THE CITY OF GLENDALE
STORMWATER MANAGEMENT PLAN

Camp Dresser & McKee Inc.

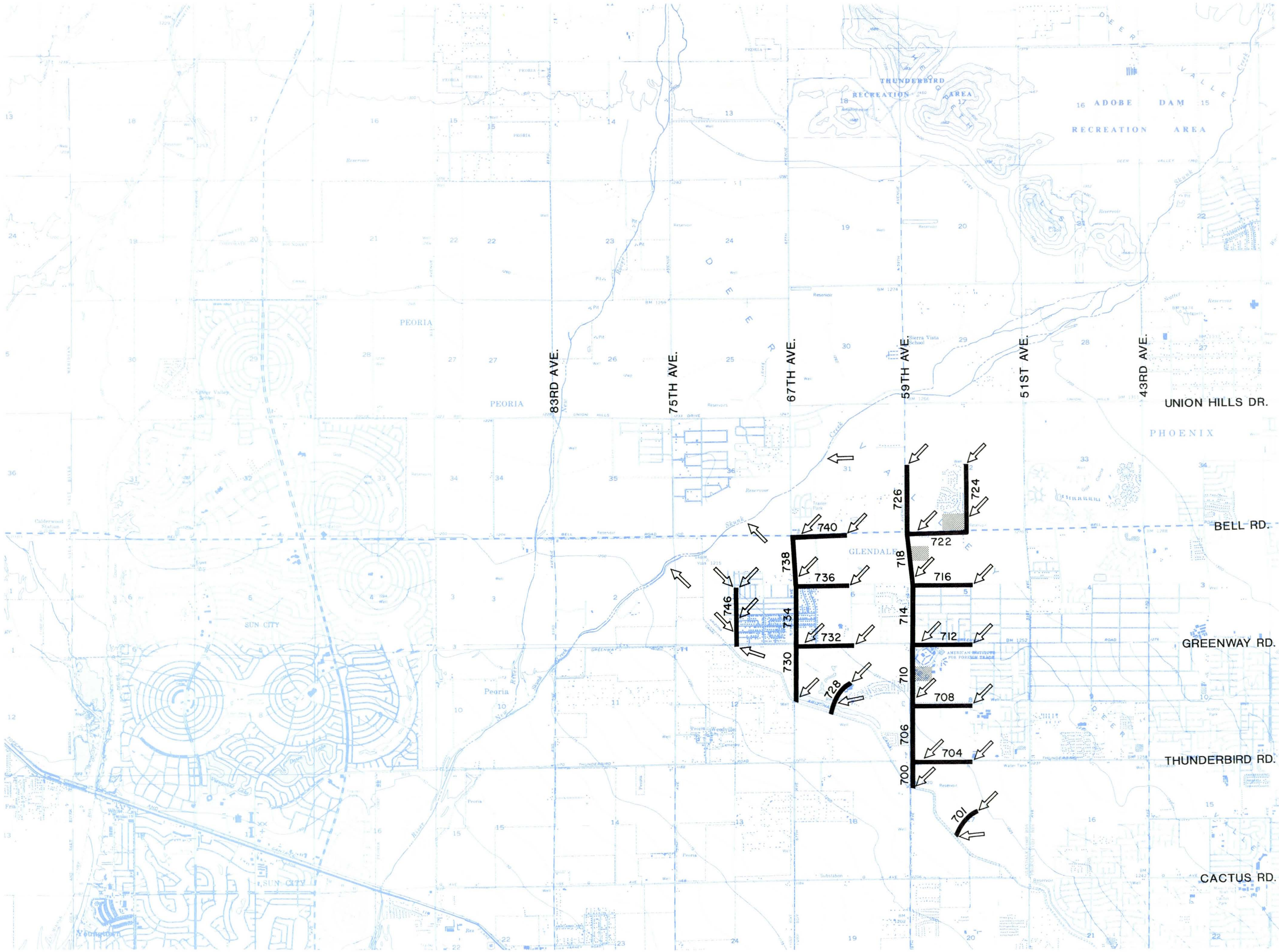


FIGURE 14
RECOMMENDED PLAN
NORTH OF ARIZONA CANAL

THE CITY OF GLENDALE
STORMWATER
MANAGEMENT PLAN

Camp Dresser & McKee Inc.

TABLE 3

PIPES FOR THE RECOMMENDED PLAN

Pipe Number	Pipe Length (ft)	Design Flow (cfs)	Pipe Size (ft)
152	2640	1000	10.0
154	2640	1000	10.0
156	2640	970	11.0
158	2640	1320	10.0
160	2640	1230	12.0
162	2640	1200	11.0
166	3800	1170	12.0
168	3820	2610	12.0
180	1960	460	8.0
182	2640	460	8.0
184	2640	3300	8.0
186	2640	440	8.0
188	2640	410	7.0
190	2640	390	7.0
192	2640	330	7.0
194	2640	1540	7.0
196	2640	1550	12.0
198	2640	1460	12.0
209	2460	690	10.0
210	2640	690	9.0
212	2640	450	8.0
214	2640	470	7.0
216	2640	250	7.0
222	2640	720	7.0
224	2640	130	5.0
226	2640	640	4.0
228	2640	350	7.0
234	2640	300	7.0
236	2640	240	6.0
240	2640	240	6.0
242	2640	50	3.5
244	2640	160	5.5
250	2640	200	6.0
252	2640	110	4.5
254	2640	370	2.0
256	2640	220	6.0
260	2640	270	6.5
262	2640	120	5.0
264	2640	480	2.0
266	2640	120	4.5
270	2640	320	6.5
272	2640	230	6.5
276	2640	80	4.0
278	2640	20	2.5

TABLE 3
(Continued)

PIPES FOR THE RECOMMENDED PLAN

Pipe Number	Pipe Length (ft)	Design Flow (cfs)	Pipe Size (ft)
280	2150	85	4.5
281	3700	340	9.0
282	2640	570	10.0
284	2460	150	5.0
286	2640	440	4.0
288	2460	150	5.5
290	2640	270	7.0
292	2460	50	3.5
294	2640	610	4.0
296	2460	70	4.0
298	2640	580	9.0
300	2460	110	4.5
302	2640	410	8.0
304	2460	90	4.0
306	2640	270	6.0
308	2460	100	4.5
310	2640	150	5.0
312	2460	90	4.5
400	1900	210	6.0
402	2500	220	5.5
404	2640	230	7.0
406	2640	180	6.0
408	2640	130	5.5
410	2640	360	1.5
412	2640	240	6.0
414	2640	200	5.5
416	2640	60	4.0
420	2640	2490	15.0
422	2640	2480	15.0
424	2640	2160	16.0
426	2640	2100	14.0
428	2640	1520	13.0
430	2640	1440	12.0
434	5280	480	10.0
435	3800	310	8.0
436	1320	860	10.0
438	1320	860	10.0
440	2640	760	9.0
442	2640	360	9.0
444	2640	270	7.0
445	3800	310	10.0
446	2640	480	4.5
448	2640	490	8.0

TABLE 3
(Continued)

PIPES FOR THE RECOMMENDED PLAN

Pipe Number	Pipe Length (ft)	Design Flow (cfs)	Pipe Size (ft)
450	2640	320	8.0
452	2640	250	6.0
454	2640	120	5.0
456	2640	580	9.0
458	2640	270	6.5
460	2640	910	6.5
462	2640	250	6.5
464	2640	710	10.0
468	1320	700	9.0
470	1320	640	10.0
472	2640	230	6.0
474	2640	390	8.0
476	2640	240	6.0
478	2640	380	8.0
480	2460	260	7.0
482	2640	670	5.0
484	2460	150	5.5
486	2640	590	10.0
488	2460	160	5.0
490	2640	370	8.0
500	2460	280	6.0
506	2640	220	7.0
508	2640	130	5.0
510	2640	360	1.5
512	2640	110	4.5
514	2640	240	7.0
516	2640	60	4.0
518	2640	170	5.5
520	2640	180	5.5
528	2640	120	5.5
534	2640	70	4.0
536	2640	340	1.5
538	2640	100	4.5
540	2640	240	6.0
542	2640	210	5.5
550	2640	150	5.5
551	2640	70	4.0
558	2640	210	6.0
560	2640	70	4.5
562	2640	200	7.0
564	2640	150	5.0
572	2640	80	4.5
574	2640	70	4.5

TABLE 3
(Continued)

PIPES FOR THE RECOMMENDED PLAN

Pipe Number	Pipe Length (ft)	Design Flow (cfs)	Pipe Size (ft)
576	2640	70	4.0
608	2640	70	4.0
610	2700	70	5.5
620	2700	110	4.0
624	2640	150	5.5
700	1900	420	8.0
701	1300	120	5.0
704	2640	270	7.0
706	2640	120	5.0
708	2640	120	4.5
710	2640	340	2.0
712	2640	210	6.0
714	2640	120	4.5
716	2640	140	5.0
718	2400	140	1.5
722	2640	240	1.5
724	3000	210	7.0
726	3000	90	4.5
728	1300	220	6.0
730	2500	500	9.0
732	2640	220	6.0
734	2640	310	7.0
736	2640	110	4.5
738	2200	250	6.0
740	2400	210	5.5
746	2700	260	7.0

Pipes in the stormwater system may vary slightly in size when a more detailed determination of runoff patterns and the extent of the stormwater system is made during the design of facilities.

Table 4 shows the estimated size and location of detention facilities for the recommended plan.

TABLE 4

DETENTION FACILITIES FOR THE RECOMMENDED PLAN

Location for System Analysis	Volume of Storage Required (acre-ft.)	Area Required (acres)
Bethany Home Rd. and 75th Avenue	26	11
Bethany Home Rd. and 83rd Avenue	21	9
Camelback Rd. and 91st Avenue	23	9
North of Bethany Home Rd. on 51st Avenue	21	9
Bethany Home Rd. and 59th Avenue	27	11
South of Bethany Home Rd. on 67th Avenue	25	10
North of Camelback Rd. on 75th Avenue	97	39
Bethany Home Rd. and 91st Avenue	87	35
So. of Peoria Ave. on 59th Ave., Sahuaro Ranch Pk.	30	12
Olive Avenue and 59th Avenue	25	10
Olive Avenue and 51st Avenue	33	13
South of Peoria Avenue and 67th Avenue	26	11
Olive Avenue and 67th Avenue	25	10
Orangewood Avenue, West of 67th Avenue	94	38
Bell Rd. East of 59th Avenue	13	5
South of Bell Rd. on 59th Avenue	7	3
South of Greenway Rd. on 59th Avenue	22	9

The SWMM model of the Glendale stormwater system will be a valuable tool for further studies leading to the design of facilities. Using the SWMM model, more detailed drainage networks may be evaluated, and variations of the recommended plan can be investigated if modified alignments are proposed.

RECOMMENDED PLAN

1. The City should implement Alternative 1A for the southern portion and Alternative 5 for the northern portion of the stormwater system, using the detention facilities to reduce the capital cost of the system.

2. If the City elects not to use detention basins at specific sites or if problems arise in acquiring certain detention basin sites, the City should implement the same alternatives, but use the larger pipe sizes corresponding to the "no detention" option in some or all parts of the system.

3. The City requires that all stormwater which falls within a new development be retained within that development for the 10-year storm of 2-hour duration. The current ordinance should be changed to require retention of all stormwater from a 100-year storm of 2-hour duration. This change would raise the retention criteria to that of other municipalities in Maricopa County.

4. The use of a rebuilt Grand Canal could also be considered as an alternative facility. Using the existing canal but providing more capacity through the use of setback levees could be a cost-effective measure. The use of a linear parkway alongside the Grand Canal with a below grade open area to carry excess stormwater might also be used. Pipes under the parkway could be used to convey runoff waters from frequent storms.

5. Since the recommended stormwater plan would provide only 10-year protection, the City should consider some additional measure to minimize the flood damage that would occur during larger storms. Such measure could include suing the building code to require flood proofing measures in structures in flood prone areas. Building Code B requirements could address factors such as type of construction, the location of the structure on the property, and grading of the site.

Section Eight

Costs of the Recommended Plan

8. Costs of the Recommended Plan

CAPITAL COSTS

The capital expenditures needed to accomplish the recommended plan have been estimated and are presented in Tables 5, 6, 7, 8 and 9. The costs are based upon recent construction costs in Maricopa County and represent July 1985 costs. The costs include 20 percent for engineering, legal, and administration, plus 20 percent for contingencies.

The total cost for the no detention alternative is $232 million and for the detention alternative $182 million. The detention alternative would cost $50 million less than the no detention alternative. Unit cost per square mile ranges from $7 million to $9 million. These estimated capital costs are for trunk stormwater facilities that accommodate 160 acres or more, except where smaller subareas are formed by a canal, road, railroad, wash, or river.

Total costs are for stormwater facilities in addition to the existing ones. Land costs are based upon purchase price at the following rates per acre:

Zoning Category	Cost per Acre
Agricultural	$ 40,000
Residential	$ 75,000
Industrial	$100,000
Commercial	$175,000

Detention basin cost of construction is defined as 20 percent of the land cost. The unit costs for pipes, or equivalent box culverts, include the cost of catch basins, manholes, and collection pipes between catch basins and the trunk stormwater pipe.

The costs for building and house drains, laterals, and retention basins will be in addition to the cost of the trunk stormwater system facilities.

TABLE 5

CAPITAL COSTS OF THE RECOMMENDED PLAN

Area	Capital Costs in Millions of Dollars			
	No Detention		Detention	
	Total Cost	Cost per Sq. Mile	Total Cost	Cost per Sq. Mile
ALTERNATIVE 1A Camelback Road to ACDC (34.5 sq. miles)				
Pipes	214		137	
Detention Basins	-		29	
	214	6.2	166	4.8
ALTERNATIVE 5 ACDC to Skunk Creek (8.5 sq. miles)				
Pipes	18		14	
Detention Basins	-		1.7	
	18	2.1	15.7	1.8
RECOMMENDED PLAN				
Pipes	232		151	
Detention Basin	-		31	
TOTAL	232		182	

TABLE 6

CAPITAL COSTS FOR ALTERNATIVE 1A FACILITIES

Pipe Size (ft)	Unit Price (dollars)	No Detention		Detention	
		Total Length (ft)	Amount (dollars)	Total Length (ft)	Amount (dollars)
1.5	58	0	0	7,920	459,000
2.0	63	0	0	5,280	333,000
2.5	71	2,640	187,000	2,640	187,000
3.5	100	5,100	510,000	5,100	510,000
4.0	120	26,100	3,132,000	34,020	4,082,000
4.5	140	28,010	3,921,000	30,650	4,291,000
5.0	160	18,120	2,899,000	23,400	3,744,000
5.5	185	28,740	5,317,000	33,880	6,268,000
6.0	210	28,860	6,061,000	36,040	7,568,000
6.5	235	13,200	3,102,000	15,840	3,722,000
7.0	260	20,940	5,444,000	42,060	10,936,000
8.0	320	30,060	9,619,000	32,160	10,291,000
9.0	390	28,040	10,936,000	18,220	7,106,000
10.0	450	41,440	18,648,000	31,340	14,103,000
11.0	530	9,880	5,236,000	5,280	2,798,000
12.0	600	1,320	792,000	18,180	10,908,000
13.0	680	5,280	3,590,000	2,640	1,795,000
14.0	760	7,740	5,882,000	2,640	2,006,000
15.0	850	0	0	5,280	4,488,000
16.0	940	10,560	9,926,000	2,640	2,482,000
17.0	1,030	9,880	10,176,000	0	0
18.0	1,130	23,760	26,849,000	0	0
19.0	1,230	2,640	3,247,000	0	0
20.0	1,330	12,900	17,157,000	0	0
Pipe Subtotal			152,631,000		98,077,000
Engineering, legal, administration 20%			30,526,200		19,615,400
Contingencies 20%			30,526,200		19,615,400
TOTAL			213,683,400		137,307,800

TABLE 7

CAPITAL COSTS FOR ALTERNATIVE 5 FACILITIES

		No Detention		Detention	
Pipe Size (ft)	Unit Price (dollars)	Total Length (ft)	Amount (dollars)	Total Length (ft)	Amount (dollars)
1.5	58	0	0	5,040	292,000
2.0	63	0	0	2,640	166,000
4.5	140	8,280	1,159,000	10,920	1,529,000
5.0	160	3,940	630,000	6,580	1,053,000
5.5	185	2,400	444,000	2,400	444,000
6.0	210	8,780	1,844,000	8,780	1,844,000
7.0	260	16,020	4,165,000	10,980	2,855,000
8.0	320	2,640	845,000	1,900	608,000
9.0	390	5,140	2,005,000	2,500	975,000
10.0	450	4,540	2,043,000	0	0
Pipe Subtotals			13,135,000		9,766,000
Engineering, legal, administration 20%			2,627,000		1,953,200
Contingencies 20%			2,627,000		1,953,200
TOTAL			18,389,000		13,672,400

TABLE 8

CAPITAL COSTS FOR ALTERNATIVE 1A DETENTION BASINS

Detention Basin Location	Area (acres)	Land Purchase and Construction (dollars per acre)	Amount (dollars)
Bethany Home Rd. and 75th Ave.	11	90,000	990,000
Bethany Home Rd. and 83rd Ave.	9	90,000	810,000
Camelback Rd. and 91st Ave.	9	90,000	810,000
North of Bethany Home Rd. on 51st Ave.	9	48,000	432,000
Bethany Home Rd. and 59th Ave.	11	48,000	528,000
South of Bethany Home Rd. on 67th Ave.	10	90,000	900,000
North of Camelback Rd. on 75th Ave.	39	90,000	3,510,000
Bethany Home Rd. and 91st Ave.	35	90,000	3,150,000
South of Peoria Ave. on 59th Ave., Sahuaro Ranch Park	12	48,000	576,000
Olive Ave. and 59th Ave.	10	120,000	1,200,000
Olive Ave. and 51st Ave.	13	90,000	1,170,000
South of Peoria Ave. on 67th Ave.	11	90,000	990,000
Olive Ave. and 67th Ave.	10	90,000	900,000
Orangewood Ave., West of 67th Ave.	38	120,000	4,560,000
Detention Basin Subtotal			20,526,000
Engineering, legal, administration 20%			4,105,000
Contingencies 20%			4,105,000
TOTAL			28,736,000

TABLE 9

CAPITAL COSTS FOR ALTERNATIVE 5 DETENTION BASINS

Detention Basin Location	Area (acres)	Land Purchase and Construction (dollars per acre)	Amount (dollars)
Bell Rd. East of 59th Ave.	5	90,000	450,000
South of Bell Rd. on 59th Ave.	3	120,000	360,000
South of Greenway Rd. on 59th Ave.	9	48,000	432,000
Detention Basin Subtotal			1,242,000
Engineering, legal, administration 20%			248,400
Contingencies 20%			248,400
TOTALS			1,738,800

OPERATION AND MAINTENANCE COSTS

The recommended trunk stormwater facilities require a continual operation and maintenance effort in order for the facilities to function appropriately. Operation and maintenance effort will consist of, but not be limited to the following described items:

- Inspections of all major pipes and detention basins each month and after all storms that generate significant runoff.
- Sand, soil, and debris removal from all inlets and pipes.
  Repair work at detention basins, including:

  - replacement of eroded sections;
  - rodent and pest control;
  - vegetation control; and
  - repair of damage from vehicles and vandals.

- Repair of damages incurred during the occurrence of runoff from storm events greater than the 10-year design frequency would also be required.

The annual operation and maintenance costs for pipes are estimated to be 0.5 percent of the capital cost of the trunk stormwater pipes. The annual operation and maintenance costs for detention basins are estimated to be 1.0 percent of the land acquisition and construction cost. Table 10 presents the annual operation and maintenance costs for the recommended plan.

Included in the 0.5 and 1.0 percent amounts are the costs for all personnel, equipment, supplies, and administration and general expenses necessary to operate and maintain the trunk stormwater facilities. An approximate breakdown of annual costs would be: operations 60 percent, equipment 20 percent, administration 15 percent, and supplies 5 percent.

These above-described costs would be in addition to the annual costs now being expended by the City for operations and maintenance of existing stormwater facilities, exclusive of current and future park operations and maintenance costs.

TABLE 10

ANNUAL OPERATION AND MAINTENANCE COSTS OF THE RECOMMENDED PLAN

	Pipes		Detention Basins		Total	
Area	No Detention	Detention	No Detention	Detention	No Detention	Detention
Camelback Road to ACDC	$1,068,000	$687,000	$0	$287,000	$1,068,000	$ 974,000
ACDC to Skunk Creek	$ 92,000	$ 68,000	$0	$ 17,000	$ 92,000	$ 85,000
TOTALS	$1,160,000	$755,000	$0	$304,000	$1,160,000	$1,059,000

Section Nine

Implementation and Construction Phasing

9. Implementation and Construction Phasing

ADOPTION OF THE STORMWATER MANAGEMENT PLAN

It is recommended that the City review and adopt this plan as Glendale's Stormwater Management Plan. An environmental impact statement should not be needed prior to the adoption of the plan. In the event that modifications to the proposed plan become necessary because of results from the current Glendale-Peoria Area Drainage Master Study, they can be included by addendum. By adopting the plan, the City would be able to prevent development of declared detention basins sites prior to their acquisition by the City and to establish alignments for trunk stormwater facilities. This action will strengthen the City's policies concerning stormwater and drainage and require new stormwater facilities to be in conformance with the Stormwater Management Plan.

INTERAGENCY COOPERATION

Stormwater from the Cities of Phoenix and Peoria enters the City of Glendale; the reverse also occurs. In addition, the City of Glendale has stormwater interfaces with Maricopa County, the Arizona Department of Transportation, the Corps of Engineers, and the Salt River Project. Because of these conditions, interagency cooperation in the management of stormwater is recommended.

Interagency agreements might address the following subjects:

1. Control of stormwater overflows;
2. Closing of certain streets during periods of heavy runoff;
3. Improvement of existing stormwater facilities;
4. Construction of new stormwater facilities (interim and/or permanent);
5. Runoff controls; and/or
6. Emergency operations plan during flood conditions.

CONSTRUCTION PHASING

It is recommended that the construction of trunk stormwater facilities be separated into three phases: immediate action, short range, and long range.

Phase 1 -- Immediate Action

The implementation of stormwater facilities with detention is heavily dependent upon the availability of land for detention basins. Sites must be large enough and in locations appropriate for creating beneficial effects in downstream conditions. The following activities are recommended for immediate action:

1. Control land use at desired sites. This is of primary concern. Land use control can be accomplished by a variety of means:
   - Granting developers increased density, then requesting that portions of their land be dedicated to detention;
   - Obtaining an option on desired property;
   - Purchasing desired property; or
   - Any other method available to the City.
2. Formulate and enter into an interagency agreement with the City of Phoenix that will provide for joint stormwater management where stormwater flows cross 43rd Avenue from east to west near Northern Avenue, and 51st Avenue from east to west in the vicinity of Thunderbird Road.
3. Design and construct interim facilities at those road intersections where flooding occurs during relatively minor storms. The interim improvements would generally conform to the management plan recommendations and could consist of a pipe that temporarily empties into SRP irrigation or drainage facilities, a roadside ditch, a temporary detention basin, a dry well, or a small sump and booster pump system.

Approximate capital expenditures that would be incurred by the City for Phase 1 are estimated to total less than $3 million.

Phase 2 -- Short Range (1985-1989)

Short range activities would include the following:

1. Formulate and enter into interagency agreements with the City of Peoria, Maricopa County (for drainage of lands near Camelback Road and New River), Arizona Department of Transportation (for use of the pipe system along Grand Avenue), Flood Control District of Maricopa County (for discharging stormwaters into the ACDC), and the Salt River Project (for temporary and/or permanent use of SRP's irrigation and drainage facilities).

2. Plan for the design of road improvements that will provide adequate space for constructing stormwater pipes within road rights-of-way. Establish alignments of major water lines and sanitary sewer pipes that will not conflict with the trunk stormwater facilities.

3. Design and construct those stormwater pipes and detention basins that are within or alongside current land development or road improvement projects.

4. Construct pipes or interim open channels at the downstream (west) end of Bethany Home Road and Orangewood Avenue, and proceed upstream as funds become available. This will establish two major stormwater outlets from Glendale to New River.

5. Construct trunk stormwater pipes along 59th and 67th Avenue that drain southerly and empty into the ACDC. These facilities will allow Glendale the use of inlets into the ACDC that currently are under design by the Corps of Engineers.

Approximate capital expenditures that would be incurred by the City for Phase 2 are estimated to be in the range of $5 million to $10 million.

Phase 3 -- Long Range (1990-1999 and 2000-2010)

The long range plan will consist of installing all of the remaining facilities not constructed during Phases 1 and 2. Downstream facilities should be constructed first, with construction proceeding upstream.

Following is a summary of estimated capital expenditures for Phases 1, 2, and 3.

Summary

	Period	Estimated Capital Expenditures
Immediate Action	1985-1989	Less than $3 Million
Short Range	1985-1989	$ 10 Million
Long Range	1990-1999	$ 70 Million
	2000-2010	$100 Million

Section Ten

Financing Alternatives

10. Financing Alternatives

INTRODUCTION

In the interest of reducing the inconvenience, property damage, and danger that can be caused by flooding, the City of Glendale has undertaken the development of this stormwater management plan. The next step, pending adoption of the plan, will be implementation of the recommended storm drainage system improvements. However, before a capital improvement program can proceed, the City must first develop a financing program that will achieve the following goals:

- Fund the construction and replacement of facilities;
- fund the operation and maintenance of the system;
- meet the financial requirements at the least possible cost;
- achieve payment equitability among system users; and
- gain the acceptance of the public, and permit realistic implementation and administration.

As a preliminary step in meeting those goals, it is helpful to view the requirements in two stages: First, those capital costs associated with new or replacement facilities, and second, the operation and maintenance costs that are necessary from year to year.

In order to assist the City in formulating its financing program, we will discuss in this section several of the most widely accepted public financing methods for capital construction and for operating and maintenance requirements, as listed in Table 11.

The key features of each alternative are also summarized in Table 12, which appears at the conclusion of this section. It should be noted that these funding mechanisms may be used alone or in various combinations to achieve the most efficient financial structure.

TABLE 11

FINANCIAL PLANNING MATRIX

Type of Funding	External	Internal
<u>Capital Requirements</u>		
Federal Loans/Grants	X	
State and County Loans/Grants	X	
Bonds	X	
Non-Profit Corporation Bonds	X	
Reserve Funds		X
<u>Operating & Maintenance Requirements</u>		
Taxation		X
Developer Fees		X
User Fees		X
Reserve Funds		X

FEDERAL LOANS/GRANTS

Numerous federal programs exist that relate to funding for drainage and flood control activities. These are initiated through the Department of Agriculture, the Department of the Interior, the Environmental Protection Agency, the Department of Commerce, and the Army Corps of Engineers. Most of the specific programs are structured in a manner that requires lengthy study, planning, design, and construction staging. The funding of all such programs is uncertain due to the need for executive branch budget approval in concert with legislative branch appropriation.

STATE AND COUNTY COST-SHARING

Drainage and flood control funding administered by the State of Arizona is handled through the Department of Water Resources. State funding mechanisms are well defined, but availability of funds is uncertain due to the impact of future budget and appropriation decisions. The Flood Control District of Maricopa County has cost-sharing capabilities for both stormwater planning studies and construction of facilities. The funds are available only for regional projects and the funding levels vary each year.

BONDS

Three basic types of bond financing are recognized by the State of Arizona: Assessment Bonds, Revenue Bonds, and General Obligation Bonds.

Assessment bond costs are those associated with public works, and represent an unpaid assessment levied against the property owners who benefit from the facilities constructed. This type of bond is also referred to as an "Improvement Act" bond and can be issued under either of two formats. In one case, the issuing agency assumes a contingent liability, and, in the case of delinquency, can advance the amount due or can establish a limited tax that applies only to the delinquent area. In the other, and more commonly used form, the issuing agency has no obligation to the bondholder other than to forward payments made by property owners.

Improvement district bonds relate to a debt obligation of an area that is less than district-wide. Debt service costs may be met through property taxes or assessments but only against the specific property contained within the improvement district.

Revenue bonds require both the demonstration of adequate revenues and the pledge to create and maintain a reserve fund.

General obligation bonds rely on their security through the taxing powers of the issuing agency. This form of financing is usually, though not necessarily, associated with property taxation.

NON-PROFIT CORPORATIONS

Initially, non-profit corporations were used in connection with the funding of a specific facility, frequently a municipal building. More recently, they have been used in relation to multiple projects or to improvements of various facilities. The essential features of a non-profit corporation are that it can be created by a public agency, that it be truly non-profit, that it act as the landlord during the term of the bond, and that the facilities become the property of the public agency at the time the debt obligation is retired.

RESERVE FUNDS

The use of reserve funds by a public agency for capital improvements or for operation and maintenance is limited to critical situations -- those in which no other funding source is appropriate. Obviously, the legal constraints that apply to existing reserve funds must be known and followed. In addition, suitable mechanisms must be developed so that reserve funds used in this way can be replaced in a timely manner.

TAXATION

A public agency can apply a general tax against property for a demonstrated revenue need. Taxation would be an appropriate financing device where the public need is apparent to the electorate. Special taxes may be per house, per lot, per lot size or other method.

DEVELOPER FEES

When an area is being developed for residential, commercial, or industrial purposes, it is sometimes appropriate to levy a fee against the developer to offset the capital costs of storm drainage facilities. These costs are then, clearly, passed along to the eventual owner or user of the property. This transfer of costs may be at cross purposes with agency goals in terms of growth or expansion. Developer fees may also create some problems when analyzed in relation to earlier development practices or in relation to the fee to be charged to some future developer. Three types of developer fees are possible. One is a drainage improvement zone fee that is tailored to the costs associated with a specific location, usually an identifiable drainage area or basin. Another is commonly referred to as an acreage fee and is uniformly applied. The third is a trunk facilities fee whose revenues are used to construct major conveyance facilities.

USER FEES

The concept of a user fee for drainage and flood control purposes is relatively well established in many parts of the country. By its nature, it resolves the issue that those who use or benefit from a public utility system should also pay the associated costs. In some cases, the technical issues relating to how much rainfall is absorbed into the ground, how much evaporates, or how much runs off from a given user's land can be of considerable concern. Nevertheless, there are accepted methods for making these determinations and in producing user fees that are equitable between users or between user classes.

OTHER METHODS

In those cases where a municipality or an existing drainage and flood control agency chooses to modify or add to its current facilities, a financial restructuring is sometimes appropriate. One method of accomplishing this is under a "redevelopment program." The basic premise of this type of program assumes that redeveloped areas will exhibit an increase in assessed valuation and that the incremental increase in property tax revenue can be used to fund redevelopment work.

SUMMARY

Table 12 is a compilation of the various alternatives. It indicates the applicability for drainage and flood control purposes, the major advantages and disadvantages, and the usual manner in which funds from the various sources are used.

TABLE 12

FUNDING SOURCES
AVAILABILITY AND APPLICABILITY

Source of Funds	Availability	Applicability	Advantages	Disadvantages
Federal Loans/Grants	Unlikely	Construction	Low Financing Costs	Competition w/Other Agencies
State & County Loans/Grants	Probable	Construction	Low Financing Costs	Competition w/Other Agencies
Bonds:				
Assessment Bonds	Possible	Construction	No Direct City Debt	Special Engineering Report Needed
Revenue Bonds	Possible	Construction	User/Benefit Relationships	Voters Must Approve
General Obligation Bonds	Unlikely	Construction	Large Bond Market	Voters Must Approve
Non-Profit Corporation	Probable	Construction	Recognized Method	Complex to Set Up
Reserve Funds	Possible	Construction and O&M	No Interest Costs	Uneven Cash Flow
Taxation	Difficult	O&M	Costs are Widely Spread	Difficult to Obtain Public Acceptance
Developer Fees:				
Zone Fees	Probable	Construction	Easily Administered	Dependent on Growth
Acreage Fees	Probable	Construction	Easily Explained	Unrelated to Land Use
Trunk Fees	Probable	Construction	Provides Advance Funding	Possible Imbalance Between Developers
User Fees:				
Uniform Service Charge	Probable	O&M	Understandable	May Lack Equitability
Variable Service Charge/ Drainage Contribution	Probable	O&M	Considers Runoff Factors	Requires Engineering Analysis
Variable Service Charge/ Zoning Drainage	Possible	O&M	Recognizes Land Use	Relatively Complex

Section Eleven

Institutional Considerations and Infrastructure Improvements

11. Institutional Considerations and Infrastructure Improvements

The actual implementation of the stormwater plan and the maintenance of the stormwater drainage facilities will require actions by political institutions. In addition, planning and coordination with other institutions that may have jurisdiction over some portion of the facilities will be required.

In addition to the City of Glendale, there are a number of other institutions that could play a part in the implementation of the plan.

Federal

The U.S. Army Corps of Engineers has traditionally been responsible for flood control planning and construction on major river systems. The Corps also issues permits for construction over navigable waters. More recently, the Corps has also devoted some attention to urban flood control with the funding of a number of urban studies. The Corps emphasizes the use of structural solutions, with the justification of these solutions based on a favorable benefit/cost ratio. The Arizona Canal Diversion Channel is a Corps project.

The Soil Conservation Service (SCS) of the U.S. Department of Agriculture is involved with planning and funding of watershed management and flood plain management programs. Traditionally, the SCS has worked with local soil and water conservation districts in rural areas to provide technical and financial assistance to local landowners, occupants, and other local agencies. However, the SCS has recently expanded its program to provide similar assistance in urban areas. There are no current SCS projects in Glendale.

The Federal Emergency Management Agency (FEMA) is responsible for administering the National Flood Insurance Act, which makes flood insurance available to property owners living on flood-prone lands. To be a part of the program, a community must meet certain requirements, including implementation of flood plain land use control measures. FEMA develops maps showing the location of the flood plain and the magnitude of flood hazards within the community.

In 1981 FEMA completed a flood insurance study for Glendale. This study indicates flood levels in the Agua Fria River, New River, and Skunk Creek, as well as the areas of the city which will be flooded during the 100-year and 500-year floods.

As part of the Central Arizona Project, the Corps of Engineers has built the Adobe Dam and New River Dam facilities. Because of the affect these facilities have on flood conditions in Glendale, FEMA is considering modifying the previous flood insurance study for Glendale.

The Environmental Protection Agency (EPA) is responsible for enforcing federal water pollution laws. Although these laws area generally concerned with point sources of pollution such as sanitary sewage outfalls and industrial outfalls, they are also concerned with non-point sources of pollution that would be associated with storm runoff.

State and County

In the State of Arizona, the Department of Water Resources is responsible for drainage and flood control. The Department is generally concerned with problems of a regional or statewide nature.

On the county level, the Flood Control District of Maricopa County was formed to deal with flood control and drainage problems. In general, the District handles problems in unincorporated areas of the county or problems that are interjurisdictional in nature.

A regional study in the Glendale-Peoria area is currently being conducted by the District. This study will consider regional stormwater and flood control facilities, augment individual studies in the two cities, and include adjacent areas of unincorporated Maricopa County and the City of Phoenix.

INFRASTRUCTURE IMPROVEMENTS

The installation of the complete storm drainage system will be a large undertaking which will have to be done over a period of many years.

In order to eliminate unnecessary disruption, the storm drainage system should be coordinated with other planned infrastructure improvements in the City. When major reconstructon of streets is planned, the stormwater system should be installed at the same time. If downstream portions of the stormwater system are not ready, the pipe can be blocked at each end and connected at a later time.

The details of the stormwater system should be coordinated with other major utilities such as water and sewer lines. Advance planning of the locations of pipes and utilities can reduce problems that could occur at a later time. During construction of facilities, sleeves should be installed at proposed crossings so that pipes can later be inserted without relocating or extensively modifying the existing facility.

Based on available maps of the sanitary sewer system, there are seven locations where sewer sizes larger than 24 inches cross the proposed path of the storm drainage system. Each of these locations would have to be examined in detail to determine the difficulty of placing an underground stormwater pipe there. Twin pipes or a squashed-shaped box may be needed to accommodate the crossing.

Major water lines are generally located on the east side of the city, and will probably not generally interfere with the proposed drainage system. Rerouting of pressure water pipes can also be accomplished more easily than gravity sewer lines.

In all areas south of the Arizona Canal being developed that are currently used for agriculture, coordination with the Salt River Project over the existing irrigation canals will be required.

The recommended plan calls for the use of detention facilities to reduce the cost of the system. Detention facilities would be located in city parks or vacant space whenever possible. Due to the multipurpose use of these areas, the use as a detention facility must be carefully coordinated to avoid unnecessary disruption, inconvenience, and maintenance problems. As an example of using a city park as a detention facility, a concept sketch is shown in the Appendix for Sahuaro Ranch Park on 59th Avenue. In the example, the soccer and baseball fields are used for detention.

In planning the detention facilities, it will be necessary to ensure that no flooding or damage will occur to buildings and structures. It may be desirable to grade or build compartments in the facility so that some unflooded space will remain after frequent, small storms. Complete inundation would occur only during major storms.

The length of time water would be stored in the detention faciltiy would depend on the size of the storm and the design of the facilities' outlet structure. However, it is anticipated that during major storms, park facilities would drain in 2 hours and other facilities would be emptied within 1 day after the end of the storm.

Section Twelve

Conditions and Limitations

12. Conditions and Limitations

In the development of the recommended plan, certain conditions and limitations have been imposed or applied. These include:

1. The plan has been based upon information about the existing stormwater system obtained from the City of Glendale, Arizona Department of Transportation, and other agencies. No field surveys were performed.

2. Stormwater runoff rates and volumes for the recommended plan have been calculated with the information in 1. There are no measurements of stormwater runoff rates. Any physical changes in the stormwater system will modify the runoff rates presented herein.

3. It was assumed that all existing stormwater system components will be adequately maintained so that their existing flow carrying capacity will not be diminished.

4. It was assumed that inlet grates are capable of allowing stormwaters to enter the inlets and that manholes and inlets along pipelines do not restrict flow.

5. The recommended plan is based on the land use projections presented in the City of Glendale General Plan 1980 - 2005 and the two supplements: Western Glendale Community Plan and the West Glendale Area Plan.

6. The recommended plan is a first step toward orderly stormwater management. Prior to the next step, preliminary designs and field surveys will be needed to verify pipe sizes, elevations, and other details about the overall stormwater system and areas tributary to the system.

7. Studies in regard to structural adequacy of the existing stormwater facilities and water quality are beyond the scope of this plan.

8. The generalized pattern of infiltration rates shown on Figure 1 is approximate. Reference 14 is to be used for the design.

9. At some locations the street gutters flow easterly for short distances. However, during periods of heavy runoff the prevailing direction of surface and pipe flow is in a southwesterly direction.

Section Thirteen

References and Acknowledgements

13. References and Acknowledgements

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Appendix

DESIGN CRITERIA USED IN THE FORMULATION OF THE RECOMMENDED PLAN

1. Facilities to carry the flow from a 10-year storm.

2. Design rainfall:

Time (hours and minutes)	Rainfall Intensity (inches per hour) 2 Year	5 Year	10 Year	100 Year
0-0:15	2.0	2.85	3.25	4.80
0:15-0:30	0.70	0.95	1.15	1.92
0:30-0:45	0.40	0.56	0.72	1.14
0:45-1:00	0.24	0.38	0.48	0.66
1:00-1:15	0.14	0.22	0.32	0.55
1:15-1:30	0.11	0.18	0.22	0.45
1:30-1:45	0.10	0.15	0.18	0.36
1:45-2:00	0.084	0.12	0.17	0.30
2:00-2:15	0.080	0.11	0.15	0.24
2:15-2:30	0.080	0.10	0.14	0.20
2:30-2:45	0.080	0.10	0.13	0.18
2:45-3:00	0.076	0.096	0.12	0.16
3:00-3:15	0.076	0.092	0.12	0.15
3:15-3:30	0.072	0.088	0.12	0.15
3:30-3:45	0.068	0.084	0.11	0.14
3:45-4:00	0.064	0.080	0.10	0.14
4:00-4:15	0.060	0.080	0.10	0.13
4:15-4:30	0.060	0.076	0.10	0.13
4:30-4:45	0.056	0.072	0.096	0.13
4:45-5:00	0.052	0.068	0.092	0.13
5:00-5:15	0.048	0.064	0.092	0.12
5:15-5:30	0.048	0.060	0.088	0.12
5:30-5:45	0.044	0.056	0.084	0.12
5:45-6:00	0.044	0.056	0.080	0.12

3. Street gutters can only carry local runoff to the next downstream inlet. Any flow in addition to local runoff will overtop the curb and enter adjacent lands.

4. Where there are no stormwater inlets, the entrance to side streets should be slightly humped so that stormwaters flowing in gutters on mile and one-half mile streets will not enter the side streets.

5. Pipes will flow full. In certain cases the pipes can flow under pressure if the hydraulic grade line at the adjacent inlets is 0.5 feet or more below the gutter invert.

6. Detention Basins:

   a. Maximum water depth of 3 feet.

   b. Maximum embankment height around the basin of 2 feet.

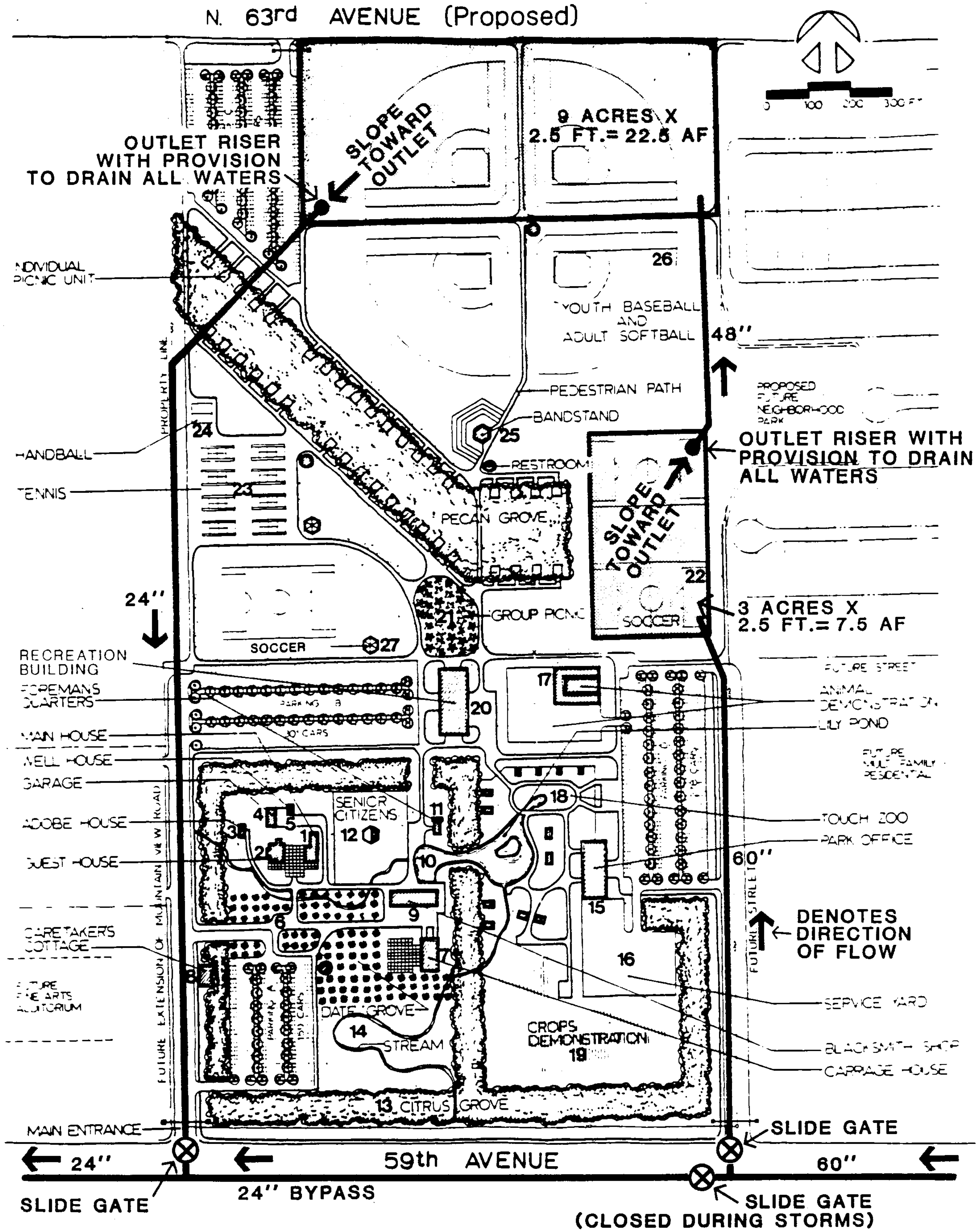
   c. Basin shall have an uncontrolled overpour spillway to keep the basin from overtopping the banks. The top of the embankment shall be 1 foot above the maximum water surface elevation.

   d. Provide a surface route for the 100-year flood flow through and downstream from the basin so that no more than nuisance damage to adjacent and downstream facilities can occur.

   e. Outlets shall be provided to release incoming flows to downstream facilities at retarded rates, but not greater than the capacity of the downstream facilities. Outlets also can be used to release temporarily stored runoff and to allow the basin to be emptied.

STORMWATER CRITERIA FOR CITIES IN MARICOPA COUNTY

	Glendale	Scottsdale	Gilbert	Chandler	Mesa	Tempe	Phoenix
Streets-design criteria	10-yr storm between curbs	10-yr storm between curbs		5-yr storm between curbs	10-yr storm between curbs	5-yr storm between curbs	10-yr storm between sidewalks
Retention Requirements							
On-site	Yes	Yes	Yes	Yes	Yes	Yes	Yes, unless served by City stormdrain
Design storm	10-yr, 2-hr 1.6"	50-yr, 24-hr 3.5"		100-yr, 6-hr 3.1"	50-yr, 24-hr 3.5"	5-yr, 1-hr 1.2" (if natural outfall) 100-yr, 1-hr 2.1" (if no natural outfall)	10-yr, 2-hr 1.6"
Max. water depth	Not specified	Not specified		3'	3.5'	3'	Not specified
Time to drain	36 hours	96 hours	48 hours	36 hours	36 hours	36 hours	36 hours
Positive discharge	Permitted	Permitted		Preferred, if possible	Preferred, required in some cases	Preferred	Permitted
Dry wells	Permitted	Permitted		Permitted, if no other discharge available	Restricted use, temporary measure if no other method available; not allowed in City-maintained areas	Permitted	Permitted
Percolation test	Yes, to prove performance of completed well	Yes, for design		Required before acceptance	No	Required, if area known to have poor percolation	Required if well not drilled 5' into permeable soil
Acceptance of runoff from adjoining ROW	No, except if required by City	Yes, to follow natural drainage	Yes, 1/2 of all adjoining streets	Yes, 1/2 of all adjoining streets	Yes, 1/2 adjacent streets if no natural outfall (not required in specific areas if approved)	Yes, in 100-yr areas with no outlet	Yes, for continuity of wash or easement
Storm drains	Required if street capacity exceeded by design storm	Required if street capacity exceeded by design storm		Surface collection preferred, subsurface required if street capacity exceeded by design storm	Required if street capacity exceeded by design storm	Required if street capacity exceeded by design storm	Required if street capacity exceeded by design storm



SAHUARO RANCH PARK DETENTION FACILITY CONCEPT

A-4

PIPE SIZES THAT WOULD BE REQUIRED WITHOUT DETENTION
FOR THE PIPE ALIGNMENTS PRESENTED
IN THE RECOMMENDED PLAN

Pipe Number	Pipe Length (ft)	Design Flow (cfs)	Pipe Size (ft)
152	2640	4300	18.0
154	2640	4320	18.0
156	2640	4280	20.0
158	2640	4270	19.0
160	2640	4220	20.0
162	2640	4220	18.0
166	3800	4040	20.0
168	3820	4160	20.0
180	1960	3300	17.0
182	2640	3300	17.0
184	2640	3300	18.0
186	2640	3300	18.0
188	2640	3300	16.0
190	2640	3300	17.0
192	2640	3260	17.0
194	2640	3270	18.0
196	2640	3290	16.0
198	2460	3210	16.0
209	2460	1810	14.0
210	2640	1790	13.0
212	2640	910	10.0
214	2640	940	10.0
216	2640	250	7.0
222	2640	720	11.0
224	2640	130	5.0
226	2640	640	9.0
228	2640	350	7.0
234	2640	300	7.0
236	2640	240	6.0
240	2640	240	6.0
242	2640	50	3.5
244	2640	160	5.5
250	2640	870	10.0
252	2640	110	4.5
254	2640	750	10.0
256	2640	220	6.0
260	2640	270	6.5
262	2640	510	9.0
264	2640	480	9.0
266	2640	120	4.5
270	2640	320	6.5

PIPE SIZES THAT WOULD BE REQUIRED WITHOUT DETENTION
FOR THE PIPE ALIGNMENTS PRESENTED
IN THE RECOMMENDED PLAN
(continued)

Pipe Number	Pipe Length (ft)	Design Flow (cfs)	Pipe Size (ft)
272	2640	230	6.5
276	2640	80	4.0
278	2640	20	2.5
280	2150	85	4.5
281	3700	340	9.0
282	2640	1210	14.0
284	2460	150	5.0
286	2640	850	10.0
288	2460	150	5.5
290	2640	700	10.0
292	2460	50	3.5
294	2640	610	8.0
296	2460	70	4.0
298	2640	580	9.0
300	2460	110	4.5
302	2640	400	8.0
304	2460	90	4.0
306	2640	270	6.0
308	2460	100	4.5
310	2640	150	5.0
312	2460	90	4.5
400	1900	490	9.0
402	2500	490	8.0
404	2640	500	10.0
406	2640	470	8.0
408	2640	430	8.0
410	2640	360	7.0
412	2640	240	6.0
414	2640	200	5.5
416	2640	60	4.0
420	2640	3770	18.0
422	2640	3730	18.0
424	2640	3000	18.0
426	2640	3000	16.0
428	2640	1880	14.0
430	2640	1780	13.0
434	5280	480	10.0
435	3800	310	8.0
436	1320	1200	12.0

PIPE SIZES THAT WOULD BE REQUIRED WITHOUT DETENTION
FOR THE PIPE ALIGNMENTS PRESENTED
IN THE RECOMMENDED PLAN
(continued)

Pipe Number	Pipe Length (ft)	Design Flow (cfs)	Pipe Size (ft)
438	1320	1230	11.0
440	2640	1140	11.0
442	2640	360	9.0
444	2640	270	7.0
445	3800	310	10.0
446	2640	480	9.0
448	2640	490	8.0
450	2640	320	8.0
452	2640	250	6.0
454	2640	120	5.0
456	2640	1090	11.0
458	2640	270	6.5
460	2640	910	10.0
462	2640	250	6.5
464	2640	710	10.0
468	1320	700	9.0
470	1320	640	10.0
472	2640	230	6.0
474	2640	390	8.0
476	2640	240	6.0
478	2640	830	10.0
480	2460	260	7.0
482	2640	670	9.0
484	2460	150	5.5
486	2640	590	10.0
488	2460	160	5.0
490	2640	370	8.0
500	2460	280	6.0
506	2640	520	10.0
508	2640	130	5.0
510	2640	360	8.0
512	2640	110	4.5
514	2640	240	7.0
516	2640	60	4.0
518	2640	170	5.5
520	2640	180	5.5
528	2640	120	5.5
534	2640	70	4.0
536	2640	340	9.0

PIPE SIZES THAT WOULD BE REQUIRED WITHOUT DETENTION
FOR THE PIPE ALIGNMENTS PRESENTED
IN THE RECOMMENDED PLAN
(continued)

Pipe Number	Pipe Length (ft)	Design Flow (cfs)	Pipe Size (ft)
538	2640	100	4.5
540	2640	240	6.0
542	2640	210	5.5
550	2640	150	5.5
551	2640	70	4.0
558	2640	210	6.0
560	2640	70	4.5
562	2640	200	7.0
564	2640	150	5.0
572	2640	80	4.5
574	2640	70	4.5
576	2640	70	4.0
608	2640	70	4.0
610	2700	70	5.5
620	2700	110	4.0
624	2640	150	5.5
700	1900	940	10.0
701	1300	120	5.0
704	2640	270	7.0
706	2640	700	10.0
708	2640	120	4.5
710	2640	630	9.0
712	2640	210	6.0
714	2640	440	8.0
716	2640	140	5.0
718	2400	330	7.0
722	2640	240	7.0
724	3000	210	7.0
726	3000	90	4.5
728	1300	220	6.0
730	2500	500	9.0
732	2640	220	6.0
734	2640	310	7.0
736	2640	110	4.5
738	2200	250	6.0
740	2400	210	5.5
746	2700	260	7.0