US Army Corps
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Los Angeles District

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OLD CROSS-CUT CANAL

PHOENIX, ARIZONA

APRIL 1988

GEOTECHNICAL FEASIBILITY REPORT

DRAFT

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GEOTECHNICAL
FEASIBILITY REPORT

1. INTRODUCTION

1.1 Purpose and Scope. This report presents a feasibility level geotechnical assessment of the proposed flood control improvements to Old Cross-Cut Canal, the Arizona Canal, and the area immediately north of the Arizona Canal. This evaluation is based on review of (1) geologic literature, (2) groundwater well data, (3) subsurface logs prepared by the City of Phoenix for local storm drain projects in the vicinity, (4) visual site inspection, (5) design parameters developed for the Arizona Canal Diversion Channel (ACDC), and (6) local production of concrete and other construction materials. The report describes the site conditions, presents design considerations, list sources of materials, and provides conclusions and recommendations.

1.2 Location and Description. This project is located on the east side of Phoenix, Arizona. General boundaries for the area north of the Arizona Canal, which will require a storm drain collector system, are Invergordon Road to the east, 44th Street to the west, Lafayette Boulevard to the north, and the Arizona Canal to the south. Old Cross-Cut Canal, which runs on a north south alignment, parallels 48th street from the Arizona Canal south to McDowell Road. The canal then shifts one block to the west and proceeds southward to the Salt River. A project vicinity map is presented on plate 1.

There are three alternatives for the storm drain collector system north of the canal:

1. The Alley Alternative consists of a two-branch collection system along with lowering the north bank of the Arizona Canal between Dromedary Road and 55th Place. The west branch has six conduits (approximately 4 feet in diameter), ranging from 1000 to 2000 feet in length, collecting runoff and discharging directly into the Arizona Canal. The conduits will be located in alleyways between 40th Street and Dromedary Road. The east branch, a single conduit approximately 7200 feet in length starting at Invergordon Road, will parallel Lafayette Boulevard westward to 56th Street and then turn southward along 56th to the Arizona Canal. The conduit will be approximately 10 by 10 foot by the time it discharges into the canal. All runoff flows contained in the Arizona Canal will be routed down the improved Old Cross-Cut Channel to the Salt River.

2. The Partial Lafayette Alternative is also a two branch collection system. However, the west branch, instead of running six conduits down the alleyways, will consist of a main conduit starting at 44th Street and paralleling Lafayette Boulevard eastward to 48th Street and then turning southward to the Arizona

Canal. The east branch of the collection system is the same as described in the Alley Alternative. The north bank of the canal will be lowered between Dromedary Road and 55th Place to allow direct runoff of surface flows into the canal.

3. The Full Lafayette Alternative consists of a collection system aligned along Lafayette Boulevard with 44th Street and Invergordon being the origins for the west and east conduits, respectively. The westward and eastward flows will meet at Arcardia Drive and then turn southward toward the Arizona Canal and Old Cross-Cut intersection. An inverted siphon will be used to cross under the Arizona Canal and discharge directly into the Old Cross-Cut Canal. No improvements are required to the Arizona Canal.

In all of the alternatives mentioned above, improvements to Old Cross-Cut Canal would be needed. These improvements would extend from the Arizona Canal to McDowell Road (Sta 191+90 to Sta 76+00). Two alternatives for these improvements will be evaluated. The first is a 1V : 1H grouted stone channel and the second is a covered concrete box approximately 10 by 10 foot. Both alternatives follow the existing alignment and will fit within the given right-of-way.

2. GENERAL SITE CONDITIONS

2.1 Topography and Geology. The project area is located on a gently sloping alluvial apron which extends about 5 miles from the base of the Camelback Mountain to the Salt River. Elevations vary from about 1500 feet (National Geodetic Vertical Datum) at the base of the Camelback Mountain to 1260 feet at the Arizona Canal and 1130 feet on the Salt River floodplain. Three geologic units are exposed in the project vicinity:

Recent (Quaternary) Alluvium: Unconsolidated calcareous clay, sand, gravel, cobbles, and boulders, slightly to well-cemented or calichified. This unit includes upper valley fill sediment, as well as Salt River floodplain deposits.

Tertiary Red Unit: Sandstone and conglomerate, red brown, slightly calcareous, thinly to medium-bedded, friable to moderately hard, moderately dense. Clasts vary from very fine sand to 1/2-inch size, with occasional rounded cobbles up to 8 inches in diameter. The unit includes the Camel's Head Formation of Camelback Mountain.

Precambrian Igneous Complex: granite, gneiss, schist, and quartzite. These rocks vary in composition, but tend to be fractured and weathered in the project area.

Recent Alluvium underlies most of the project area, reaching a maximum thickness of 250 feet near the Salt River. Underlying the Recent Alluvium are basement rocks of various ages, including the Red Unit and the Precambrian Igneous rocks. The Red Unit is exposed in the western portion of Camelback Mountain, in the vicinity of Papago Buttes where it reaches a maximum thickness of 2000 feet, and in the banks of the Arizona Canal upstream of 56th Street. The Precambrian Igneous rocks are exposed in the eastern portion of Camelback Mountain, and in the banks of the Old Cross-

Cut Canal between Van Buren and Washington streets.

2.2 Seismicity. The dominant seismic feature in the surrounding region is the Verde fault system, located 55 miles northeast of the project. A maximum credible earthquake of magnitude 7.0 could produce a maximum bedrock acceleration of 0.07g at the project site, however, this would require the unlikely occurrence of simultaneous movement on all segments of the system. The project is located in Seismic Zone 1 (U.S. Army Corps of Engineers, 1983), indicating that minor seismic activity may be expected, with accelerations less than 0.05g. Seismic ground shaking may occur in the Phoenix area within the project life, however, it is anticipated that the proposed structures will be able to withstand the stresses from the accompanying low accelerations.

2.3 Groundwater. The project area spans two groundwater basins which are separated by a north-south trending bedrock ridge connecting Camelback Mountain and the Papago Buttes. The ridge passes under the Arizona Canal near 56th street, and is exposed at the Arizona Falls. Groundwater lies at depths of less than 20 feet along the Arizona Canal west of 56th Street, and along the entire length of the Old Cross-Cut Canal. Due to the existence of a bedrock ridge between Camelback Mountain and the Papago Buttes, combined with a high rate of groundwater withdrawal in the Scottsdale vicinity, groundwater levels drop abruptly east of 56th Street, reaching depths as great as 300 feet near the east end of the proposed collector channel. While groundwater levels east of 56th Street have dropped as much as 200 feet since the earliest records in the 1940's, levels on the west side have been relatively stable. In general, most of the groundwater level drops experienced in the project area occurred prior to 1964; reduced pumpage over the last 20 years has resulted in slower rates of decline. During site visitations on 7-8 October 1986, the Old Cross-Cut Canal contained as much as 1 foot of water at a depth of 20 feet below the surrounding ground surface. Maximum flow was estimated at 2 cfs.

2.4 Subsidence. Land subsidence and associated earth fissure development have occurred in the Phoenix area due to major groundwater declines. A National Geodetic Survey level line has been established along the Arizona Canal, and no significant subsidence has been measured in the immediate project area. The nearest zone of measured subsidence is approximately 4 miles northeast of the site, where a 0.9-foot land surface decline occurred between 1948 and 1981. Major groundwater declines in the future could result in subsidence along the project alinement. If current trends toward reduced pumpage continue, however, groundwater level declines will be considerably less than those which have occurred in the past; consequently subsidence is not expected to affect the proposed structures. Earth fissures have not been observed in the project area; the

closest occurrences are 18 miles southeast in the vicinity of the city of Mesa, where 1 to 3 feet of subsidence has been measured. Since earth fissure formation is associated with major subsidence resulting from groundwater declines of at least 150 feet, such phenomena are not expected to occur in the project area.

3. INVESTIGATION

3.1 Previous Investigations. The City of Phoenix has conducted subsurface soil investigations in this urban area. The location of three test holes (PHX - 1,2 and 3) are shown on the vicinity map (plate 1). Depths of the test holes range from 11 to 15 feet. The materials are classified and described as silty clayey sands to sandy clays with a moderate calcareous cementation of the soil in the form of caliche below 5 feet. The soil information obtained from the city logs (shown in figure 1 and 2) was used in determining a typical soil type for the area.

3.2 Field Inspection. The area north of the Arizona canal is fully developed and consists largely of residential properties. The Arizona Canal is part of the SRP irrigation system and conforms to their design specification. Its northern bank appears to be a sandy clay material with an aggregate base course (ABC) top surface for light maintenance traffic.

Inspection of the Old Cross-Cut Canal revealed that, at the Indian School Road / Old Cross-Cut intersection, the channel embankment and foundation is composed of Recent Alluvium consisting of light brown, gravelly sandy silts and silty sands. Soil appeared to be coarser-grained with higher percentages of gravel with some cobbles in the downstream direction, and is moderately to well cemented by caliche at depths of approximately 5 to 10 feet below the ground surface. The uncemented layer above the caliche is susceptible to erosion, and in some portions of the channel, between the Arizona Canal and Osborn Road, the slopes are eroded to approximately 1V : 1/2H. The deeper cemented material has been eroded to vertical slopes. A caliche-cemented boulder deposit is exposed in the canal banks upstream of Indian School Road. The boulders are rounded, up to approximately one foot in diameter, and are embedded in a light brown, hard, dense, calcareous silty sand matrix.

Bedrock is exposed at two locations on the project alignments. Sandstone of the Red Unit is exposed in the banks of the Arizona Canal east of 56th Street in an outcrop extending about 100 feet downstream from the Arizona Falls. Precambrian quartzite is exposed along the banks of the Old Cross-Cut Canal, from about 500 feet north of Washington Boulevard to about 200 feet south of Van Buren Street. The quartzite is grayish pink, highly fractured, moderately weathered, hard, and dense. It occurs in the lower 4 to 8 feet of the canal and is overlain with as much as 10 feet of soft to moderately hard caliche.

4. DESIGN ASSESSMENT

4.1 Design Parameters. From the previous investigations by the

City of Phoenix and laboratory testing of soils for ACDC, design parameters were developed. These values represent the predominant material in the vicinity and are not necessarily representative of the entire reach. The material, a sandy clay (CL), has a moist unit weight of 132 pcf and a dry unit weight of 116 pcf with an optimum moisture content of 13.6 percent, when compacted to 90 percent of maximum density according to ASTM D-1557. Strength parameters of the material are defined by an internal angle of friction equal to 22.5 degrees and a cohesion of 250 psf. Lateral earth pressures, defined by an equivalent fluid weight, for the active (Ka) and the passive (Kp) cases are 40 and 326 pcf, respectively.

Bearing capacity for structures and other loads will be limited to 2400 psf. Reduced strengths (i.e. phi & cohesion) were used to compute the bearing in lieu of a settlement analysis. Although caliche appears in the borings and may support higher bearing capacities, areas of uncertainties exist, so the higher available strength was not used in the analysis.

4.2 Slope Stability. Stability of the 1V : 1H grouted stone side slope of the Old Cross-Cut channel was analyzed for the end of construction with and without seismic loading, and the sudden drawdown conditions. Again, the effects of the caliche, which is a strong but unpredictable material, were not considered in the analyses.

Factors of Safety

End of Construction	FS = 2.0
End of Construction W/ Seismic ...	FS = 1.6
Sudden Drawdown	FS = 1.7

5. CONSTRUCTION CONSIDERATIONS

5.1 Diversion and Control of Water. Groundwater is at or near the proposed invert elevations throughout the Old Cross-Cut reach. Dewatering would be required to remove groundwater during excavation and construction of structures such as drop structures and the entrenched channel that extend below the existing canal invert. In addition, diversion and control of varying amounts of surface flow would be required for construction during any season.

5.2 Excavation. Excavation can be accomplished with conventional heavy construction equipment. Dozers with ripper blades or heavy duty hammering equipment would be required to loosen bedrock and calcareous cemented soils (i.e. caliche) where encountered in the collector system excavation or channel excavation. Blasting would not be allowed due to the surrounding urban area. Temporary excavation of slopes would be no steeper than 1V : 3/4H in soil and 1V : 1/2H in bedrock and cemented soils. Vertical trenching with shoring may be required for the collector system north of the Arizona Canal due to limited work

space. Following excavation to design grades, the foundation materials for subsurface structures or a lined invert would be compacted to at least 90 percent of the maximum density determined by ASTM test method D 1557.

5.3 Fill/Backfill. For the conduits in the collection system north of the Arizona Canal, suitable backfill material can be obtained from the required excavation. Coarse-grained soils obtained from suitable sources will be used as fill and backfill material behind channel walls and other subsurface structures subjected to high groundwater or expansive soils. Backfill and the miscellaneous fill would be compacted to at least 90 percent of maximum density. Maximum density for each soil type would be determined according to ASTM test method D 1557.

5.4 Channel/Box Conduits. A rectangular covered box culvert or trapezoidal concrete-lined or grouted stone open channel would protect the banks from erosion and prevent invert degradation. A subdrain system will be required to relieve hydrostatic pressure under the invert and behind the channel walls, as shown schematically on figure 3. The subdrain system would consist of a slotted 6-inch diameter collector pipe behind the heel of the channel walls, a gravel drain layer beneath the invert to transport ground water to the pipes, and a sand filter layer under the gravel to prevent clogging with fine grained foundation soils. The gravel drain layer would be 6 inches thick under concrete and 12 inches thick under grouted stone to account for disturbance caused by placing large stones directly on the gravel. The sand filter layer would be 6 inches thick. Subdrain outlets would be provided at intervals not exceeding 1000 feet. The pervious materials from channel excavation would be used as backfill behind the channel walls. After grading and proof-rolling, the in situ materials would provide a suitable foundation, except where bedrock or caliche is exposed in the invert. Bedrock or caliche would be over-excavated to a depth of one foot below the bottom of the concrete lining and a subdrain system and a bedding layer of pervious material would be provided.

5.5 Erosion Control. Erosion control will be needed for the north bank of the Arizona Canal for the alternatives that employ overbank flow to collect local surface runoff. Stone revetment, gabions and concrete aprons are three erosion control methods that may be used. However, the stone revetment will not be considered because it would require a 1V : 2H slope into the canal, thereby, significantly effecting the canal hydraulics.

Gabions may be used as an alternative form of stone slope protection using smaller sized stones. The slopes would be covered with 18-inch deep wire cells laid parallel to the slope. The cells would be filled with 4-inch to 8-inch diameter cobbles imported from offsite commercial sources, or possibly produced by processing material from required rock excavation in the channel.

No filter material would be required beneath the gabions. Excavation would be less extensive since gabion structures can be constructed on the surface of the embankment and are flexible enough to follow changing contours. The effect of the gabions on the canal hydraulics are unknown at this point and will require SRP (Salt River Project) approval.

Concrete aprons, strategically located, are possibly the most economical erosion control method for the north bank. The apron would provide a controlled path for the surface runoff water into the canal and have no significant effect on the canal hydraulics. The size and placement of these aprons will be determined by the contour of the surrounding ground surface, and the quantity of surface runoff.

5.6 Grouted Stone. Grouted stone may be used for slope protection on the Old Cross-Cut Canal channel. For estimating purposes, the Old Cross-Cut Canal channel would have grouted side slopes of 1V : 1H. However, hand placement of the stone may be required for this slope, so economically it would be better to flattened the slope to 1V : 1.5H (i.e. 1V : 2H is typically used for grouted stone side slopes). Grouted stone may be susceptible to cracking due to hydrostatic pressure from high ground water and from differential movement due to expansion of clay soils. Therefore, a subdrain system as described in the section 5.4, would be needed to reduce uplift forces, and all expansive soils would be removed and replaced with suitable fill. Thickness of the grouted stone is estimated to be 15 to 18 inches depending on the hydraulic design of the channel.

6. CONSTRUCTION MATERIALS

6.1 Concrete. The concrete work necessary for the Old Cross Cut Canal project will consist of the box culvert for the Old Cross Cut Canal, and the sections of the collection system which are not prefabricated. The concrete used shall be 4000 PSI concrete made with Type II cement and 1 1/2 inch maximum aggregate and will have a maximum water cement ratio of 0.45. The quantity of the cement necessary will be dependent on the alternatives selected.

6.2 Local Concrete Producers. There are numerous ready mix firms in the Phoenix area which are capable of supplying the amount of concrete of the desired specifications necessary for the completion of the job. The following is a brief description of three of the larger local firms, Blue Circle, Cal Mat of Arizona, and Tanner. Price data based on February 1988 prices for concrete delivered to the project site is shown in Table A.

Blue Circle is currently running 14 plants at 10 locations in the Phoenix area ranging in capacity from 120 to 350 cy/hr. They use both Mexican and American Type II cement and have available both Class F and Class C flyash. The Mexican cement source is not currently prequalified by WES (see Section 6.5).

Cal Mat of Arizona currently operates 12 ready mix plants in

the Phoenix metropolitan area. These facilities use Type II cement and have available both Class F and C flyashes.

Tanner currently has 13 plants in the Phoenix area with an average plant capacity of 250 yds/hr. These plants use Type II cement and Class F flyash. Tanner operates a fleet of 155 delivery trucks for their Phoenix ready mix operations.

TABLE A
Concrete Prices
Dollars per Cubic Yard
(February 1988)

SOURCE	1 1/2" Max	1" Max
BLUE CIRCLE	44.00	44.00
CAL MAT OF AZ	42.00	42.00
TANNER	47.00	47.00

6.3 GROUT. The grout to be used in the event that the grouted stone alternatives are chosen will be a 7-1/2 sack mix with 8-1/2 gallons of water per sack. It will be available from the ready mix producers previously discussed. Cost data reflecting February 1988 prices is contained in Table B.

TABLE B
Grout prices
(February 1988)

SOURCE	$/C.Y.
BLUE CIRCLE	58.00
CAL MAT OF AZ	50.00
TANNER	57.00

6.4 AGGREGATES. The three main aggregate sources in the Phoenix area are located on the Salt River, Cave Creek and the Agua Fria River. Blue Diamond, Cal Mat of Arizona, and Tanner each operate aggregate plants at both the Salt and Agua Fria Rivers. Each general source is described by the stream from which the materials are taken.

Coarse aggregates from the Salt River in sizes up to 12 inches are readily available although in some cases materials up to 2 feet in diameter can be obtained. While some sources now contain nothing larger than gravel, there is still sufficient sand for economical production.

Cave Creek contains cobbles and boulders up to two feet and a sufficient supply of coarse aggregates. Some plants have ceased to produce sands for fine aggregate.

The Agua Fria River produces materials of 18 inches maximum size, with the largest proportion of its material being sand. The sources on the Agua Fria River should be able to supply sufficient aggregate for the needs of this project.

6.5 CEMENT. There are currently two major producers of cement in the state of Arizona who have been prequalified by the Waterways Experiment Station for use in Corps of Engineer's projects. These plants are the Phoenix Portland Cement Corporation at Clarksdale, Az, and the Arizona Portland Cement Corporation at Rillito, AZ.

The Phoenix Portland Cement Corporation is located approximately 95 miles north of the job site and produces Type II cement conforming to ASTM Specification C-150 and Type IP cement which meets the requirements of ASTM C-595.

The Arizona Portland Cement Corporation produces Type II and Type V cement, both conforming to ASTM C-150, and is located approximately 115 miles southwest of the project site.

The Cement Campana plant is owned and operated by Blue Circle and is located approximately 320 miles south of the project site in Hermosillo, Mexico. This plant is not currently on the Corps of Engineer's prequalified list and therefore the cement would need to be tested and approved by the Waterways Experiment Station before its use could be authorized.

6.6 POZZOLANS. In accordance with current Federal Regulations the option to use flyash as a substitute for Portland cement will be allowed for all work on the Old Cross Cut Canal. Concrete produced in the Phoenix area generally uses flyash to offset the reactivity between the cement and the silicates in the aggregates and to reduce the heat of hydration.

Flyash which has been approved for use in Corps projects in the past is available from two sites in Arizona. Western Ash's Navajo Plant in Page, Arizona produces Class F flyash and is located approximately 390 miles north of the project site. Also producing Class F flyash is the Western Ash plant in Cochise, Az which is approximately 195 miles southeast of the project site.

Currently only Class F flyash has been approved for work in the LA District, however studies are currently being conducted to determine the acceptability of Class C flyash for future projects.

6.7 ADMIXTURES. The ready mix concrete industry in Phoenix generally makes use of two types of admixtures, air entrainers and water reducers. It is expected that both of these will be used in the Old Cross Cut Canal mix design.

6.8 WATER. Sufficient water for the mixing of concrete and grout should be available from local municipal water supplies.

7. CONCLUSIONS

7.1 General Feasibility. All of the proposed flood control alternatives for the Old Cross-Cut Canal project appear to be technically feasible. No adverse geotechnical site conditions have been discovered which would preclude the construction of any of the proposed improvements, however, the costs associated with

each type of construction can only be roughly estimated at this time due to the uncertainty of the subsurface conditions.

Field inspections and a review of geotechnical literature, water well data and boring logs indicate a generally high groundwater level and the presence of bedrock (i.e. Arizona Falls and Washington Boulevard to Van Buren Street areas) and caliche near the surface at several locations in the project area. The associated requirements for caliche and rock excavation for the various alternatives would have a significant impact on the cost of construction of collector system and canal channel improvements. The grouted stone for the channel will also have an impact on the construction costs if the slopes remains 1V:1H. This is due to the fact that the stone on a steep slope will require hand placement.

8. RECOMMENDATIONS

8.1 General Exploration and Testing. Subsurface exploration and testing of foundation and construction materials would be conducted during the design phase of the project as previously agreed upon by geotechnical and project management personnel. Geotechnical investigations would be conducted to determine depths to ground water, location and extent of caliche and bedrock, and to obtain the engineering properties of the project site, borrow area, aggregate and stone materials. Subsurface explorations would be conducted along the channel alignment and in other key areas using seismic refraction, core drilling, and hollow stem auger drilling and sampling. Subsurface exploration for aggregate, stone and borrow sources would be accomplished by bucket auger drilling or backhoe trenching. Representative samples of foundation and borrow materials would be tested at Corps laboratories to determine material properties for design and construction.

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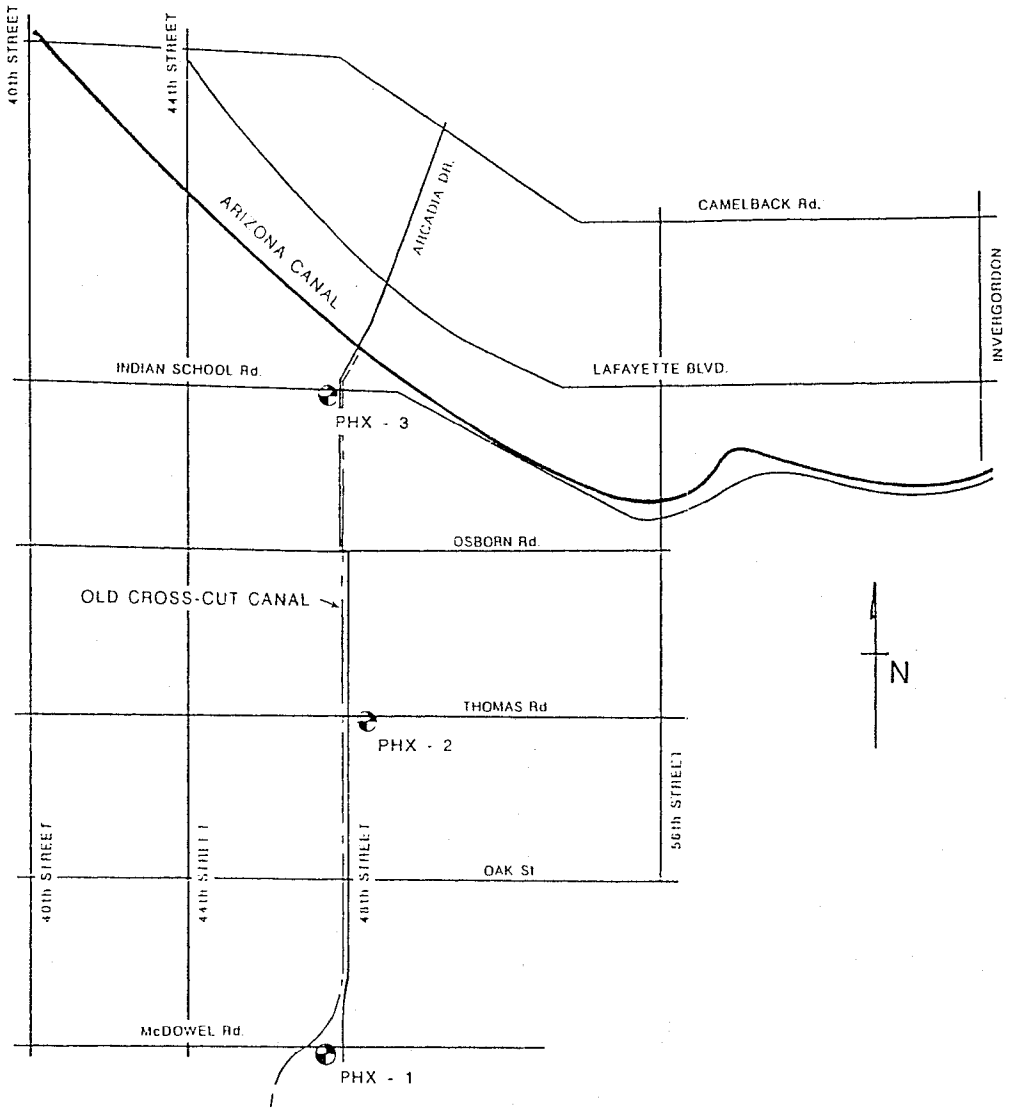

LEGEND:

PHX - X TEST HOLES DONE BY THE CITY OF PHOENIX.

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PHOENIX, ARIZONA

OLD CROSS-CUT

VICINITY MAP

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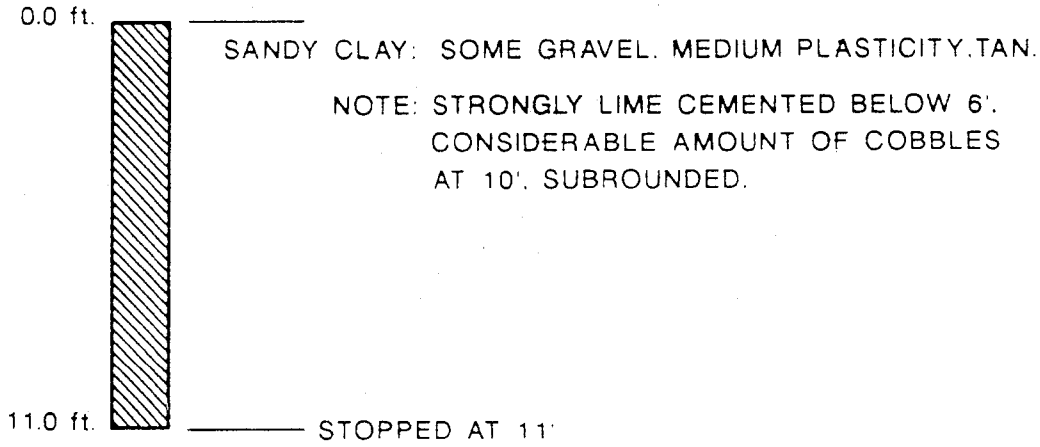
PHX - 1



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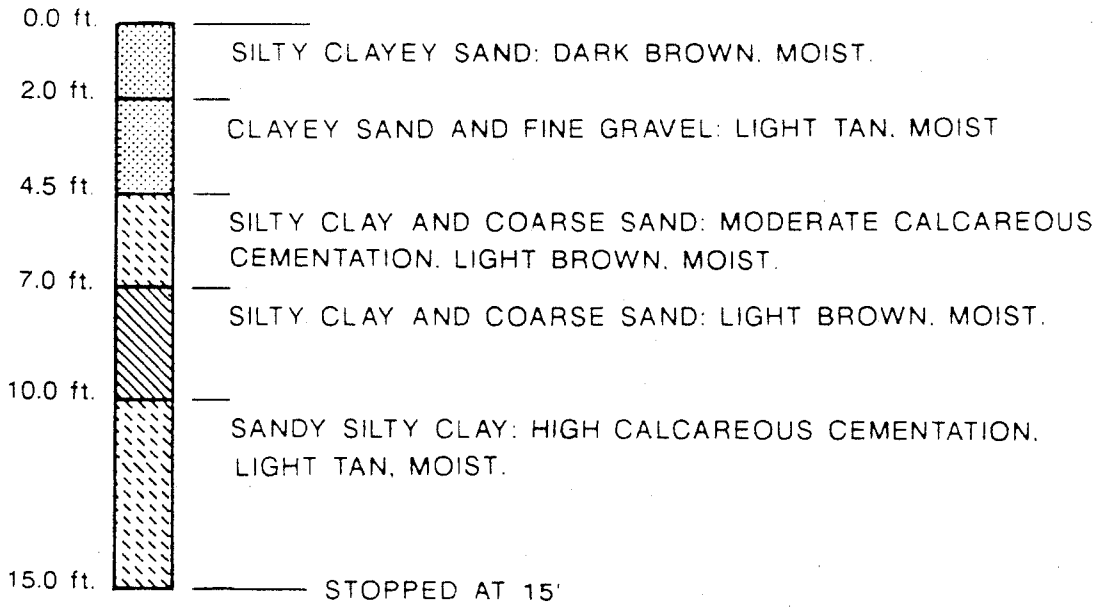

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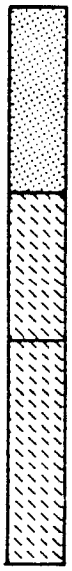
SOIL BORING TEST HOLES

FIGURE 1

PHX - 3



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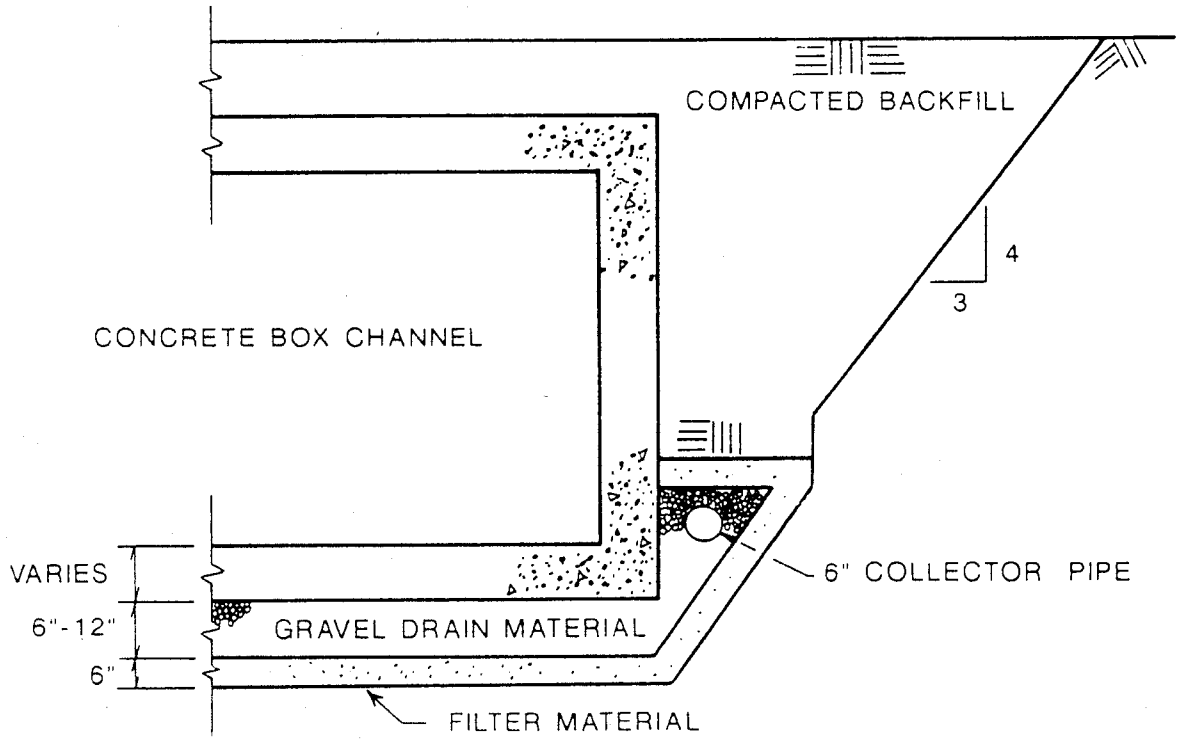
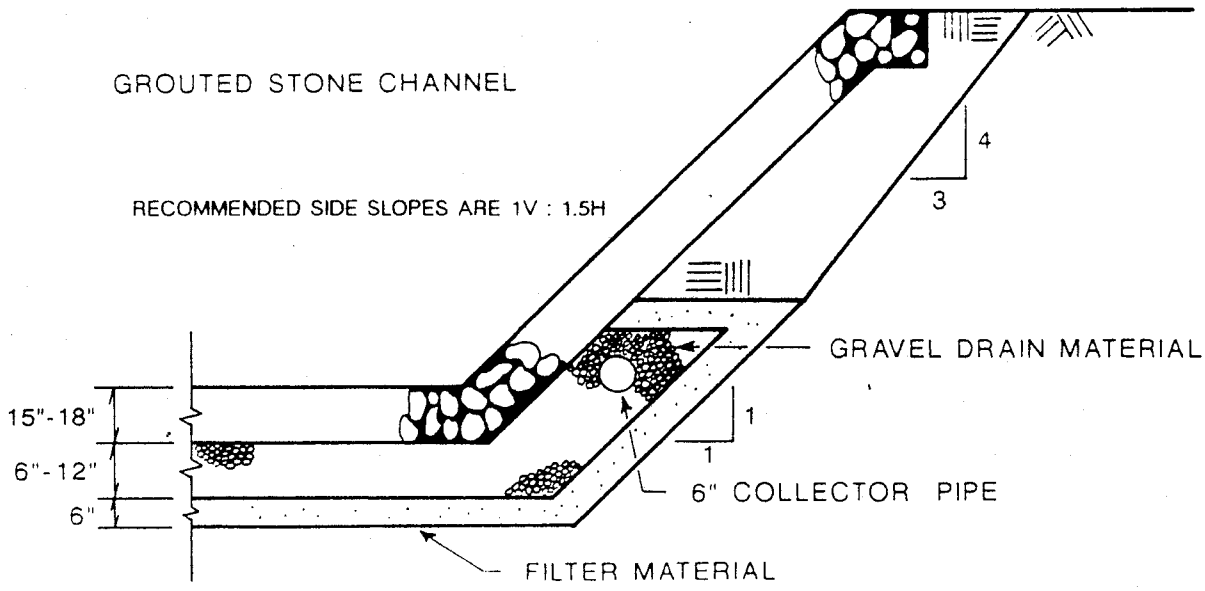
SOIL BORING TEST HOLES

FIGURE 2





SUBDRAIN DETAILS

FIGURE 3