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RIO SALADO HABITAT RESTORATION PROJECT
MARICOPA COUNTY, ARIZONA

GEOTECHNICAL REPORT

US Army Corps
of Engineers®

U.S. ARMY ENGINEER DISTRICT, LOS ANGELES
CORPS OF ENGINEERS

February 2000

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TABLE OF CONTENTS

Section Page

I. EXECUTIVE SUMMARY 1

SECTION A
GEOLOGY AND SOILS

1.0 REGIONAL GEOLOGY 2

2. 0 GEOLOGY AND GEOTECHNICAL PROPERTIES OF THE SALT RIVER BED ALLUVIUM, PHOENIX PORTION 3

2.0.1 Foundation Materials 3

2.0.2 Excavation 5

2.0.3 Compacted Fill and Backfill 5

3. 0 SEISMICITY 6

3.0.1 Faulting 6

3.0.2 Seismic Conditions 6

3.0.3 Project Design Earthquake 7

4.0 GROUND WATER 7

4.0.1 Ground Water Levels and Ground Water Profile 7

4.0.2 Construction Dewatering 8

4.0.3 Production Wells 11

4.0.4 Hydrogeology 11

4.0.5 HTRW (Hazardous, Toxic and/or Radioactive Waste Contamination to Ground Water 14

4.0.6 Ground Water Monitoring Wells 14

5.0 HTRW CONTAMINATION TO SOILS. 15

6.0 SUBSIDENCE 17

7.0 STONE SOURCES. 17

8.0 REFERENCES. 18

SECTION B
MATERIALS

REPORT ON ROLLER COMPACTED CONCRETE (RCC) FOR CONSTRUCTION, table of contents starts on page 20 20-37

FIGURES

Figure No.	Title
1	Geologic Map
2	Plan View of Hydrogeologic Profile (Cross Section)
3	Generalized Hydrogeologic Cross Section (Profile)
4	Stratigraphic Cross Section (Profile)
5	Generalized Ground Water Profile
6	Monitoring Well Locations for Corps Installed Wells No. RSMW-1 to RSMW-3
7	Monitoring Well Construction Diagram (Profile)
8	Production Well Design
9-13	Logs of 1999 Corps of Engineers Geotechnical Exploration
14-25	Plan Views of Geotechnical Exploration (Rough Grading Plans for Low Flow Channel)

I. Executive Summary

The geotechnical appendix herein covers the general existing geotechnical conditions and concerns of the project prior to construction of the Low Flow Channel. Section A of this appendix discusses the existing regional geology, geology and geotechnical properties of the foundation materials, ground water and hydrogeology, seismicity, large stone borrow sources and HTRW (Hazardous, Toxic and Radioactive Waste) issues for the project. The Low Flow Channel (LFC) for the entire project was explored in 1999 by the Corps of Engineers, Geotechnical Branch, Materials and Investigations Section, for the purpose of defining the types and gradation of native soil materials present in the existing channel in order to formulate a materials design for the LFC. From the exploration analysis, a Roller Compacted Concrete (RCC) mix design was chosen as the construction material of which the LFC will be composed of. The full details of the RCC mix and summary of the exploration are in Section B of this appendix. The Corps of Engineers, Geology and Investigations Section (Geotechnical Branch) installed three ground water monitoring wells along the Salt river banks, at the Central Avenue, 16th, 24th Streets bridge crossings, for the purpose of establishing static ground water levels and determining basic ground water quality along the river. These recent geotechnical investigations and other recent explorations and/or other most recent background information, since the writing of the final feasibility study, dated April 1998, are discussed more fully in detail throughout this appendix.

Section A

1.0 Regional Geology

The project area is in the Phoenix basin of the Salt River Valley. Metropolitan Phoenix is located geomorphically within the Gila Lowland Section of the Sonoran Desert Subprovince, a part of the Southern Basin and Range Physiographic Province. This province is characterized by broad, gently sloping, connected alluvial valleys (basins) bounded by moderately high northwest to southeast trending, rugged mountains (ranges). During late Miocene time (Tertiary period), the mountain ranges were extensively dissected, uplifted and down dropped by northwest to southwest and east to west trending sub-parallel normal faults (Reynolds 1985). An extensive amount of volcanic eruptions and activity accompanied the faulting. After late Miocene time and until the late Tertiary period, the ranges deeply eroded and filled their down dropped areas (basins) with sediments, which were later consolidated into sedimentary rocks. After the late Tertiary and until recent (Holocene) time, the basins, including the Salt River Valley, filled with unconsolidated and occasional semi-consolidated sediment (alluvium) eroded from the ranges. The thickest accumulations of Valley alluvium formed during the early to middle (approximately 1 million years ago) Quaternary period.

Today the alluvium of the Salt River Valley is in the final stages of development as evidenced by the numerous low-lying isolated hills (inselbergs), which project above the valley surfaces. These hills represent peaks of former mountain ranges that are now almost completely buried by alluvial material.

The mountain ranges that border the project area consist mostly of Tertiary age sedimentary and volcanic rocks that lie unconformably upon an ancient Precambrian igneous and metamorphic basement complex (AGS 1986). The complex is composed predominantly of igneous granite and diorite, metamorphosed schist, gneiss and volcanic rock. The Tertiary rocks are made up of volcanic basalt, andesite, rhyolite and sedimentary sandstone, siltstone and conglomerate.

The sediments within the Phoenix area consist primarily of Quaternary to Tertiary sediments that constitute the valley fill. They consist mostly of poorly to well consolidated (cemented) and unconsolidated gravel, sand, silt, and clay, representing several environments and ages of deposition. The total thickness of the alluvial materials range from near zero meters along the mountain fronts to 3,000 meters (9,840 feet) under the valley interior. These Quaternary sediments as shown on figure 1, geologic map for the project (Arizona Bureau of Mines (ABM), 1957), is the only geologic unit that will be encountered during construction of the Phoenix project portion. The next section, describes in detail, the geotechncial properties of this Quaternary sediment and the appropriate geologic/geotechnical nomenclature that shall be in use for the rest of this appendix

2.0 Geology and Geotechnical Properties of the Salt River Bed Alluvium, Phoenix Project Area-

The Phoenix portion of the Rio Salado Habitat project extends a total of approximately 7.2 km (4.5 miles) along a stretch of the river, from west of the Interstate 10 bridge crossing to just west of the 19th Avenue bridge crossing. The Salt river flows west into the project area from the Superstition and Goldfield mountain ranges. The width of the Salt river bed (channel) ranges from approximately 61 to 243 km (200 to 800 feet) throughout the project area. The habitat project limits extend somewhat beyond the river bed and into the slopes along the channel. The slopes of the channel vary in height from 7.6 to 18.3 km (25 to 60 feet), as measured from the top of the existing river bed.

The predominant natural materials within the river bed are composed of Quaternary age river deposited sediment or alluvium, as previously mentioned, which is a part of the greater Salt River Valley Alluvium, a sequence of alluvial deposition within the entire Phoenix basin (figure 1). For the specific geotechnical purposes of this project and for convenience in nomenclature, the river bed materials, Salt River Valley alluvium, etc., are herein collectively referred to as the **Salt River Bed Alluvium** (figure 1). The upper 12 meters (40 feet) of the Salt River Bed Alluvium is the foundation material upon which the main project hydrologic engineering features LFC, Guide Dike Structures (GDS), etc.) are designed and constructed. The upper 12 meters of foundation material is considered as that measured from the river bed surface to approximately 12 meters (40 feet) depth.

2.0.1 Foundation Materials-

The upper 12 meters (40 feet) of the Salt River Bed Alluvium is the foundation material upon which the main project hydrologic engineering features (LFC, GDS, etc.) are designed and constructed. The upper 12 meters of foundation material is considered as that measured from the river bed surface to approximately 12 meters (40 feet) depth.

Overall, the Salt River Bed Alluvium within the Phoenix portion of the project consists of a general mixture of: approximately 460 meters (1,542 feet) (figure 1) of unconsolidated gravel and boulders, interbedded with irregular silt, sand and gravel lenses that become cemented gradually with depth. On a regional scale, the Salt River Bed Alluvium thickens towards the east and west of Tempe Butte gap, in the city of Tempe as shown in figures 3 and 4. At the gap, the Salt River Bed Alluvium averages less than 18 meters (60 feet) thick and in some places bedrock from Tempe Butte is exposed at the river bed surface. Hydrogeologically, the Salt River Bed Alluvium is divided into three distinct alluvial units named in depositional order, starting with youngest to oldest, as (ADWR, 1993):

A. Upper Alluvial Unit (UAU)- approximately 55 meters (180 feet) thick; the unit extends from river bed surface (0 meters and 0 feet reference) to approximately 55 meters (180 feet) depth; it is primarily a coarse soil (alluvium) which is composed of the following basic Unified Soil Classification (USCS) descriptions of sand (S), gravel (G) and cobbles, with small percentages of fines.

B. Middle Alluvial Unit (MAU) ("Middle Fine Unit" according to Dames & Moore, 1990)- approximately 91 meters (300 feet) thick; the unit extends from approximately 55 meters (180 feet) below river bed surface to approximately 146 meters (480 feet) depth; it consists mostly of fine grained soil (alluvium) which is composed of silts (M) and silty sands (SM), clayey silts (ML) and small amounts of gravel (G, a coarse soil).

C. Lower Alluvial Unit (LAU)- approximately 305 meters (1,000 feet) thick; the unit extends from approximately 146 to 451 meters (480 to 1,480 feet) below the river bed surface; it consists of a mixture of weakly to strongly cemented coarse and fine grained soils (alluvium). The coarse grained soils are composed of gravel (G) and boulders. The fine grained soils are composed of sand (S), sandy clay (SC), silty sand (SM)and interlayered beds of clay (C).

The local geology and general soils description of the Salt River Bed Alluvium is summarized in the stratigraphic profile shown on figure 4. This figure shows the UAU divided into 5 subunits, S, A_1, A_2, B, C (contacts are shown as dotted lines) and in contact with the underlying MAU (MFU), the contact is shown as a dark solid line. The UAU is exposed at the banks of the river and extends from this elevation to approximately 200 feet in depth.

In 1999, trenches were excavated by the Corps Geotechnical Branch, into the upper 5.2 meters (17 feet) of subunit A_1. Logs of the test trenches are shown on figures 9-13). According to the results of the field investigation and laboratory testing, the upper 5.2 meters can be described as a heterogeneous soil stratigraphys, consisting of:

1.2 to 3 meter (4 to 10 feet) thick layers of light brown, loose, poorly graded gravel with sand (GP) containing approximately 25% cobbles and 5% boulders; 1.2 to 3 meter (4 to 10 feet) thick layers of light brown, loose, well graded gravel with sand (GW) containing approximately 25% cobbles and 5% boulders; 0.3 to.61 meter (1 to 2 feet) thick layers of light brown, very loose, poorly graded sand (SP); 0.3 to 0.61 meter (1 to 2 feet) thick, light brown, loose, poorly graded sand with silt (SP-SM). The general gradation for the river bottom according to the laboratory tests indicates that the percent by weight passing the 3-inch sieve ranges from 85 to 100, the percent by weight passing the No. 4 sieve ranges from 10 to 100, and the percent passing the No. 200 sieve ranges from 1 to 9.

All of the soil within the trenches were dry , except in the six test trenches (TT99-6, 7, 8, 12, 19, 22 and 33), where water was found at variable depths. The water is considered to be perched, except for TT99-19 and 22, for which static water level was encountered.

The trench log soil descriptions are fairly consistent with the composite drill log descriptions of subunit A_1 made by Dames & Moore from previous explorations as shown on the stratigraphic profile in figure 4. One important feature of note on the figure is subunit B, which is a fairly laterally continuous silty sand (SM) that acts as a confining layer within the UAU for most of the phoenix portion of the project area. This layer in turn behaves as a semi-confining layer on a regional hydrogeologic scale.

2.0.2 Excavation-

Analysis from the geotechnical exploration indicates that excavations in the various materials, as mentioned above, would be stable at cut slopes of 1 vertical on 1.5 horizontal for temporary slopes and 1 vertical on 2 horizontal for permanent cut slopes. The excess excavated materials can be disposed of in the various landfills in the project area.

2.0.3 Compacted Fill and Backfill-

The excavated material will be suitable for use as compacted fill and backfill. Materials for compacted fill and backfill will be obtained from suitable materials from channel excavation. A balance factor of approximately 0.9 can be expected for compacted fill when compacting the material to 90 percent of maximum density obtained by ASTM D 698. The compacted fill will be placed in

12-inch loose lifts and compacted to a minimum 90-percent maximum density (ASTM D 698). Backfill placed over the Grade Control Structures, and Guide Dikes will be compacted to 85 percent of maximum density obtained by ASTM D 698. The backfill over the Grade Control Structures, and Guide Dikes will be placed in 24 inch layers and compacted to a minimum 95 percent maximum density (ASTM D 698). The excavation will yield sufficient amounts of suitable materials for the compacted fill and backfill

3.0 Seismicity

3.0.1 Faulting-

Faults in central Arizona are generally short, discontinuous, normal faults, some of which have been interpreted to displace Quaternary formations. Most fall within the Jerome-Wasatch Structural Zone, a 75 km (46.5 mile) wide band which extends from Utah into Mexico. In Utah, the zone is associated with current earthquake activity and displays evidence of abundant Quaternary faulting. In Arizona, the zone includes the Main Street Fault in the northwest corner of the state and the Verde Fault located approximately 90 km north of the Rio Salado. Both faults are considered to be potentially active.

Nearest to the Phoenix portion, a zone (approximately 400 meters (1,312 feet) wide) of exposed, Tertiary age inactive normal faults, exists just north of Tempe Butte gap. The zone trends northwest to southeast and is located approximately 333 meters (1,092 feet) north-northwest of the edge of the Salt River and extends northwestward where it ends at a distance of approximately 4,400 meters (2.75 miles) from here. An east to west trending (approximately 1,760 meter (1.1 mile) long) Tertiary age fault lies concealed below the alluvium, in the middle of the Salt river, at Tempe Butte Gap.

3.0.2 Seismic Conditions-

An evaluation of the geologic and seismic conditions within a 162-km (101 mile) radius of the project area indicates that the proposed project is in an area of low seismicity as referenced in Zone 1 of the Seismic Zone Map of the Contiguous States (Uniform Building Code, UBC 1997). About 30 earthquakes with maximum epicentral intensities between II and VI on the Modified Mercalli Intensity Scale (MM) have occurred within a 162-km radius of the project area from 1870 through 1980. The seismic historical record for the last 124 years indicates that only one major damaging earthquake (1887 Sonora, Mexico) has occurred and was located outside the 162-km radius.

The historical 1887 7.2M Sonora, Mexico earthquake was located more than 411 km from Tempe, AZ, and expressed 50 kilometers (31 miles) of surface rupture with 3 meters (9.8 feet) of normal displacement, causing rockfalls in the nearby prexposed bedrock hills of the phoenix basin. The most recent (1974) events, located about 24 km (38.6 miles) northeast of the project area, had recorded Richter magnitudes of only 2.5 and 3.0.

3.03 Project Design Earthquake-

The United States Geological Survey (USGS) probabilistic method for determining the peak ground acceleration (PGA) was chosen for this project. The life expectancy for the project was selected as 50 years = T. The PGA for the Operating Base Earthquake (OBE) and Maximum Design Earthquake (MDE) was calculated as directed by Corps of Engineer regulation (ER 1110-2-1806, 1995). The results of the calculations are as follows: For the OBE at 10% probability of excedence in 50 years, the PGA is 0.037% gravity (g). The MDE at 2% probability of excedence in 50 years is 0.077% g.

Definitions:

MDE- the maximum level of ground motion for which a structure is designed or evaluated. Performance requirement is not catastrophic failure. Severe damage or economic loss can be tolerated.

OBE- the earthquake that can reasonably be expected to occur during the service life of the project, with a 50% probability of exceedence during the service life, i.e. a return period of 144 years for a project with a service life of 100 years. The performance requirement is that the project function with little or no damage and without interruption of function.

4.0 Ground Water

The project area overlies portions of the principal aquifer within the Phoenix Basin that consists primarily of Quaternary and late Tertiary alluvium.

The Basin groundwater flow moves generally east to west, from the Salt River toward a major cone of depression near Luke Air Force Base, approximately 24 km (15 miles) west of Phoenix (Schumann, 1974). To a lesser extent, groundwater also flows in a northwestward direction toward a second cone of depression in the Deer Valley area.

Recharge to the groundwater basin is derived from seepage of irrigation waters, Salt river flows, rainfall, and underflow of groundwater. Recharge from streamflow and rainfall is minor, and the amount of recharge from irrigation seepage and underflow has not been high enough to offset progressive lowering of the water table.

Long-term groundwater withdrawal, since the 1940's, has resulted in a general decline in water levels from 67-100 meters (200-300 ft) throughout the Phoenix Basin. However, water-level declines have usually been less than 16.5 meters (50 ft) near the Salt River. The overall trend indicates a progressive decline in water levels westward from the project area toward Luke Air Force Base and northwestward toward Deer Valley.

4.0.1 Ground Water Levels and Ground Water Profile-

A ground water profile for the project was developed from compiling all existing ground water level data found closest to the river bed. This data was obtained from the following references: A. Existing ground water monitoring wells, including Corps installed monitoring wells RSMW-1 through RSMW-3 (the Corps monitoring wells were installed in Fall of 1999 and are in good condition-water level reading data was gathered from wells screened in the upper UAU, and designed to monitor the first encountered water level and it's fluctuations. B. Open gravel pits- water levels observed in open gravel pits as excavated along the river banks by sand and gravel operations. C. Test trenches- water levels observed in the test trenches from the 1999 Corps of Engineers geotechnical explorations for the project.

The ground water depth below the river bed surface varies from 5.5 to 11.5 meters (18 to 38 feet), (figure 5). From the ground water profile, it is anticipated that most of the Low Flow Channel construction, with the exception of the Grade Control Stuctures at Central Avenue bridge crossing and the three Drop Structures (DS) between 16th and 24th Street bridge crossings, will not occur within ground water. The perched ground water table is not continuous across the project, therefore the ground water profile only shows the static water table, as developed from the test trenches and wells in the project area.

4.0.2 Construction Dewatering-

The design drawings of the subgrade elevations for the Low Flow

Channel are shown to be above the elevation of the ground water profile in most cases for the entire project. Therefore, dewatering is not anticipated during most of the construction of the Low Flow Channel, except within areas of phase 1 of the Phoenix portion, whereby the river bed is constantly saturated from nearby surface water drainage into the river. The LFC dewatering areas, according to engineering stationing, for the phase 1 portions, are as follows: near Central Avenue bridge crossing, approximately between 90+00 to 140+00 and near 7th Avenue, approximately between 50+00 to 75+00. It is also anticipated that sections of the Grade Control Structures and Drop Structures will need dewatering during construction.

The dewatering calculations for the GCS and LFC are given for the phase 1 construction portion of the Phoenix reach of the project only The calculations are based on the following formula (Driscoll 1987) that incorporates depth of the foundations below the water table, the dewatering well radius and the well penetration length into the water table:

$$Q = \frac{K(H^2 - h^2)}{1055 \log(R/r)} + 2\,\frac{x(K)(H^2 - h^2)}{2880(L_o)};$$

x = unit length of trench excavation in feet.
Q = discharge in gallons per minute (gpm).
K = hydraulic conductivity in gallons per day/ft^2.
H = saturated thickness of the aquifer before pumping in feet.
h = depth of water in the dewatering well while pumping in feet.
R = radius of the cone of depression in feet.
r = radius of the dewatering well in feet.
L_o = distance from point of greatest drawdown to point where there is no drawdown in feet.

For **GCS**:
Given assumptions for Phoenix Reach, Phase 1, for current ground water conditions that include a *static water table and no perched water:*
x = 800 feet (244 meters); K = 1,496 gpd/ft^2 (61.1 m^2/day); r = 0.5 feet (0.15 meters); H = 60 feet (18.3 meters); h = 20 feet (3 meters); R = 40 feet (12.2 meters); L_o = 100 feet (30.5 meters).

Q = 31,695 gallons per minute (120 cubic meters per minute) total.

Thus for a Q of 31,695 gpm across a 800' long X 100' wide (244 meter long X 30.5 meter wide) trench:

The minimum number of wells with a 0.15 meters (0.5 feet) radius needed to be
installed to dewater the trench would be approximately 75, spaced a minimum of 3.3 meters (11 feet) apart. Each well would have to pump at least 1.6 cubic meters per minute (423 gallons per minute). In addition, each well would have to penetrate at least 6.1 meters (20 feet) below the bottom elevation of the GCS.

For **LFC**:
Given assumptions for Phoenix Reach, Phase 1, for current ground water conditions that include a *static water table and no perched water:*
x = 6,500 feet (1,982 meters); K = 1,496 gpd/ft^2 (61.1 m^2/day); r = 0.5 feet (0.15 meters); H = 40 feet (12.2 meters); h = 10 feet (3 meters); R = 40 feet (12.2 meters); L_o = 100 feet (30.5 meters).

Q = 101,292 gallons per minute (384 cubic meters per minute) total.

Thus for a Q of 101,292 gpm across a 6,500' long X 200' wide (1,982 meter long X 60.9 meter wide) trench:

The minimum number of wells with a 0.15 meters (0.5 feet) radius needed to be installed to dewater the trench would be approximately 200, spaced a minimum of 9.8 meters (32 feet) apart. Each well would have to pump at least 1.9 cubic meters per minute (506 gallons per minute). In addition, each well would have to penetrate at least 6.1 meters (20 feet) below the bottom elevation of the LFC.

The dewatering wells should be arranged along the perimeter of the total excavation area for the foundation preparation for the GCS or LFC so as not to interfere with the construction activities. As mentioned previously, the dewatering calculations take into account the presence of a static water level only and does not take into account perched water conditions. The dewatering operations should not be affected to a great deal if a perched water is encountered in dewatering during construction activities. It is anticipated that perched water should be withdrawn fairly quickly during dewatering startup activities and should shortly thereafter become a part of the general Q calculated for the dewatering wells.

4.0.3 Production Wells-

Six production wells are planned to be installed during sometime after phase two of the construction of the project, each well will be required to withdrawal a minimum of 1 million gallons per day. The water will ultimately be used to feed the habitat. One of the wells is proposed for installation during phase one of the construction project, once installed this well will provide temporary water for construction activities and will provide long term water for the habitat for the life of the project. The well will be located on the south side of the Salt river at the southwest side of the Central Avenue bridge crossing, very close to the existing Corps monitoring well number RSMW-1 (Rio Salado Monitoring Well-1) site, see figure 6. The well will be named RSPW-1 (Rio Salado Production Well-1). The well shall be carefully drilled to a depth of approximately 190 feet from ground surface (the river bank elevation of approximately 322 meters (1,060 feet) above mean sea level, or to the top of subunit B, such that it does not penetrate below the subunit B layer, a confining layer as previously mentioned. The project goals are to limit the withdrawal of water from all of the production wells to the upper portions [approximately 323 meters (190 feet)] of the UAU.

4.0.4 Hydrogeology-

Ground water at the Rio Salado project site occurs primarily within three major units that are bounded below by impermeable Tertiary and Precambrian basement rocks (USEPA 1991). A north looking conceptual regional hydrogeologic cross section (profile) of the Upper Alluvial Unit (UAU), Middle Alluvial Unit (MAU) and Lower Alluvial Unit (LAU) is seen in figure 3 (ADWR 1993). The amount of storage and flow within the units varies considerably with area and depth (USEPA 1993). The four hydrogeologic units are derived from Phoenix Basin alluvial materials. The UAU is the only unit of concern for this project, since excavation during construction is anticipated to occur at a maximum of approximately 40 feet below the river bed surface. In addition, ground water wells for use during construction and project implementation will only be installed within the UAU (to a maximum of approximately 58 meters (190 feet) depth below the river bank ground surface. The units are described in the following tables (their age of deposition increasing with descending order), (ADWR 1993):

UAU (Upper Alluvial Unit)
The base of this unit occurs atop the bedrock of Tempe Butte at approximately 18 meters (60 feet) below the Salt river bed surface at Tempe and approximately 61 meters (200 feet) below ground surface at Phoenix (figure 3). The unit was formed during the final stages of alluvial development of the Phoenix Basin, approximately late Pleistocene to recent (Holocene, last 10,00 years before present) time. The unit lithology (USCS) consists of unconsolidated sand (S), gravel (G), cobble and boulders with local thin interlayered beds of clay (C) and silt (M). The entire unit is an unconfined aquifer that is both saturated and unsaturated and exhibits the following aquifer characteristics (USEPA 1990): Hydraulic Conductivity (K) - The K within this unit at Phoenix is approximately 8.20 meters per day (200 gallons per day per foot per foot), (Dames & Moore 1991). Aquifer Thickness - The saturated aquifer thickness of this unit is approximately 49 meters (160 feet) at Phoenix (Dames & Moore, 1990).
Water Level (water level data as measured from approximately 1990 to 1999, from monitoring wells closest to river bed, including the three 1999 Corps installed monitoring wells RSMW-1 through RSMW-3, test pits from the Corps 1999 geotechnical exploration and from open water surfaces in gravel pits along the river bed) - The current water levels in this unit measure approximately 5.5 to 11.5 meters (18 to 38 feet) below the Salt river bed surface at Phoenix. Ground water levels at Phoenix fluctuate between 7 to 10 meters (23 to 33 feet) during both discharge and recharge events, but rise 0.23 to 0.43 meters (3/4 to 1.5 feet) per day during recharge from flood events (Dames & Moore 1991). The current water levels are declining and represent a discharge event, in direct response from the 1993 flooding at the Salt river. Aquifer Production - Approximately 25% of the ground water pumpage in the Phoenix basin is directed towards this unit (ADWR 1993). A very large portion of the ground water from the UAU is used for agriculture. Little or none of the water is used for drinking water purposes (Wilson 1991).

MAU (Middle Alluvial Unit) This unit underlies the UAU and is in contact with the Lower Alluvial Unit (LAU) at approximately 153 meters (500 feet) below river bed surface at Phoenix (figure 3). This unit was formed during the middle stages of alluvial development of the Phoenix Basin, approximately late Tertiary to late Pleistocene time. Unit lithology consists of weakly cemented, interlayered beds of clay (C), silt (M), sand (S) and gravel (G). This unit is a saturated, unconfined aquifer, although it contains layers of aquitards. It exhibits the following aquifer characteristics (USEPA 1993): <u>Hydraulic Conductivity (K)</u> - The K within this unit is approximately 1 to 10 meters/day (24.5 to 245 gallons per day/ft/ft) within the Phoenix Basin. <u>Aquifer Thickness</u> - The thickness of this unit is approximately 91 meters (300 feet) at Phoenix. <u>Semi-Confining Layer</u> - This unit is generally comprised of more than several discontinuous semi-confining layers that consist predominantly of silt and clay.
<u>Aquifer Production</u> - Approximately 50% of the ground water pumpage in the Phoenix basin is directed towards this unit. A large portion of the ground water is used for agriculture. A smaller portion of the ground water is used for drinking water purposes (Wilson 1991).
LAU (Lower Alluvial Unit) This unit underlies the MAU and is estimated to be at least eight thousand meters (thousands of feet) thick within the Phoenix Basin. This unit was formed during the early stages of alluvial development of the Phoenix Basin, approximately late to middle Tertiary time. The unit lithology consists of weakly to <u>strongly</u> cemented gravel (G), boulders, sand (S), sandy clay (SC), silty sand (SM) and interlayered beds of clay (C). This unit is a saturated, unconfined aquifer that contains layers of aquitards. The LAU exhibits the following aquifer characteristics (USEPA 1993): <u>Hydraulic Conductivity (K)</u> - The K within this unit is higher than the MAU and averages approximately 1 to 25 meters/day (5 to 60 gallons per day/ft/ft) within the Phoenix Basin. <u>Aquifer Thickness</u> - The thickness of this unit is unknown. <u>Semi-Confining Layer</u> - This unit is generally comprised of more than several discontinuous semi-confining layers that consist predominantly of clay and mudstone (a silty clay or clayey silt). <u>Aquifer Production</u> - Approximately 25% of the ground water pumpage in the Phoenix basin is directed towards this unit. A large portion of the ground water is used for agriculture. A smaller portion of the ground water is used for drinking water purposes (Wilson 1991).

Ground water movement and connection within all three of the upper alluvial units is mostly lateral and somewhat vertical. Vertical ground water flow occurs through a combination of leakage through all three unit geologic contacts and through water wells that extend vertically across more than one unit, but is more prevalent in Tempe, where a steeper vertical ground water gradient exists. Although there are distinct, impermeable layers (perched layers included) in some of the three aquifers, there is a definite natural geologic connection between them at a regional scale, in this regard all three aquifers can be visualized as combined and interconnected hydrogeologically and therefore the Phoenix Basin can be recognized as having one <u>unconfined</u> aquifer.

4.0.5 HTRW (Hazardous, Toxic and Radioactive Waste) Contamination to Ground Water

At present, nearly all of the HTRW contamination to the ground water within or near the project has been attributed to floating and sinking Volatile Organic Carbons (VOCs) leaching into the ground water (ADEQ and EPA 1987-1997). VOC leaching has occurred from either mismanaged storage, pumping into ground water and/or improper dumping of VOC and related chemical compounds at Superfund sites located within or near the project boundaries. VOCs have been detected within the UAU and MAU, but not the LAU. There is no direct evidence that surface water recharge from the Salt River from flooding or normal releases has contaminated the three alluvial aquifers with Hazardous and Toxic Waste (HTW) unless such recharge has been associated with the Superfund sites and/or other recognized HTRW sties.

4.0.6 Ground Water Monitoring Wells-

The feasibility study recommended that a series of twelve monitoring wells be installed and sampled in order to determine the presence, migration and impact of VOC and/or other ground water contaminants to the entire project. In a general sense, three of the wells will be used to determine the immediate HTRW impacts to ground water at the chosen production well locations, the other nine wells will serve as sentry wells to monitor the migration of HTRW contaminants in ground water to the project. Eventually, data from all twelve wells will be used to ultimately determine if wellhead treatment should be designed for the production wells.

As previously mentioned, in the Fall of 1999 the Corps installed three ground water monitoring wells, RSMW-1 through RSMW-3. These wells are in good condition and are strategically located close to the proposed production well locations. Ground water samples collected from these three wells will be analyzed to determine the presence of HTRW contamination at the production well locations and the magnitude, type of contamination, etc., if any, will compared to existing Applicable or Relevant and Appropriate Requirements (ARARs) (ground water cleanup standards set for the project) to determine if wellhead treatment should be designed for the production wells. Ground water test results from these three wells for HTRW constituents were non-detect. The non-detect results indicate that ground water quality is good and may not have any detrimental effects for use during construction activities.

Nine monitoring wells remain to be installed in order to complete the monitoring well program, four of these wells are contracted to be installed in

December 1999 and sampled in January 2000. The last series of wells are scheduled for installation after January 2000. The installation and sampling is being performed for the Corps by the Phoenix offices of Dames & Moore. The final decision on wellhead treatment for the production wells will be made after all the data from all twelve ground water monitoring wells is analyzed.

The installation of all ground water monitoring wells will be limited to the upper 190 feet of the UAU or the top of subunit B, whichever is encountered first during drilling. The wells will be screened at the top 60 feet or so of the water table, separated by blank casing and then screened again at the bottom 60 feet or so of the well. Isolated ground water samples will be withdrawn from the two screened intervals through the use of a downhole inflatable packer, see figure 7. The screen separations are designed so that the differences, if any, in contaminant concentrations at variable depths within the unconfined aquifer (upper UAU) can be determined.

5.0 HTRW Contamination to Soils-

No HTRW contamination to soils was detected in the 1999 Corps geotechnical exploration, except for one of the trenches that contained small amounts of trash. The trash was not characterized, i.e., it was not determined whether the trash composition contained HTRW components, since this trench was abandoned shortly thereafter. Non-HTRW contamination was detected in the project area from the subsequent HTRW explorations by the City of Phoenix (COP) as part of the Phase I and II Environmental Investigations for the project. The contamination was found along the river banks, atop the slopes, primarily in the phase two portion of the project, near the Estes landfill. The contamination consisted of non-hazardous and non-toxic municipal trash, inert construction debris and rubber tires. This type of contamination is man-induced and is a structured or engineered fill type of dumping activity, i.e., dumping that occurs within permitted or engineered landfills, i.e., it is considered a regulated waste. From these findings, it is anticipated that most of the contamination is confined to the either the river bank slopes and/or atop the river bank, however, additional contamination may be present within and throughout the river bed along the entire project. The contamination in the river bed is anticipated to contain scattered piles or areas of municipal trash, construction debri and rubber tires. This type of contamination is man-induced and often sporadic and is considered an unregulated type of dumping activity, i.e., an unregulated waste.

It is anticipated that contamination in soils during construction of the project will be limited to mostly Municipal Solid Waste (MSW). The MSW should be a solid or semi-solid and can be further described according to the following common criteria as referred to in the waste industry: (the following descriptions/definitions of MSW may differ from those referenced in Arizona statutes.

A. Large percentages of construction waste that consists of wood, metal, cardboard, concrete, brick, dirt, sand, gravel and cobbles. This type of MSW is considered non-HTRW contaminated.

B. Large percentages of commercial and residential waste consisting of rubber tires, i.e., a "special waste" that may occur within landfills and the river bed. This type of MSW is considered non-HTRW contaminated.

D. Small amounts of commercial waste consisting of paper, cardboard, plastics, wood, organic food wastes, glass, metals, fabrics, *special wastes and **hazardous wastes.

E. Small amounts of residential waste consisting of paper, cardboard, plastics, wood, organic food wastes, glass, metals, fabrics, *special wastes and ***household hazardous wastes, furniture, appliances, car bodies and auto parts and yard wastes.

*Special Waste- a waste that is collected separately and recycled, i.e., used oil, batteries, household cleaners and tires, etc.

**Hazardous Waste- a waste that is disposed of at a hazardous waste disposal or recycling facility, it meets the Code of Federal Regulations (CFR) and Environmental Protection Agency (EPA) definitions of hazardous, in that it is either ignitable, flammable, corrosive and/or toxic.

***Household Hazardous Waste- a waste that meets the CFR and EPA definitions as a hazardous waste and is disposed of at a hazardous waste recycling or disposal facility.

As part of construction plans and specifications, the COP will provide a Health and Safety Plan (HSP) that will address all the health and safety issues due to possible soil contamination to the construction workers and visitors to the site during construction. The HSP and also the construction specifications will include provisions for characterizing and removing MSW during construction. In summary, the HSP and construction specifications direct the Contractor to do the following: a. Hire a qualified health and safety specialist (HSP) and/or industrial hygienist (IH) to provide oversight during construction. b. The HSP or IH shall stop all construction activities once MSW is encountered and if obvious, identify the waste as non-hazardous and then remove and dispose of as non-hazardous MSW. c. If not obvious, the Contractor shall contact the COP hazardous waste Contractor who will then characterize the waste and if hazardous, will remove and dispose of it.

6.0 Subsidence

Subsidence measurements from 1974 suggest that subsidence in the project area has not occurred. Ground failure in the form of subsidence and earth-fissures has occurred in other areas of the Phoenix Basin. The closest ground failure occurrences to the project area are near Luke Air Force Base, approximately 18 miles from the site, where 1/2 to 3 feet of subsidence has been measured and exhibits the shape of a 2 mile diameter "bowl" depression.

Earth-fissures and subsidence are produced by groundwater (pumping) withdrawal, which causes aquifer compaction, whereby ground (soil) compresses (subsides) because it has lost the support of water within its pores. Earth-fissures develop when the soil subsides differentially and pulls apart.

The Phoenix area will continue to be affected by subsidence because of groundwater overdraft, principally where ground water withdrawal is most severe.

7.0 Stone Sources

Two stone borrow sites have been identified as sources of construction material and are available for use, in the event an engineering design is proposed for the Rio Salado project. The two stone quarries are less than 10 miles from the site and have produced stone for previous Corps flood control projects at the Arizona Diversion Canal and Indian Bend Wash areas. Stone from both quarries exhibit a good service record and passed all rock quality compliance tests. The quarries are listed as:

<u>Sunstate Rock and Materials</u> and
-located 20th St. and E. Beardsley Rd, Phx, AZ.
-passed rock 1990 quality tests.
-passed 1994 visual inspection.
-produces granite.

<u>Salt River Sand & Rock</u>
-located at Dobson & McKellips Rds, Phx, AZ.
-passed 1994 rock quality tests.
-passed 1994 visual inspection.
-produces green schist.

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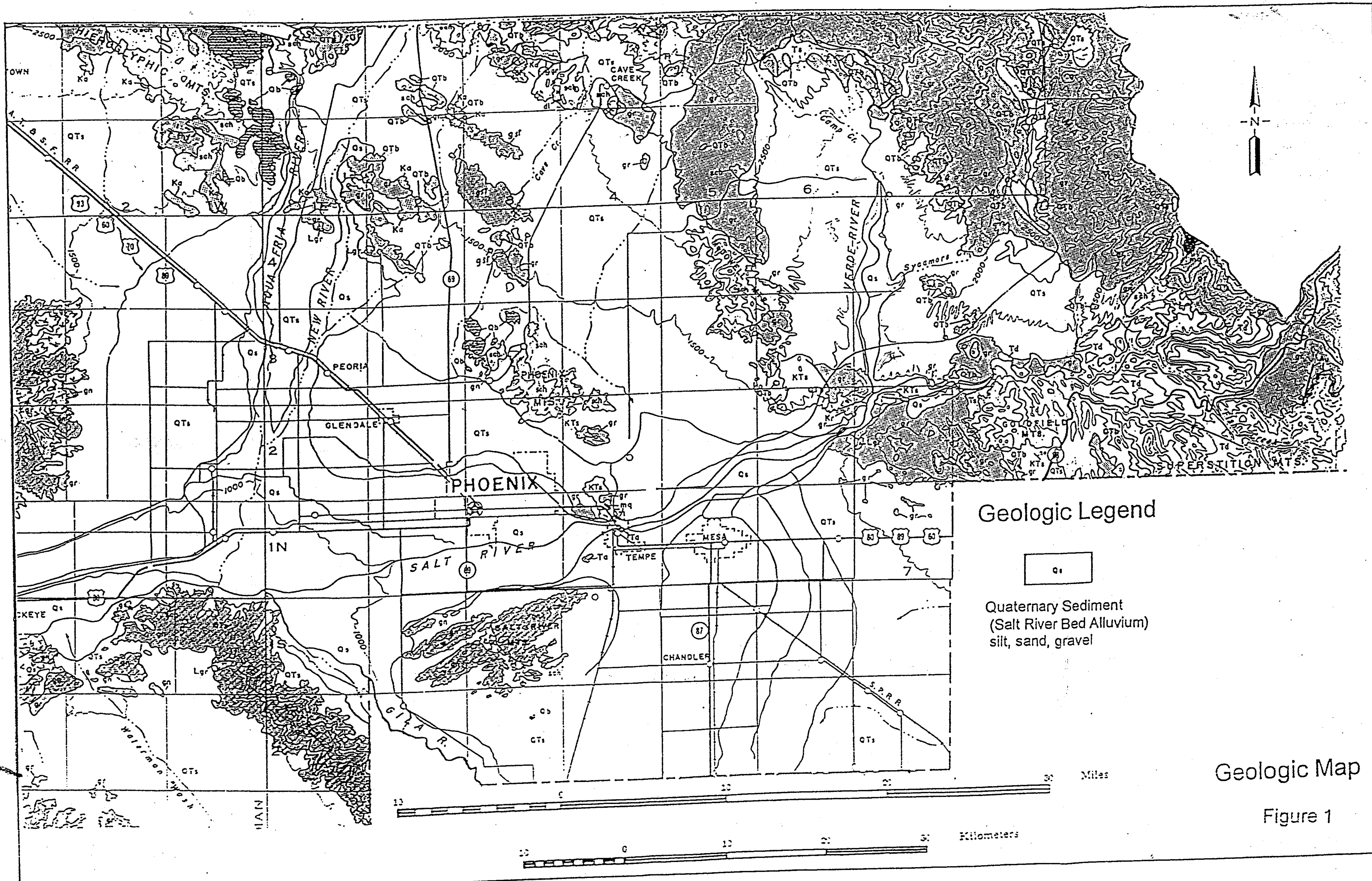
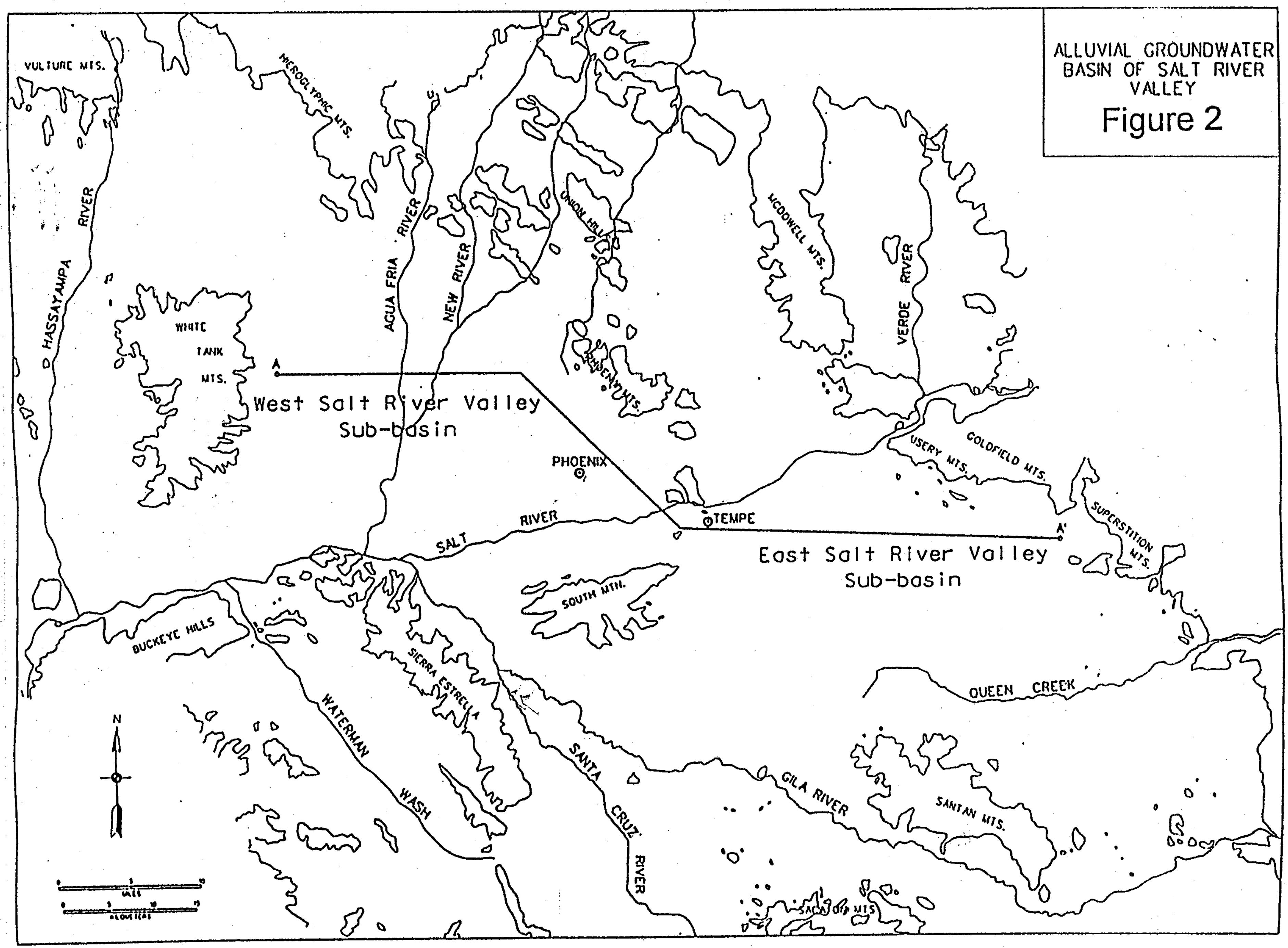


Geologic Map

Figure 1



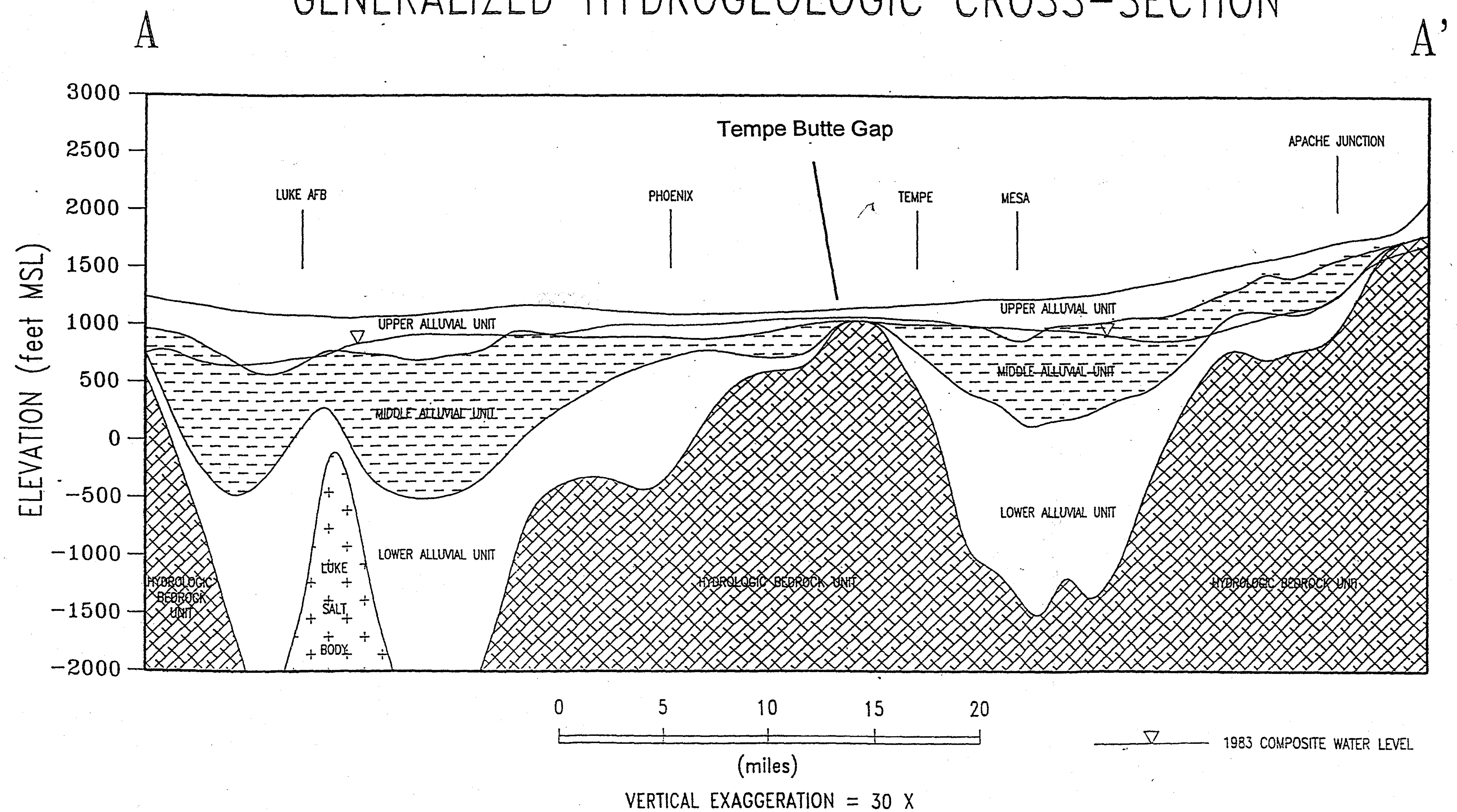
ALLUVIAL GROUNDWATER BASIN OF SALT RIVER VALLEY

Figure 2

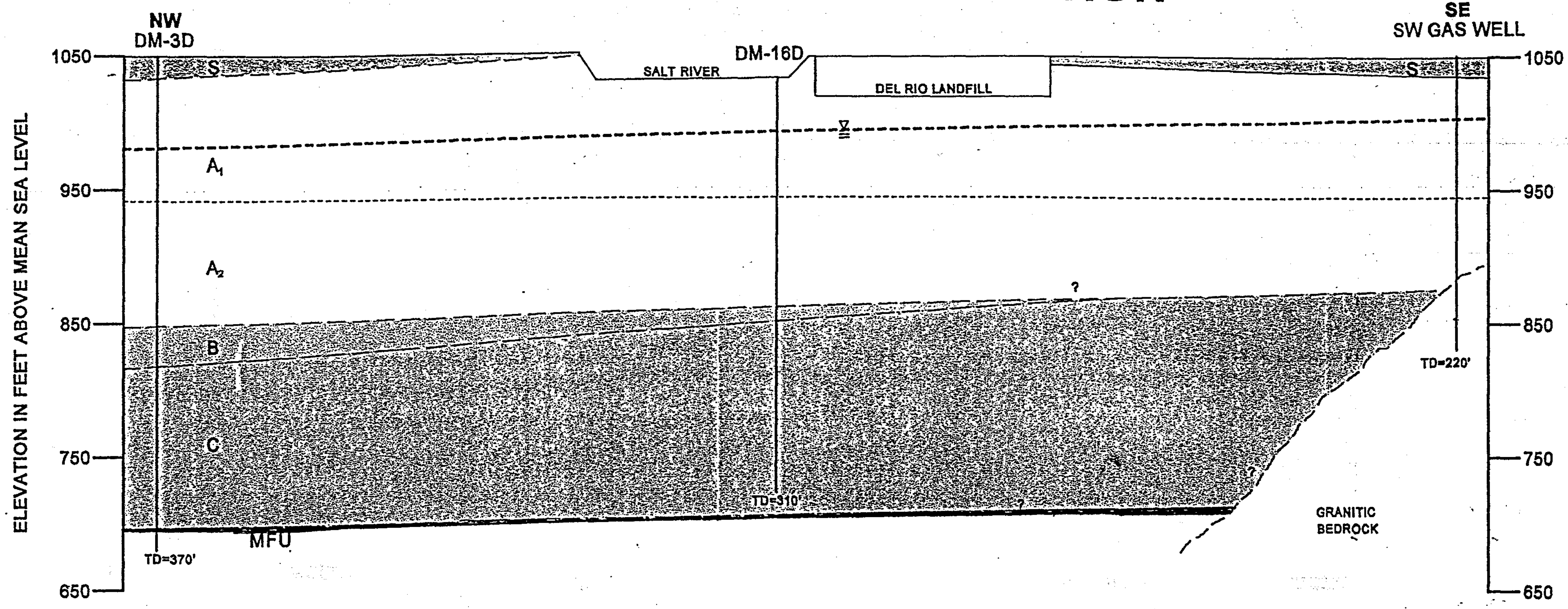
Figure 3

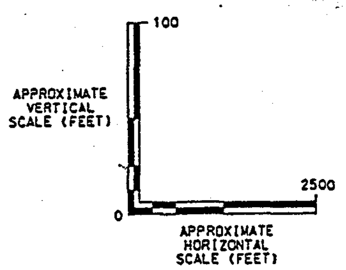
Rio Salado Habitat Project, Phoenix Portion

GENERALIZED HYDROGEOLOGIC CROSS-SECTION



CROSS SECTION





EXPLANATION

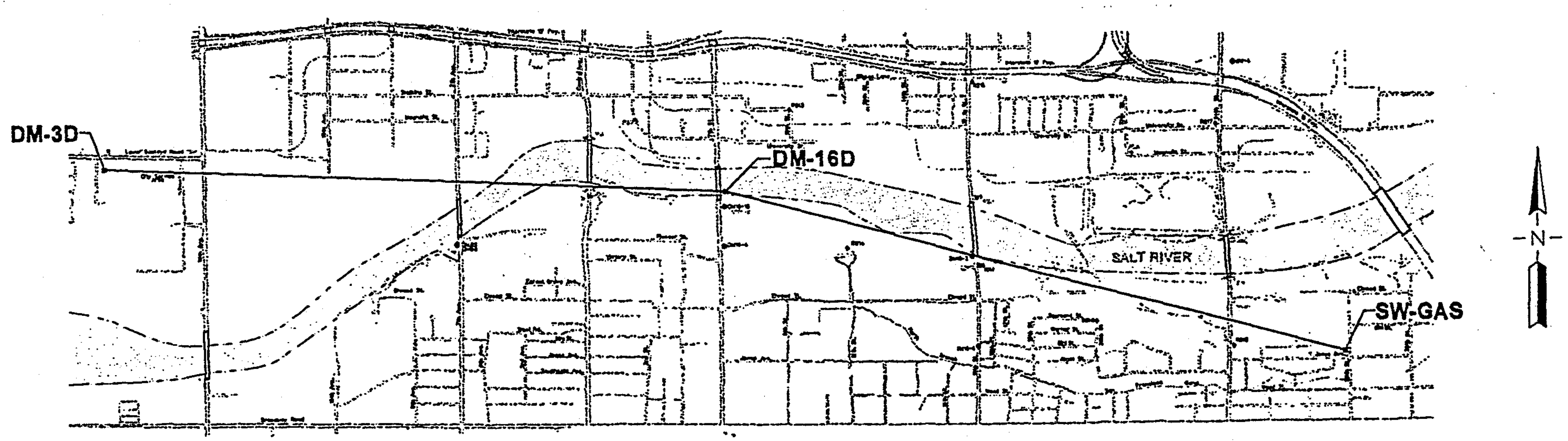
INFERRED UNIT CONTACT

INFERRED SUBUNIT CONTACT (TRANSITIONAL)

APPROXIMATE WATER TABLE DAMES AND MOORE (1991)

	Geologic Subunit	DESCRIPTION
	S	SILTY SAND, BROWN TO LIGHT BROWN, 50-60% FINE TO MEDIUM SAND, 30-40% SILT WITH CLAY, <10% GRAVEL, TRACE CALICHE
UAU	A	SUBUNIT A1: GRAVEL, 80-90% FINE TO COARSE GRAVEL AND COBBLES, 20-10% MEDIUM TO COARSE SAND, LITTLE TO NO FINES SUBUNIT A2: SANDY GRAVEL, 60-70% FINE TO COARSE GRAVEL, 30-40% FINE TO COARSE SAND, MINOR SILT, INCREASING FINES (SAND & SILT) WITH DEPTH INTERBEDDED SAND (SP) LENSES
	B	SILTY SAND WITH GRAVEL, REDDISH BROWN, 40-50% FINE TO MEDIUM SAND, 40-50% SILT WITH CLAY, 10-15% FINE GRAVEL
	C	SANDY GRAVEL WITH SILT AND CLAY, BROWN, 40-50% FINE TO MEDIUM GRAVEL, 40-50% FINE TO COARSE SAND, 0-20% SILT WITH CLAY, INTERBEDDED SAND (SP) AND GRAVEL (GP) LENSES, DECREASING FINES (SILT & CLAY) WITH DEPTH
MAU	(MFU)	SILTY SAND WITH GRAVEL, CLAYEY SILTS, BROWN INTERBEDDED SANDY SILT, CLAYEY SILT AND SILTY SAND WITH MINOR FINE TO MEDIUM GRAVEL

NOTE: GEOLOGIC UNIT AND SUBUNIT DESCRIPTIONS ARE FOR UAU AND MAU ONLY, DAMES AND MOORE 1989.



CROSS SECTION LOCATION
N.T.S.

Plan View

Phoenix Portion of Rio Salado, From 19th Avenue to I-10

SCHEMATIC STRATIGRAPHIC CROSS SECTION THROUGH PROJECT AREA

U.S. ARMY CORPS OF ENGINEERS
RIO SALADO HABITAT RESTORATION
Phoenix, Arizona

Figure 4

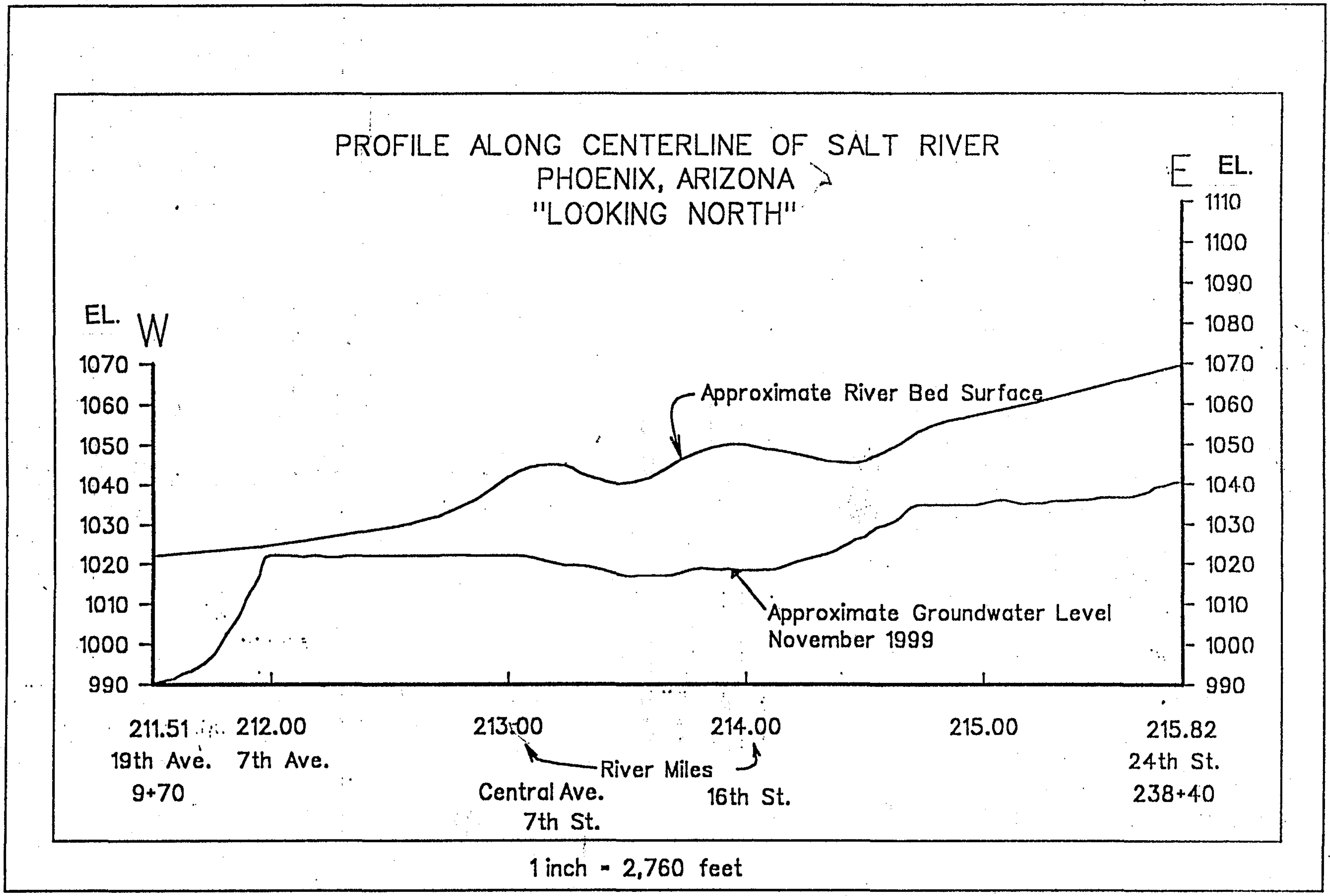
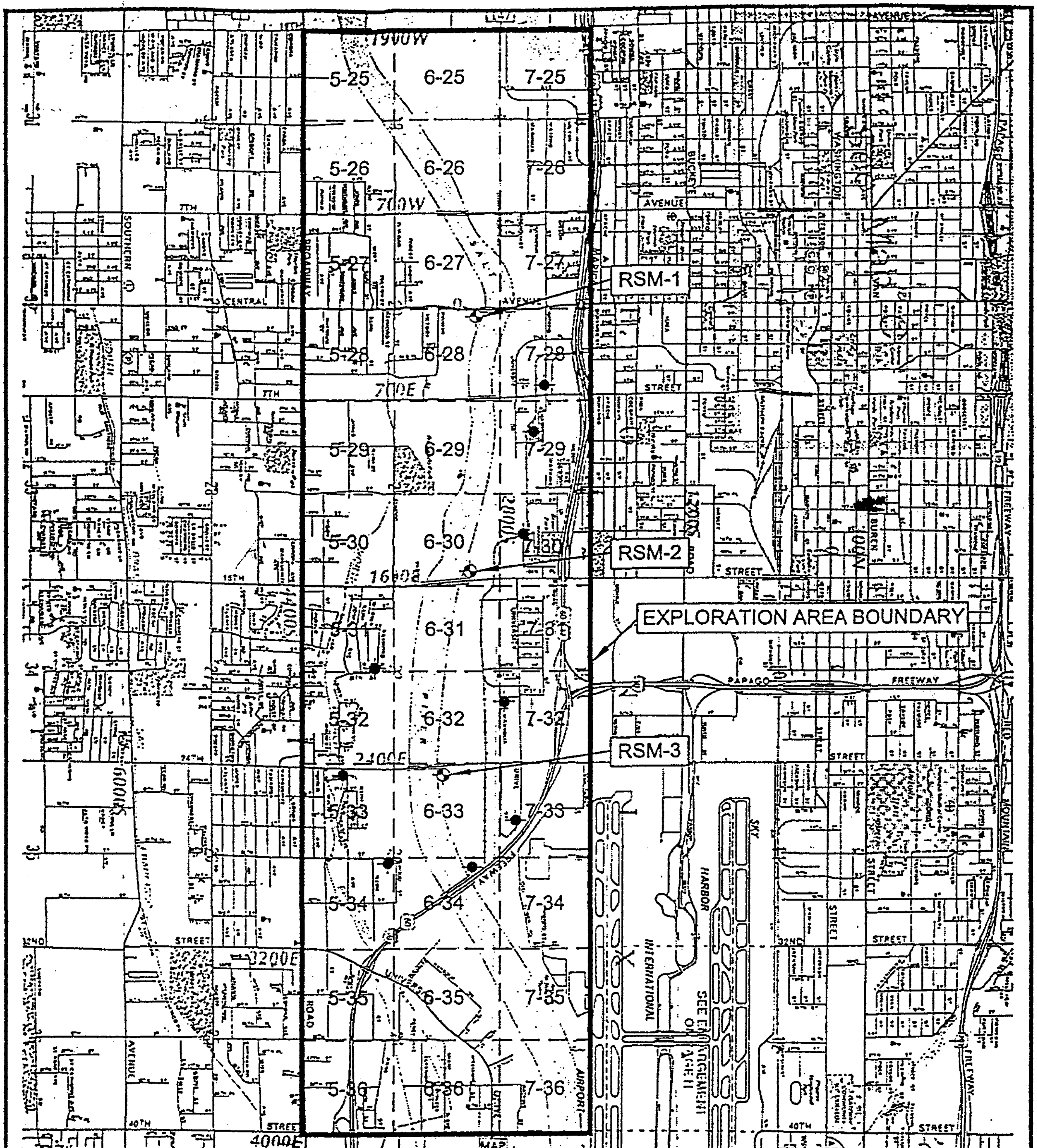

PROFILE ALONG CENTERLINE OF SALT RIVER
PHOENIX, ARIZONA
"LOOKING NORTH"
W
E
EL.
EL.
1110
1100
1090
1080
1070
1060
1050
1040
1030
1020
1010
1000
990
Approximate River Bed Surface
Approximate Groundwater Level
November 1999
211.51
19th Ave.
9+70
212.00
7th Ave.
213.00
Central Ave.
7th St.
River Miles
214.00
16th St.
215.00
215.82
24th St.
238+40
1 inch = 2,760 feet

Figure 5



Monitoring Well Locations for RSMW-1 to RSMW-3

EXPLANATION:

- Currently Proposed Monitor Well Location
- Future Monitor Well Location

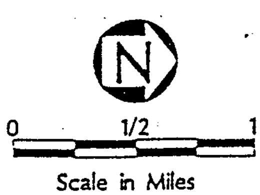
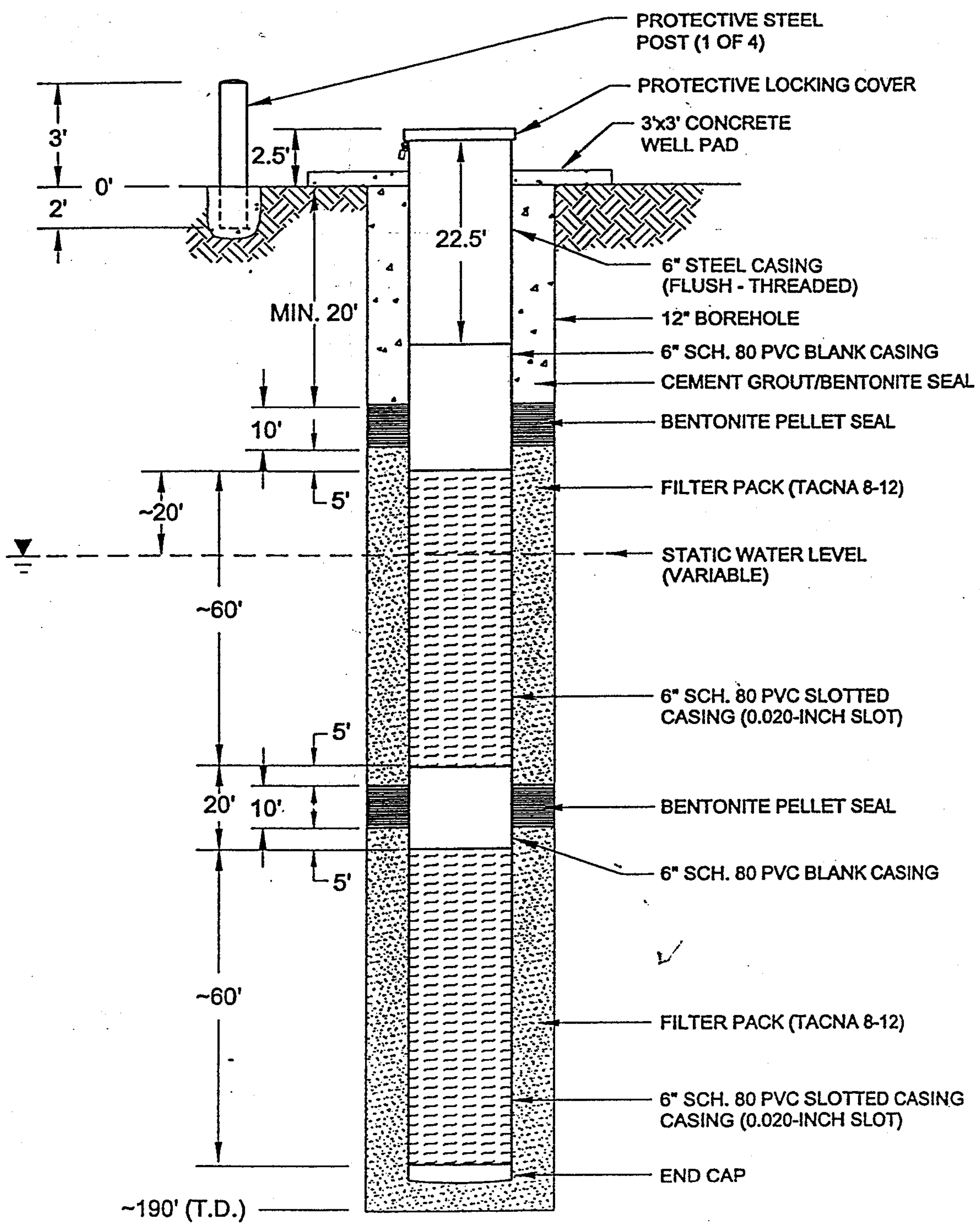
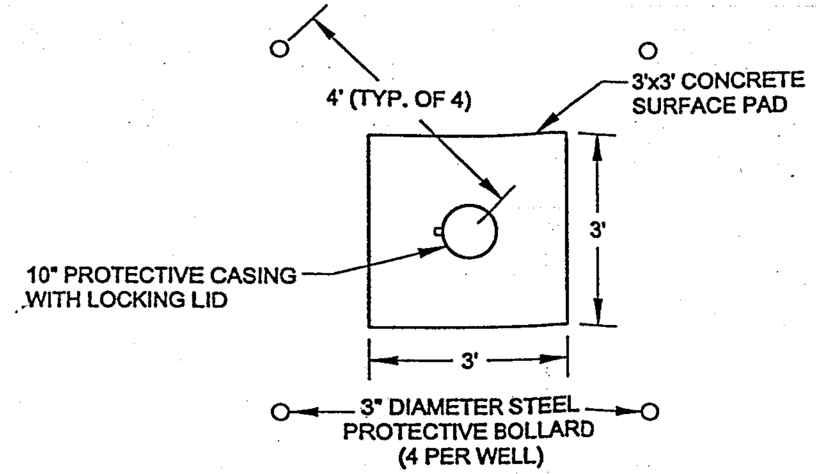


Figure 6

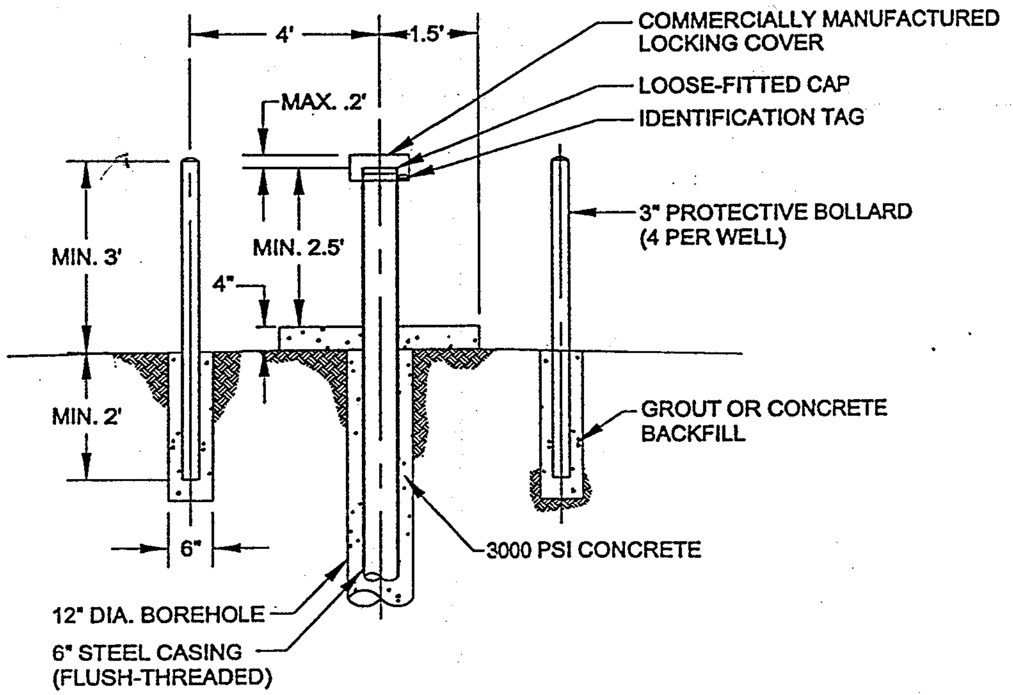


NOT TO SCALE



PLAN VIEW

NOT TO SCALE



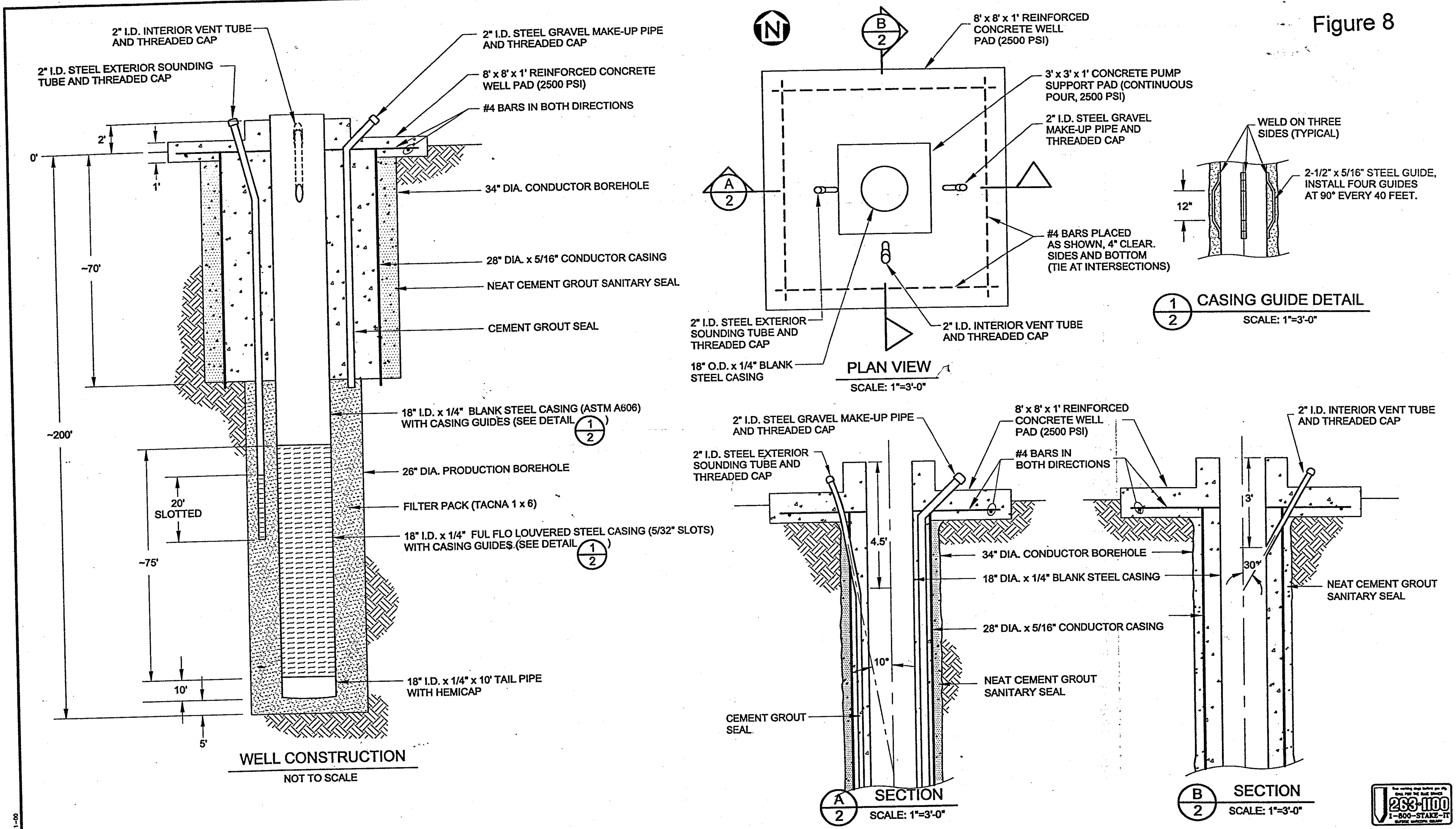
SURFACE COMPLETION DETAILS FOR MONITORING WELLS

NOT TO SCALE

Monitor Well Construction Diagram and Surface Completion Detail

Figure 7

Figure 8



REFERENCES TITLE	REFERENCES TITLE	REVISIONS NO.	BY	DATE	DESCRIPTION	REVISIONS NO.	BY	DATE	DESCRIPTION
		△	CB	11/99	PRELIMINARY DESIGN	△			
		△				△			
		△				△			
		△				△			
		△				△			

SCALE: AS NOTED	DATE
DESIGNED BY: CCB	11-99
DRAWN BY: MDH/KLP	11-99
CHECKED BY: CSW	01-00
APPROVED BY: XXX	X-00
CLIENT APPROVAL BY:	

DAMES & MOORE

U.S. ARMY CORPS OF ENGINEERS AND CITY OF PHOENIX

PRODUCTION WELL RSPW-1 DESIGN DETAILS

RIO SALADO HABITAT RESTORATION PROJECT

JOB NO. 00109-042-058

DRAWING NO. 2 REV. B

00109\042\REV-B\A1351588 2-11-00

TT99-5

DEPTH (ft)	SOIL CLASS	3	1.5	3/4	3/8	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
3.0	GP	90	70	47	31	22	19	16	11	6	4	2		NP	4.5	POORLY GRADED GRAVEL WITH SAND, gray, approximately 20% cobbles and 10% boulders.
5.0		100	63	46	33	27	23	19	14	10	7	4		NP	12.2	
6.0	SP	100	94	91	86	84	81	75	53	23	7	3		NP	16.9	POORLY GRADED SAND WITH GRAVEL, brown, dense.
11.0		100	100	100	100	100	100	98	77	30	8	2		NP	12.3	POORLY GRADED SAND, brown.
16.0	GP	100	78	56	44	39	37	33	22	10	6	3		NP	13.7	POORLY GRADED GRAVEL WITH SAND, brown, gravels, less than 5% cobbles.

TT99-6

DEPTH (ft)	SOIL CLASS	3	1.5	3/4	3/8	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
3.0	GP	100	77	59	44	34	28	18	7	2	1	1		NP	4.8	POORLY GRADED GRAVEL WITH SAND, brown, approximately 25% cobbles and 15% boulders.
7.0		100	46	27	18	13	8	5	2	1	1	1		NP	NS	POORLY GRADED GRAVEL, same as above, more cobbles. Stopped trench due to caving and water in the trench.

TT99-7

DEPTH (ft)	SOIL CLASS	3	1.5	3/4	3/8	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
3.0	GP	100	79	61	46	36	32	24	12	5	2	1		NP	1.8	POORLY GRADED GRAVEL WITH SAND, brown, approximately 25% cobbles and 10% boulders.
6.0		100	69	38	28	23	21	18	12	6	4	2		NP	25.9	
10.0	GW	100	68	47	36	29	28	26	21	9	4	2		NP	11.4	WELL GRADED GRAVEL WITH SAND, brown, very dense, approximately 20% cobbles.
13.0	GP	100	73	57	44	36	33	29	20	10	6	2		NP	12.4	POORLY GRADED GRAVEL WITH SAND, brown, approximately 10% cobbles.
16.0		100	64	51	39	32	29	26	18	8	4	2		NP	11.2	Water at 14 feet.

TT99-8

DEPTH (ft)	SOIL CLASS	3	1.5	3/4	3/8	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
3.0	GW	85	77	58	43	33	27	20	12	5	2	1		NP	2.0	WELL GRADED GRAVEL WITH SAND, brown, approximately 20% cobbles and 5% boulders.
6.0	GP	100	62	36	29	23	21	18	13	5	2	1		NP	8.3	POORLY GRADED GRAVEL WITH SAND, brown, approximately 20% cobbles and 5% boulders.
9.0		100	70	43	32	26	25	22	15	8	5	3		NP	NS	Stopped hole due to trench caving, water entered trench beginning at 7 foot depth.

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES
COARSE GRAINED SOILS More than half of material is larger than no. 200 sieve size.	GRAVELS More than half of coarse fraction is larger than no. 4 sieve size.	Clean Gravels	GW	Well graded gravels, gravel-sand mixtures, little or no fines.
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines.
		Gravels with fines	GM	Silty gravels, gravel-sand-silt mixtures.
			GC	Clayey gravels, gravel-sand-clay mixtures.
	SANDS More than half of coarse fraction is smaller than no. 4 sieve size.	Clean Sands	SW	Well graded sands, gravelly sands, little or no fines.
			SP	Poorly graded sands, gravelly sands, little or no fines.
		Sands with fines.	SM	Silty sands, sand-silt mixtures.
			SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS More than half of material is smaller than no. 200 sieve size.	SILTS AND CLAYS	Low liquid limit.	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts, with slight plasticity.
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
			OL	Organic silts and organic silty clays of low plasticity.
		High liquid limit.	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
			CH	Inorganic clays of high plasticity, fat clays.
			OH	Organic clays of medium to high plasticity, organic silts.
Highly organic soils			Pt	Peat and other highly organic soils.

NOTES:

1. BOUNDRY CLASSIFICATION: SOILS POSSESSING CHARACTERISTICS OF TWO GROUPS ARE DESIGNATED BY COMBINATIONS OF GROUP SYMBOLS. FOR EXAMPLE, GW-GC, WELL GRADED GRAVEL-SAND MIXTURE WITH CLAY BINDER.
2. ALL SIEVE SIZES ON THE CHART ARE U.S. STANDARD.
3. THE TERMS "SILT" AND "CLAY" ARE USED RESPECTIVELY TO DISTINGUISH MATERIALS EXHIBITING LOWER PLASTICITY FROM THOSE WITH HIGHER PLASTICITY. THE MINUS NO. 200 SIEVE MATERIAL IS SILT IF THE LIQUID LIMIT AND PLASTICITY INDEX PLOT BELOW THE "A" LINE ON THE PLASTICITY CHART, AND IS CLAY IF THE LIQUID LIMIT AND PLASTICITY INDEX PLOT ABOVE THE "A" LINE ON THE CHART.
4. THE SOIL CLASSIFICATION SYSTEM IS BASED ON THE AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM).
   A. (ASTM) D2487 STANDARD TEST METHOD FOR CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES.
   B. (ASTM) D2488 STANDARD RECOMMENDED PRACTICE FOR DESCRIPTION OF SOILS (VISUAL MANUAL PROCEDURE).

LEGEND

TT99-5	TEST TRENCH, YEAR AND NUMBER
LL	LIQUID LIMIT.
PI	PLASTICITY INDEX (LIQUID LIMIT - PLASTIC LIMIT).
NP	NONPLASTIC.
NS	NOT SAMPLED
-4	PERCENT OF MATERIAL, BY WEIGHT, PASSING NO. 4 SIEVE.
-200	PERCENT OF MATERIAL, BY WEIGHT, PASSING NO. 200 SIEVE.
N	NUMBER OF BLOWS OF A 140-POUND DROPHAMMER FALLING 30 INCHES REQUIRED TO DRIVE A SAMPLING SPOON ONE FOOT. OUTSIDE DIAMETER IS 2 INCHES; INSIDE DIAMETER IS 1-3/8 INCHES.
PCC	PORTLAND CEMENT CONCRETE (PCC) RUBBLE. PCC RUBBLE FROM VARIOUS DEMOLITION ACTIVITIES.
AC	ASPHALTIC CONCRETE PAVEMENT RUBBLE.

NOTES

1. LOGS OF EXPLORATION INDICATE GEOTECHNICAL CONDITIONS AT THE TIME AND LOCATION OF THE EXPLORATIONS INDICATED. CONDITIONS CAN CHANGE. STRATIFICATION LINES SHOWN ON LOGS REPRESENT APPROXIMATE BOUNDARIES BETWEEN SOIL TYPES.
2. GROUNDWATER WHEN ENCOUNTERED, NOTED ON EACH BORING LOG.
3. TEST TRENCHES WERE EXCAVATED IN JANUARY, 1999, USING RUBBER-TIRED BACKHOE, CASE MODEL 580 SUPER L, WITH A 24-INCH BUCKET.
4. TEST TRENCHES WERE GENERALLY TERMINATED AT 16 FEET DEPTH BY DESIGN.
5. PERCENTAGE OF PLUS 3-INCH MATERIAL BASED ON VISUAL OBSERVATIONS IN THE FIELD. GRADATION INDICATED HEREIN REPRESENTS MINUS 3-INCH SAMPLE RETURNED TO THE LABORATORY FOR DETAILED ANALYSIS.
6. ALL PARTICLES EXAMINED DURING THE INVESTIGATION WERE GENERALLY SUBROUNDED TO ROUNDED, UNLESS NOTED OTHERWISE.
7. TEST TRENCHES 34 TO 39 WERE VISUALLY LOGGED ONLY.
8. SEE SHEETS 3 TO 14 FOR LOCATION OF TEST TRENCHES.

Figure 9

SCALE 5 0 5 10 15 FEET

SYMBOL	DESCRIPTIONS	DATE	APPROVAL
	REVISIONS		

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: W H
DRAWN BY: W H
CHECKED BY: JDD

SALT RIVER, MARICOPA COUNTY, ARIZONA
RIO SALADO, PHOENIX REACH
(19TH AVENUE TO I-10 FREEWAY)

LOGS OF EXPLORATION TT99-5 TO TT99-8

SUBMITTED BY: ABBAS T. ROODSARI, P.E.
CHIEF, GEOTECHNICAL BRANCH

DISTRICT FILE NO. NOT APPLICABLE | SPEC. NO.: NOT APPLICABLE | CADD FILE NAME: g01.dgn

TT99-9

DEPTH (ft)	SOIL CLASS	3	1.5	¾	⅜	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
3.0	GP	100	81	61	48	42	39	32	19	7	3	1		NP	4.5	POORLY GRADED GRAVEL WITH SAND, brown, loose, approximately 15% cobbles, and 5% boulders.
6.0	GP	100	80	59	48	21	20	18	14	8	4	1		NP	3.4	
8.0	SP	100	90	77	70	66	60	54	43	25	12	4			17.2	POORLY GRADED SAND WITH GRAVEL, gray, loose, approximately 5% cobbles.
10.0	GP	100	81	65	52	43	40	33	22	10	5	2		NP	9.4	POORLY GRADED GRAVEL WITH SAND, gray, very loose.
13.0	GP	100	45	20	13	10	9	8	6	4	3	2		NP	57.3	POORLY GRADED GRAVEL, primarily brown, some black, green, very moist.
16.0	GW	100	75	54	40	32	28	22	15	8	3	1		NP	20.7	WELL GRADED GRAVEL WITH SAND, gray/brown, approximately 25% cobbles and 15% boulders.

TT99-13

DEPTH (ft)	SOIL CLASS	3	1.5	¾	⅜	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
3.0	GP	100	86	61	44	36	32	24	9	3	1	1		NP	4.9	POORLY GRADED GRAVEL WITH SAND, light brown, very loose, approximately 5% cobbles.
6.0	GP	100	89	69	51	40	33	21	6	1	1	1		NP	2.0	same as above, less cobbles.
8.0	GP	100	89	69	52	39	35	29	18	10	7	4		NP	5.0	same as above, light brown, less than 5% cobbles, some PCC debris.
11.0	GP	90	80	66	51	40	33	24	12	4	2	1		NP	37.0	same as above, aproximately 10% cobbles, 5% boulders, some PCC and AC debris.
16.0	GP	100	77	51	40	32	29	25	12	3	1	1		NP	3.9	same as above, light brown, very loose, approximately 5% cobbles.

TT99-10

DEPTH (ft)	SOIL CLASS	3	1.5	¾	⅜	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
3.0	GP	100	74	57	44	34	30	26	20	9	5	1		NP	16.7	POORLY GRADED GRAVEL WITH SAND, gray, loose, approximately 20% cobbles and 5% boulders, PCC on surface.
7.0	GP	100	73	54	42	36	33	28	17	7	3	1		NP	5.7	same as above, approximately 25% cobbles.
10.0	GP	100	78	56	43	35	32	26	11	5	4	3		NP	14.6	same as above, reddish brown, approximately, 5% cobbles, loose.
13.0	GP	100	68	41	26	20	18	14	8	4	3	1		NP	21.0	same as above, reddish brown, approximately 5% cobbles.
16.0	GP	100	85	59	41	35	33	30	17	6	3	2		NP	15.1	same as above, reddish brown, approximately 5% cobbles.

TT99-14

DEPTH (ft)	SOIL CLASS	3	1.5	¾	⅜	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
2.0	GP	100	80	59	44	36	32	29	19	5	1	1		NP	5.3	POORLY GRADED GRAVEL WITH SAND, very loose, approximately 15% cobbles.
6.0	GP	100	60	24	21	19	17	13	7	3	2	1		NP	38.2	same as above, brown, approximately 20% cobbles, less than 5% boulders.
10.0	GP	100	75	53	39	32	28	24	12	3	1	1		NP	n/s	same as above.
16.0	GW	100	69	44	32	25	21	16	8	2	1	1		NP	12.6	WELL GRADED GRAVEL WITH SAND, brown, very dense, approximately 25% cobbles, less than 5% boulders.

TT99-11

DEPTH (ft)	SOIL CLASS	3	1.5	¾	⅜	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
3.0	GP	100	81	63	50	41	38	31	19	9	5	3		NP	1.5	POORLY GRADED GRAVEL WITH SAND, light brown, loose, approximately 10% cobbles, some boulders.
6.0	GW	100	70	45	34	30	29	27	14	3	1	1		NP	2.6	WELL GRADED GRAVEL WITH SAND, light brown, loose, approximately 10% cobbles, less than 5% boulders.
9.0	GW	100	76	53	38	30	28	25	15	4	1	1		NP	2.6	same as above, light gray to brown, approximately 15% cobbles and 5% boulders.
13.0	SP	100	89	75	68	63	60	53	28	6	2	2		NP	3.4	POORLY GRADED SAND WITH GRAVEL, light gray to brown, very loose, less than 5% cobbles.
16.0	GW	100	62	43	34	29	27	24	14	4	2	1		NP	6.5	WELL GRADED GRAVEL WITH SAND, light brown, loose, approximately 5% cobbles.

TT99-15

DEPTH (ft)	SOIL CLASS	3	1.5	¾	⅜	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
4.0	GP	100	73	55	40	33	27	21	10	3	1	1		NP	5.7	POORLY GRADED GRAVEL WITH SAND, light brown, loose, 10% cobbles.
7.0	SP	100	98	94	91	90	88	84	69	38	9	1		NP	8.1	POORLY GRADED SAND, light brown, very loose.
10.0	GP	100	75	55	45	39	37	34	20	7	2	1		NP	9.4	POORLY GRADED GRAVEL WITH SAND, light brown, loose, some cobbles, odor of fuel detected.
12.0	SP	100	93	88	86	84	83	76	19	2	1	1		NP	16.5	POORLY GRADED SAND WITH GRAVEL, light brown, dense.
16.0	GP	100	82	58	44	39	37	33	15	3	1	1		NP	13.7	POORLY GRADED GRAVEL WITH SAND, light brown, approximately 10% cobbles.

TT99-12

DEPTH (ft)	SOIL CLASS	3	1.5	¾	⅜	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
2.0	GW	100	60	43	33	28	26	23	15	5	2	1		NP	2.3	WELL GRADED GRAVEL WITH SAND, light brown, loose, approximately 5% cobbles.
5.0	SP	100	99	93	89	87	87	85	66	26	5	1		NP	10.3	POORLY GRADED SAND, light brown, no cobbles, water encountered at 5 feet.
8.0	SP	100	77	68	63	61	60	56	34	11	2	1		NP	11.1	POORLY GRADED SAND WITH GRAVEL, light brown. Terminated trench due to water in trench.

TT99-16

DEPTH (ft)	SOIL CLASS	3	1.5	¾	⅜	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
2.0	GP	100	87	63	49	43	42	38	20	5	1	1		NP	5.6	POORLY GRADED GRAVEL WITH SAND, light brown, some cobbles.
3.0	SP	100	89	82	73	67	63	58	49	31	9	1		NP	10.1	POORLY GRADED SAND WITH GRAVEL, light brown, very loose, percentage of cobbles increases with depth.
4.0	SP	100	85	70	61	54	49	41	26	14	7	2		NP	15.9	
5.0	SP	100	89	84	81	79	58	29	13	6	2	1		NP	33.3	
7.0	SP-SM	100	100	100	99	99	93	88	83	75	48	9		NP	26.7	POORLY GRADED SAND WITH SILT, brown, very loose.
11.0	GP	100	85	59	42	33	29	24	12	5	2	1		NP	16.2	POORLY GRADED GRAVEL WITH SAND, light brown, approximately 20% cobbles, hard digging due to large rock.
16.0	SP	100	75	64	57	53	49	42	21	6	1	1		NP	17.7	POORLY GRADED SAND WITH GRAVEL, more cobbles than above, approximately 10% boulders.

Figure 10

SYMBOL | DESCRIPTIONS | DATE | APPROVAL

REVISIONS

SALT RIVER, MARICOPA COUNTY, ARIZONA
RIO SALADO, PHOENIX REACH
(19TH AVENUE TO I-10 FREEWAY)
LOGS OF EXPLORATION
TT99-9 TO TT99-16

DESIGNED BY: W H
DRAWN BY: W H
CHECKED BY: JDD

CADD FILE NAME: 902.dgn

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SUBMITTED BY:
ABBAS T. ROODSARI, P.E.
CHIEF, GEOTECHNICAL BRANCH

DISTRICT FILE NO. NOT APPLICABLE | SPEC. NO.: NOT APPLICABLE

SHEET 16 OF 19 SHEETS

FIGURE 11

TT99-17

DEPTH (ft)	SOIL CLASS	3	1.5	3/4	3/8	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
3.0	GW	100	68	51	36	28	24	20	10	3	1	1		NP	9.3	WELL GRADED GRAVEL WITH SAND, light brown, loose, approximately 5% cobbles, 5% boulders, hard digging due to large rock,
6.0	GP	100	83	59	45	37	33	30	22	14	7	1		NP	12.0	POORLY GRADED GRAVEL WITH SAND, light brown, loose, approximately 15% cobbles, 5% boulders.
9.0	GP	92	78	60	43	33	30	25	13	4	1	1		NP	13.5	same as above, light brown, approximately 20% cobbles and 10% boulders.
12.0	GP	100	89	67	53	45	40	29	14	4	1	1		NP	16.3	same as above, brown, approximately 15% cobbles, and 5% boulders.
16.0	GW	92	75	50	36	29	26	23	13	4	1	1		NP	16.6	WELL GRADED GRAVEL WITH SAND, brown, approximately 15% cobbles and 5% boulders.

TT99-18

DEPTH (ft)	SOIL CLASS	3	1.5	3/4	3/8	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
3.0	GP	100	77	62	48	40	37	33	22	9	3	1		NP	7.4	POORLY GRADED GRAVEL WITH SAND, light brown, moist, loose to dense, 20% cobbles.
6.0	GP	100	69	48	35	27	23	21	16	9	3	1		NP	7.3	same as above, less than 5% boulders.
10.0	GP	100	71	54	42	34	30	26	16	7	2	1		NP	12.2	same as above, brown, very dense, approximately 15% cobbles, less than 5% boulders.
16.0	GW	100	73	51	38	29	24	20	13	5	2	1		NP	16.5	WELL GRADED GRAVEL WITH SAND, brown, very dense, approximately 20% cobbles.

TT99-19

DEPTH (ft)	SOIL CLASS	3	1.5	3/4	3/8	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
3.0	GP	100	73	55	43	37	35	30	17	7	3	1		NP	11.1	POORLY GRADED GRAVEL WITH SAND, brown, dense, approximately 20% cobbles.
6.0	GP	100	67	45	36	33	32	28	13	2	1	1		NP	8.9	same as above, approximately 25% cobbles.
10.0	GW	100	58	43	31	26	24	19	7	2	1	1		NP	11.1	WELL GRADED GRAVEL WITH SAND, brown, approximately 20% cobbles, hard digging. Hit water at 10 feet.
14.0	GP	100	74	42	25	20	19	17	13	7	3	2		NP	NS	POORLY GRADED GRAVEL WITH SAND, brown, same as above. Stop trench due to caving and water inflow.

TT99-20

DEPTH (ft)	SOIL CLASS	3	1.5	3/4	3/8	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
2.0	GP	91	81	64	51	41	36	30	18	9	6	3		NP	4.2	POORLY GRADED GRAVEL WITH SAND, light brown, loose, approximately 5% cobbles.
3.0	SM	100	99	87	73	62	57	54	44	35	29	23		NP	8.2	SILTY SAND WITH GRAVEL, brown, dense, debri of: asphalt-concrete and tires.
6.0	ML	100	99	98	98	98	98	97	96	95	91	75			8.6	SILT WITH SAND, light brown, very loose, powdery.
8.0	ML	100	100	100	100	100	100	100	99	99	97	87			24.3	SILT, brown, chunky, falls apart on handling.
11.0	SM	100	100	100	100	100	100	99	99	97	73	31		NP	3.9	SILTY SAND, brown, dry.
13.0	SM	100	100	99	98	98	97	97	95	93	81	46			23.2	SILTY SAND, brown.
16.0	SM	100	79	79	74	71	69	67	59	53	44	25		NP	7.3	SILTY SAND WITH GRAVEL, light brown, loose, approximately 5% cobbles.

TT99-21

DEPTH (ft)	SOIL CLASS	3	1.5	3/4	3/8	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
3.0	GW	100	68	50	38	31	28	25	18	9	5	3		NP	5.9	WELL GRADED GRAVEL WITH SAND, light brown, loose, approximately 20% cobbles and 5% boulders.
6.0	SP	90	90	81	74	70	69	66	59	41	19	4		NP	5.5	POORLY GRADED SAND WITH GRAVEL, light brown, loose, approximately 20% cobbles and 5% boulders.
9.0	GP	100	87	63	51	44	41	37	28	18	7	2		NP	8.4	POORLY GRADED GRAVEL WITH SAND, light brown, very loose, approximately 20% cobbles and less than 5% boulders.
12.0	GP	100	58	23	15	13	12	11	9	4	1	1		NP	14.6	POORLY GRADED GRAVEL, light brown, loose, approximately 10% cobbles, less than 5% boulders.
16.0	GP	94	77	40	28	25	24	22	17	9	3	1		NP	7.3	POORLY GRADED GRAVEL WITH SAND, light brown, loose, approximately 10% cobbles, less than 5% boulders.

TT99-22

DEPTH (ft)	SOIL CLASS	3	1.5	3/4	3/8	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
3.0	GW	100	76	51	38	30	27	23	16	7	3	1		NP	9.9	WELL GRADED GRAVEL WITH SAND, brown, very dense, approximately 25% cobbles and 20% boulders.
6.0	GW	100	80	57	42	32	28	24	15	4	1	1		NP	13.3	same as above, brown, approximately 15% cobbles.
10.0	GP	100	64	41	28	22	20	18	9	2	1	1		NP	12.4	POORLY GRADED GRAVEL WITH SAND, brown,, approximately 15% cobbles, hard digging as above. Hit water at 10 feet.
16.0	GP	100	72	45	30	24	22	20	17	11	5	2		NP	21.6	WELL GRADED GRAVEL WITH SAND, brown to black, approximately 40% cobbles and 15% boulders, hard to dig as above.

TT99-27

DEPTH (ft)	SOIL CLASS	3	1.5	3/4	3/8	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
1.0	GP-GM	100	69	52	44	38	36	34	27	19	13	8		NP	10.4	POORLY GRADED GRAVEL WITH SILT AND SAND, brown, loose, approximately 15% cobbles.
6.0	GP	100	47	39	35	32	30	27	22	14	6	1		NP	11.2	POORLY GRADED GRAVEL WITH SAND, light brown to gray, loose approximately 15% cobbles, less than 5% boulders.
8.0	GW	88	60	47	36	29	27	24	18	11	7	4		NP	11.0	WELL GRADED GRAVEL WITH SAND, light brown to gray, loose, approximately 15% cobbles, less than 5% boulders.
10.0	SP	100	89	81	76	71	68	56	18	2	1	1		NP	16.0	POORLY GRADED SAND WITH GRAVEL, light brown to gray, very loose, less than 5% cobbles.
16.0	GW	89	57	40	32	27	26	23	13	5	2	1		NP	18.4	WELL GRADED GRAVEL WITH SAND, light brown to gray, loose, approximately 20% cobbles.

TT99-28

DEPTH (ft)	SOIL CLASS	3	1.5	3/4	3/8	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
4.0	GP	100	91	74	45	36	33	29	19	8	3	1		NP	10.5	POORLY GRADED GRAVEL WITH SAND, light brown, loose, approximately 15% cobbles, less than 5% boulders.
8.0	GW	100	83	62	45	32	27	21	17	4	1	1		NP	6.6	WELL GRADED GRAVEL WITH SAND, brown, loose, approximately 20% cobbles and 5% boulders.
12.0	SP	100	82	64	57	52	49	45	29	11	3	1		NP	6.6	POORLY GRADED SAND WITH GRAVEL, brown, loose, approximately 20% cobbles and 5% boulders.
16.0	GP	100	55	23	16	13	11	10	7	3	1	1		NP	8.4	POORLY GRADED GRAVEL, brown, approximately 20% cobbles and 5% boulders, some trash.

Figure 11

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SALT RIVER, MARICOPA COUNTY, ARIZONA
RIO SALADO, PHOENIX REACH
(19TH AVENUE TO I-10 FREEWAY)
LOGS OF EXPLORATION
TT99-17 TO 20, 27, AND 28

DESIGNED BY: W H
DRAWN BY: W H
CHECKED BY: JDO

SUBMITTED BY: ABBAS T. ROODSARI, P.E.
CHIEF, GEOTECHNICAL BRANCH

DISTRICT FILE NO. NOT APPLICABLE | SPEC. NO.: NOT APPLICABLE | CADD FILE NAME: g03.dgn

SYMBOL | DESCRIPTIONS | DATE | APPROVAL
REVISIONS

SHEET 17 OF 19 SHEETS

FIGURE 12

TT99-29

DEPTH (ft)	SOIL CLASS	3	1.5	3/4	3/8	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
2.0	GP	100	64	52	40	33	30	23	11	3	1	1		NP	13.3	POORLY GRADED GRAVEL WITH SAND, brown, very loose, approximately 10% cobbles, less than 5% boulders.
8.0	GP	100	66	42	31	25	20	16	9	1	1	1		NP	6.6	same as above, loose, approximately 20% cobbles, less than 5% boulders.
12.0	SP	100	92	88	84	82	80	78	66	23	8	1		NP	5.7	POORLY GRADED SAND WITH GRAVEL, light brown, very loose.
16.0	GP	100	87	69	56	48	44	40	29	11	3	1		NP	6.2	POORLY GRADED GRAVEL WITH SAND, light brown, very loose, less than 5% cobbles.

TT99-30

DEPTH (ft)	SOIL CLASS	3	1.5	3/4	3/8	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
5.0	GP	90	45	33	27	23	21	16	8	3	1	1		NP	15.5	POORLY GRADED GRAVEL WITH SAND, brown, loose, approximately 10% cobbles, less than 5% boulders.
8.0	SW-SM	100	98	94	91	88	71	52	37	23	14	6		NP	14.1	WELL GRADED SAND WITH SILT, dark brown, dense.
12.0	GP	90	78	62	52	47	44	35	13	3	1	1		NP	12.2	POORLY GRADED GRAVEL WITH SAND, light brown, very loose, less than 5% cobbles.
16.0	GP	100	55	32	23	20	18	16	11	4	1	1		NP	21.8	same as above.

TT99-31

DEPTH (ft)	SOIL CLASS	3	1.5	3/4	3/8	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
6.0	GP	90	44	32	25	22	21	19	11	3	1	1		NP	14.3	POORLY GRADED GRAVEL WITH SAND, brown, loose approximately 20% cobbles, some PCC rubble.
12.0	GP	100	67	43	32	26	24	21	10	2	1	1		NP	13.6	same as above, light brown, loose, approximately 25% cobbles.
17.0	GP	100	58	41	26	20	18	15	7	2	1	1		NP	16.3	same as above, dark brown to black, loose, approximately 15% cobbles.

TT99-32

DEPTH (ft)	SOIL CLASS	3	1.5	3/4	3/8	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
1.0	GP	91	75	58	50	44	42	40	30	16	8	3		NP	12.4	POORLY GRADED GRAVEL WITH SAND, brown, loose, approximately 15% cobbles, less than 5% boulders.
10.0	GP	100	75	50	41	36	34	31	21	9	3	1		NP	15.7	same as above, light brown, loose, approximately 20% cobbles, some boulders, some PCC rubble.
16.0	GP	100	74	57	46	37	32	26	15	5	2	1		NP	14.8	same as above, dark gray/brown, loose, approximately 25% cobbles, less than 5% boulders.

TT99-33

DEPTH (ft)	SOIL CLASS	3	1.5	3/4	3/8	4	8	16	30	50	100	200	LL	PI	MC	DESCRIPTION
1.0	GW	100	78	52	39	31	27	23	12	5	2	1		NP	5.9	WELL GRADED GRAVEL WITH SAND, brown, loose, approximately 15% cobbles, some PCC debris.
2.0	SP	100	100	95	81	52	46	38	25	15	7	3		NP	13.3	POORLY GRADED SAND WITH GRAVEL, light brown, loose, approximately 10% cobbles.
8.0	GP	100	96	88	68	49	42	33	21	11	6	3		NP	21.1	POORLY GRADED GRAVEL WITH SAND, dark green, loose, trash (wood, metal tires, brick), approximately 10% cobbles. Encountered water at 7 feet.
9.5	SM	100	100	100	100	100	92	81	75	70	65	42			44.0	SILTY SAND, brown to dark green. Stopped trench due to water.

TT99-34

DEPTH (ft)	SOIL CLASS	DESCRIPTION
2.0	SP	POORLY GRADED SAND WITH GRAVEL, brown, very dry, dense to loose, fine to medium grained sand, 5% gravels.
9.0	GP	POORLY GRADED GRAVEL WITH SAND, light gray to brown, dry to moist, loose, medium to coarse grained sand, 5% cobbles, less than 5% boulders.
13.0	GP	GRAVELLY SAND WITH COBBLES, dark brown, very moist, coarse grained sand, approximately 25% cobbles and 5% boulders, hard digging, due to many large particles.
14.0	GP	same as above, approximately 10% boulders.

TT99-35

DEPTH (ft)	SOIL CLASS	DESCRIPTION
3.0	GP	POORLY GRADED GRAVEL WITH SAND, light brown, dry to moist, loose, medium to coarse grained sand, approximately 20% cobbles and 10% boulders, less than 5% chunks of concrete rubble, asphalt, and brick.
7.0	GP	same as above, approximately 25% cobbles, no trash, sand is very clean.
11.0	GP	same as above, with approximately 5% boulders. Terminated hole at 11 feet due to layer of cobbles.

TT99-36

DEPTH (ft)	SOIL CLASS	DESCRIPTION
3.0	GM	POORLY GRAVEL WITH SAND AND SILT, brown, moist, dense, fine to medium grained sand, approximately 15% cobbles and 5% boulders.
7.0	SP	SANDY GRAVEL, brown, moist, dense, medium to coarse grained sand, hard digging, approximately 10% cobbles.
16.0	SP	same as above, approximately 5% cobbles.

Figure 12

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

SALT RIVER, MARICOPA COUNTY, ARIZONA
RIO SALADO, PHOENIX REACH
(19TH AVENUE TO I-10 FREEWAY)

LOGS OF EXPLORATION
TT99-29 TO TT99-36

DESIGNED BY: W H
DRAWN BY: W H
CHECKED BY: JDD

CADD FILE NAME: g04.dgn

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SUBMITTED BY:
ABBAS T. ROODSARI, P.E.
CHIEF, GEOTECHNICAL BRANCH

DISTRICT FILE NO. NOT APPLICABLE
SPEC. NO.: NOT APPLICABLE

SHEET 18 OF 19 SHEETS

FIGURE 13

TT99-37

DEPTH (ft)	SOIL CLASS	DESCRIPTION
4.0	GP	POORLY GRADED GRAVEL WITH SAND, brown, dry, loose, medium to coarse grained sand, approximately 20% cobbles.
5.0	GP	POORLY GRADED GRAVEL, light brown, wet, fine grained sand, approximately 20% cobbles, less than 5% boulders.
16.0	GP	SANDY GRAVEL, brown, moist to wet, dense, coarse grained sand, hard digging, approximately 20% cobbles.

TT99-38

DEPTH (ft)	SOIL CLASS	DESCRIPTION
1.0	SM	SILTY SAND, very fine to fine sands.
6.0	GP	GRAVELLY SAND WITH COBBLES. brown, moist, loose, medium grained sands. approximately 35% gravels 40%cobbles and 5% boulders.
10.0	GP	SANDY GRAVEL, brown, moist, dense, medium grained sand, approximately 40% gravels, 35% cobbles, and 5% boulders.
16.0	GP	same as above.

TT99-39

DEPTH (ft)	SOIL CLASS	DESCRIPTION
4.0	SP	POORLY GRADED SAND WITH GRAVEL, brown, moist, loose, fine to medium grained sand, approximately 35% gravels, 20% cobbles, and 5% boulders. PCC rubble on surface.
9.0	GP	SANDY GRAVEL. brown, moist, very loose, medium grained sands. approximately 45% gravels, 20% cobbles, and 5% boulders.
12.0	GP	same as above, denser, some silt.
16.0	GW	SANDY GRAVEL, brown, very moist, dense, approximately 50% gravels, 15% cobbles, 5% boulders, medium grained sands.

Figure 13

SYMBOL	DESCRIPTIONS	DATE	APPROVAL
	REVISIONS		

SALT RIVER, MARICOPA COUNTY, ARIZONA
RIO SALADO, PHOENIX REACH
(19TH AVENUE TO I-10 FREEWAY)

LOGS OF EXPLORATION
TT99-37 TO TT99-39

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: W H
DRAWN BY: W H
CHECKED BY: JDO

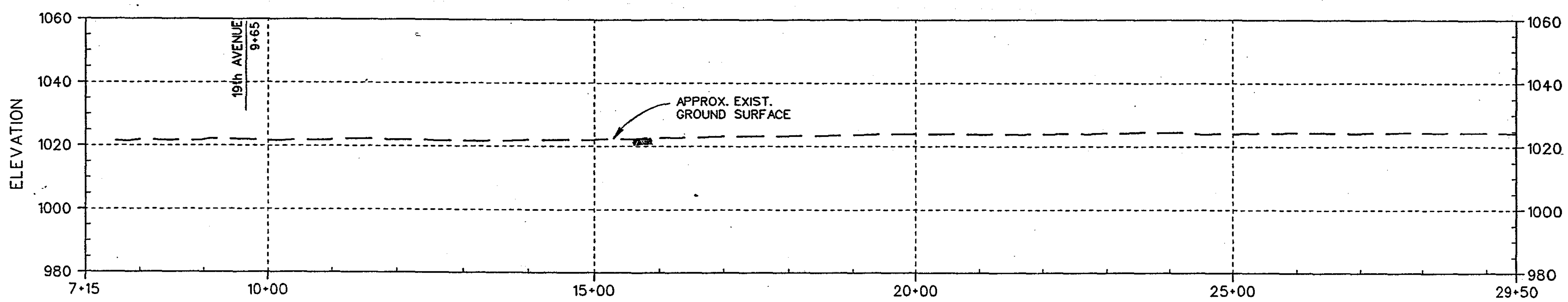
SUBMITTED BY: ABBAS T. ROODSARI, P.E.
CHIEF, GEOTECHNICAL BRANCH

DISTRICT FILE NO. NOT APPLICABLE | SPEC. NO.: NOT APPLICABLE | CADD FILE NAME: g05.dgn

SHEET 19 OF 19 SHEETS

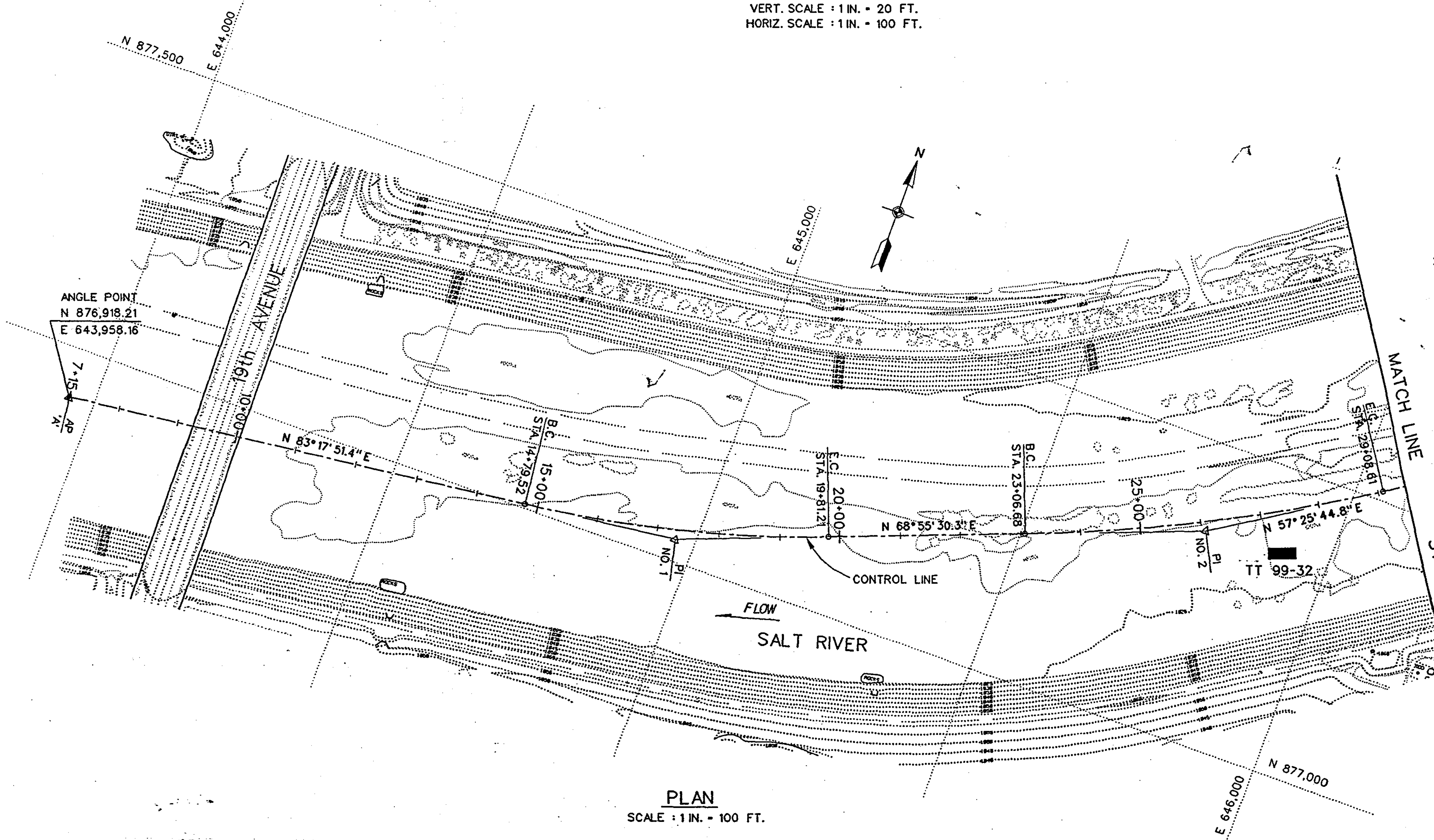
FIGURE 14

Figure 14



PROFILE AT CONTROL LINE

VERT. SCALE : 1 IN. = 20 FT.
HORIZ. SCALE : 1 IN. = 100 FT.



PLAN

SCALE : 1 IN. = 100 FT.

CURVE DATA AT CONTROL LINE

P.I. NO.	1	2
NORTHING	877,036.87	877,353.17
EASTING	644,967.90	645,788.68
Δ=	14° 22' 21.1"	11° 29' 45.5"
R=	2,000'	3,000'
T=	252.17'	301.98'
L=	501.70'	601.93'
B.C. STA.	14+79.52	23+06.68
E.C. STA.	19+81.21	29+08.61

NOTES:

1. THIS SHEET IS FOR INFORMATION PURPOSES ONLY. NO GRADING IN THIS AREA.
2. SEE SHEETS 15 TO 19 FOR LOGS OF EXPLORATION AND UNIFIED SOIL CLASSIFICATION SYSTEM.

TT 99-32 — LOCATION, YEAR AND NUMBER OF TEST TRENCH BY CORPS OF ENGINEERS

20 10 0 20 40FT
SCALE: 1"= 20'

100 50 0 100 200FT
SCALE: 1"= 100'

SYMBOL	DESCRIPTIONS	DATE	APPROVAL
	REVISIONS		

SALT RIVER, MARICOPA COUNTY, ARIZONA
RIO SALADO, PHOENIX REACH
(19TH AVENUE TO I-10 FREEWAY)

ROUGH GRADING, PLAN AND PROFILE
STA. 7+15 TO STA. 29+50

DESIGNED BY: CC / WD
DRAWN BY: WD
CHECKED BY: DC

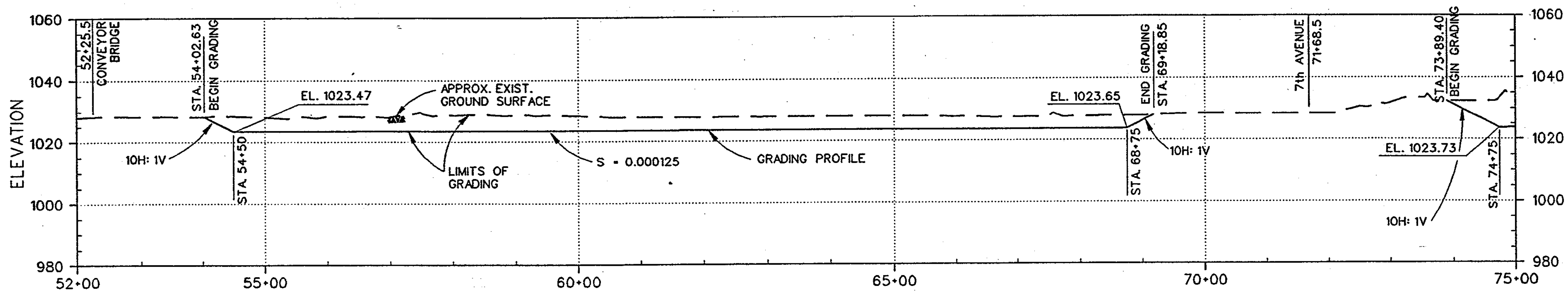
U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SUBMITTED BY: THOMAS H. SAGE, P.E.
CHIEF, DESIGN BRANCH

DISTRICT FILE NO.: NOT APPLICABLE
SPEC. NO.: NOT APPLICABLE
CADD FILE NAME: CL4pp

SHEET 3 OF 19 SHEETS

Figure 16

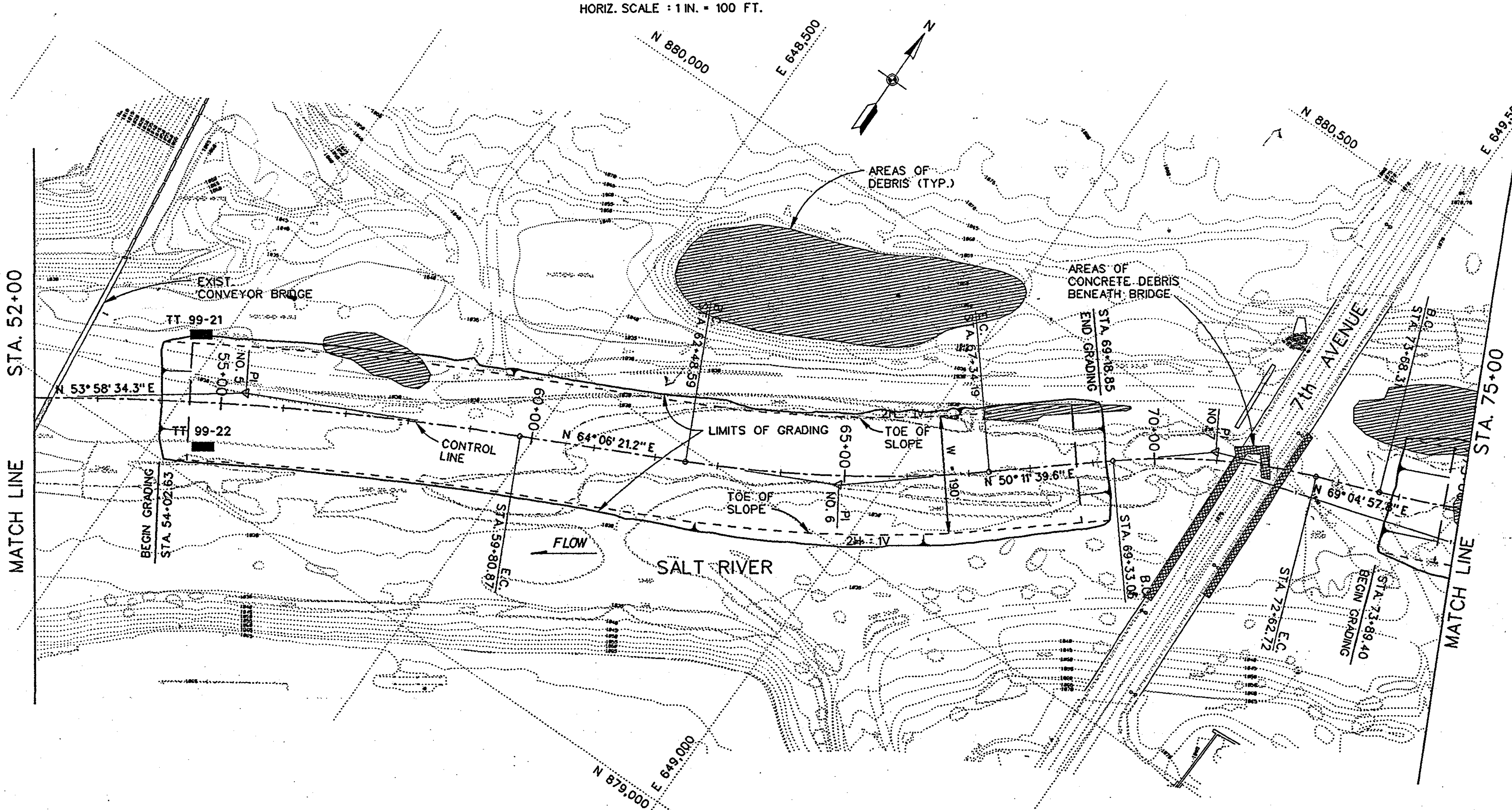


PROFILE AT CONTROL LINE

VERT. SCALE : 1 IN. = 20 FT.
HORIZ. SCALE : 1 IN. = 100 FT.

CURVE DATA AT CONTROL LINE	
P.I. NO.	5
NORTHING	879,168
EASTING	648,081
Δ=	10° 07' 46.7"
R=	5,000'
T=	443.14'
L=	883.98'
B.C. STA.	50+96.89
E.C. STA.	59+80.87

CURVE DATA AT CONTROL LINE		
P.I. NO.	6	7
NORTHING	879,585	879,975
EASTING	648,940	649,408
Δ=	13° 54' 41.3"	18° 53' 18.4"
R=	2,000'	1,000'
T=	244.00'	166.34'
L=	485.60'	329.67'
B.C. STA.	62+48.59	69+33.05
E.C. STA.	67+34.19	72+62.72



PLAN

SCALE : 1 IN. = 100 FT.

NOTES:

1. SEE SHEETS 15 TO 19 FOR LOGS OF EXPLORATION AND UNIFIED SOIL CLASSIFICATION SYSTEM.
2. SEE SHEET 2 FOR TYPICAL SECTION OF EXCAVATION.
3. EXCAVATION SHALL NOT EXCEED THE LIMITS OF GRADING SHOWN.

TT 99-21 — LOCATION, YEAR AND NUMBER OF TEST TRENCH BY CORPS OF ENGINEERS

20 10 0 20 40FT
SCALE: 1" = 20'

100 50 0 100 200FT
SCALE: 1" = 100'

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

SALT RIVER, MARICOPA COUNTY, ARIZONA
RIO SALADO, PHOENIX REACH
(19TH AVENUE TO I-10 FREEWAY)
ROUGH GRADING, PLAN AND PROFILE
STA. 52+00 TO STA. 75+00

DESIGNED BY: CC / WD
DRAWN BY: WD
CHECKED BY: DC

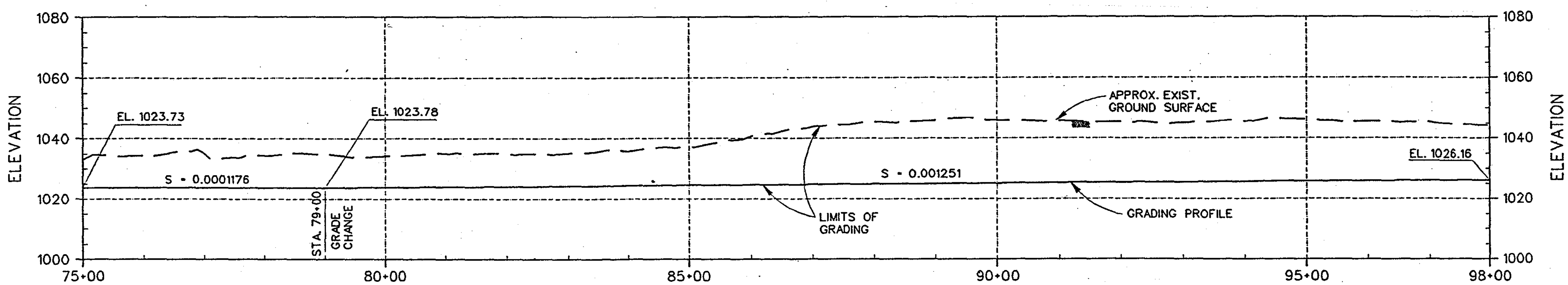
U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SUBMITTED BY:
THOMAS H. SAGE, P.E.
CHIEF, DESIGN BRANCH

DISTRICT FILE NO.: NOT APPLICABLE
SPEC. NO.: NOT APPLICABLE
CADD FILE NAME: s3.dgn

SHEET 5 OF 19 SHEETS

Figure 17

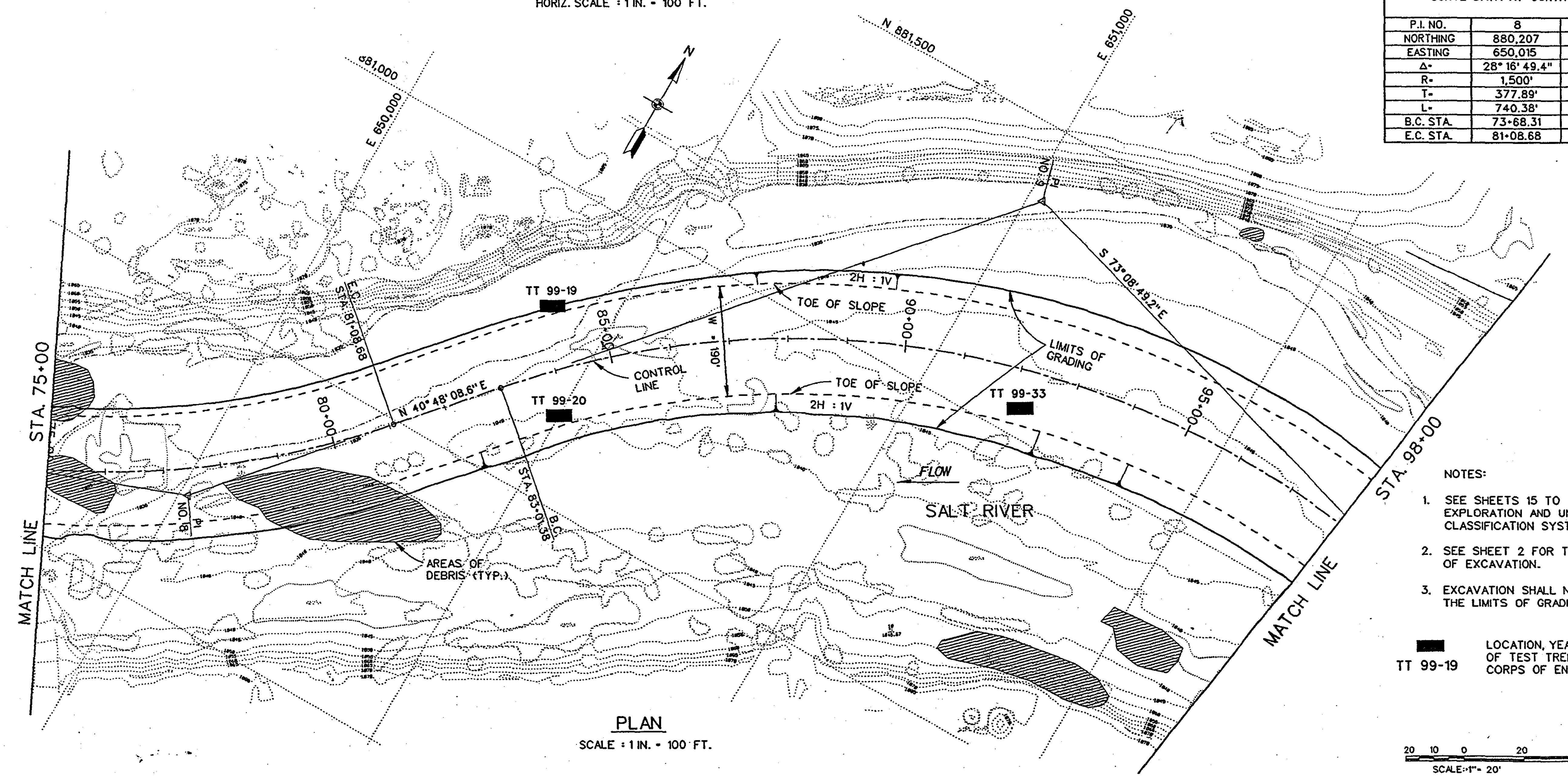


PROFILE AT CONTROL LINE

VERT. SCALE : 1 IN. = 20 FT.
HORIZ. SCALE : 1 IN. = 100 FT.

CURVE DATA AT CONTROL LINE

P.I. NO.	8	9
NORTHING	880,207	881,377
EASTING	650,015	651,025
Δ=	28° 16' 49.4"	66° 03' 02.2"
R=	1,500'	1,500'
T=	377.89'	975.05'
L=	740.38'	1,729.20'
B.C. STA.	73+68.31	83+01.38
E.C. STA.	81+08.68	100+30.58



PLAN

SCALE : 1 IN. = 100 FT.

NOTES:

1. SEE SHEETS 15 TO 19 FOR LOGS OF EXPLORATION AND UNIFIED SOIL CLASSIFICATION SYSTEM.
2. SEE SHEET 2 FOR TYPICAL SECTION OF EXCAVATION.
3. EXCAVATION SHALL NOT EXCEED THE LIMITS OF GRADING SHOWN.

TT 99-19 — LOCATION, YEAR AND NUMBER OF TEST TRENCH BY CORPS OF ENGINEERS

SCALE: 1" = 20' (20 10 0 20 40FT)

SCALE: 1" = 100' (100 50 0 100 200FT)

SYMBOL | DESCRIPTIONS | DATE | APPROVAL — REVISIONS

SALT RIVER, MARICOPA COUNTY, ARIZONA
RIO SALADO, PHOENIX REACH
(19TH AVENUE TO I-10 FREEWAY)

ROUGH GRADING, PLAN AND PROFILE
STA. 75+00 TO STA. 98+00

DESIGNED BY: CC / WD
DRAWN BY: WD
CHECKED BY: DC

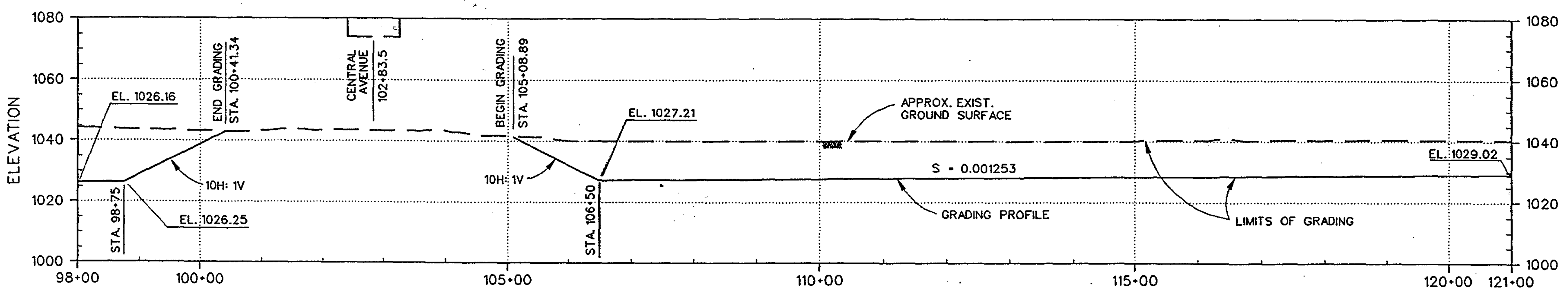
U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SUBMITTED BY: THOMAS H. SAGE, P.E.
CHIEF, DESIGN BRANCH

DISTRICT FILE NO.: NOT APPLICABLE | SPEC. NO.: NOT APPLICABLE | CADD FILE NAME: c4.dgn

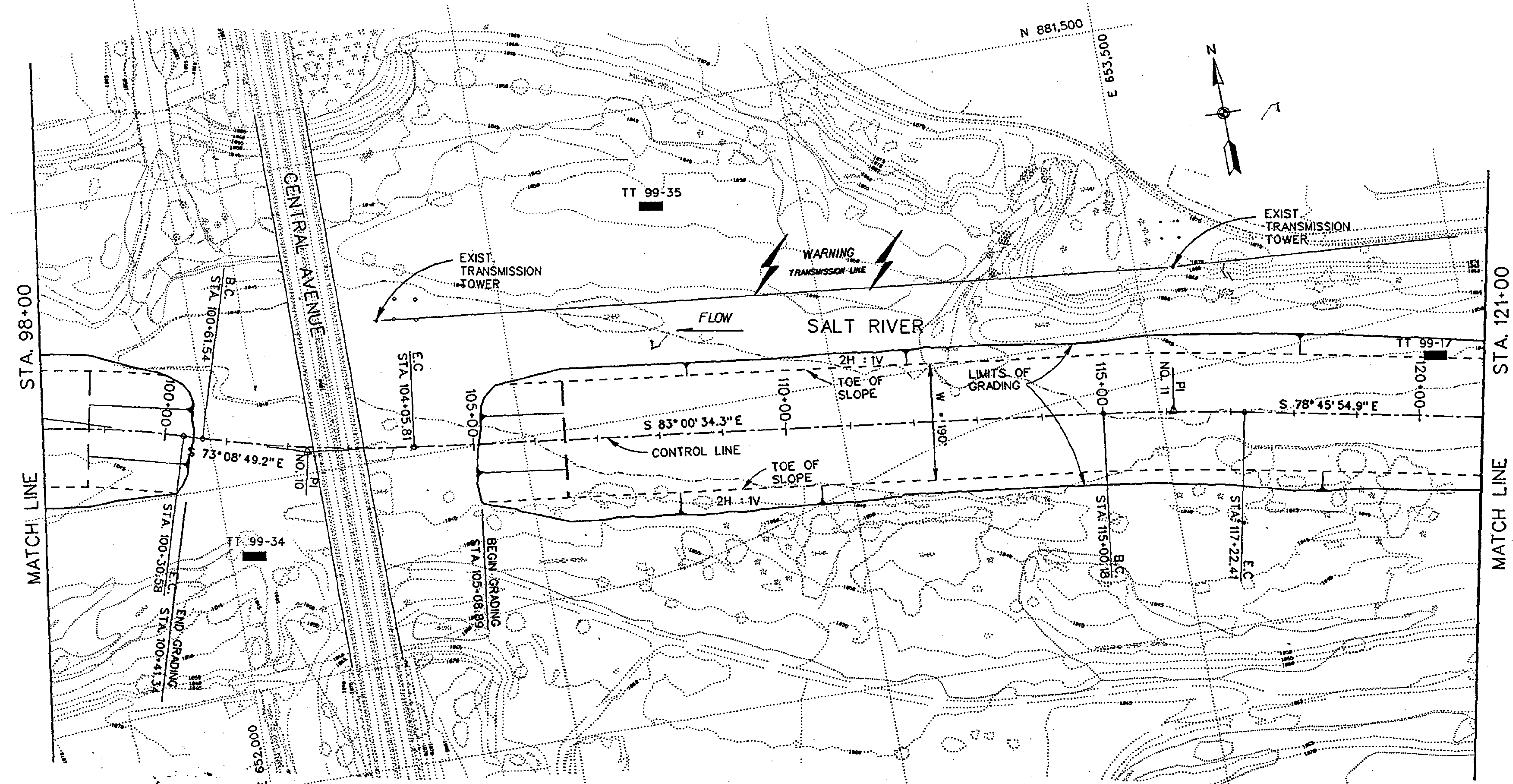
SHEET 6 OF 19 SHEETS

Figure 18



PROFILE AT CONTROL LINE

VERT. SCALE : 1 IN. = 20 FT.
HORIZ. SCALE : 1 IN. = 100 FT.



PLAN

SCALE : 1 IN. = 100 FT.

CURVE DATA AT CONTROL LINE	
P.I. NO.	10
NORTHING	881,035.31
EASTING	652,152.96
Δ=	9° 51' 45.1"
R=	2,000'
T=	172.56'
L=	344.27'
B.C. STA.	100+61.54
E.C. STA.	104+05.81

CURVE DATA AT CONTROL LINE	
P.I. NO.	11
NORTHING	880,867.59
EASTING	653,520.81
Δ=	4° 14' 39.4"
R=	3,000'
T=	111.17'
L=	222.23'
B.C. STA.	115+00.18
E.C. STA.	117+22.41

NOTES:

1. SEE SHEETS 15 TO 19 FOR LOGS OF EXPLORATION AND UNIFIED SOIL CLASSIFICATION SYSTEM.
2. SEE SHEET 2 FOR TYPICAL SECTION OF EXCAVATION.
3. EXCAVATION SHALL NOT EXCEED THE LIMITS OF GRADING SHOWN.

TT 99-34 — LOCATION, YEAR AND NUMBER OF TEST TRENCH BY CORPS OF ENGINEERS

20 10 0 20 40FT
SCALE: 1"= 20'

100 50 0 100 200FT
SCALE: 1"= 100'

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

SALT RIVER, MARICOPA COUNTY, ARIZONA
RIO SALADO, PHOENIX REACH
(19TH AVENUE TO I-10 FREEWAY)

ROUGH GRADING, PLAN AND PROFILE
STA. 98+00 TO STA. 121+00

DESIGNED BY: CC / MD
DRAWN BY: MD
CHECKED BY: DC

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

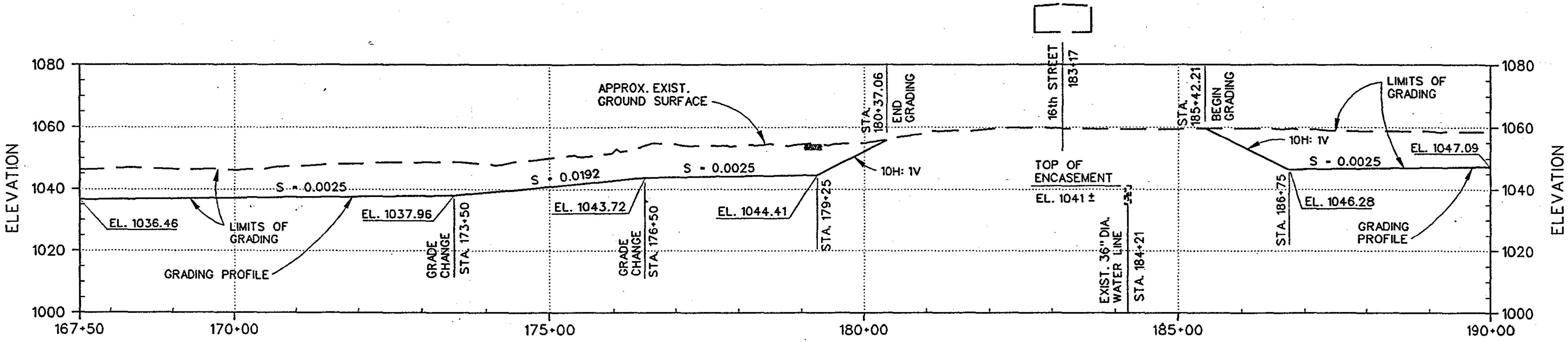
SUBMITTED BY:
THOMAS H. SAGE, P.E.
CHIEF, DESIGN BRANCH

DISTRICT FILE NO.: NOT APPLICABLE
SPEC. NO.: NOT APPLICABLE
CADD FILE NAME: C5.dgn

SHEET 7 OF 19 SHEETS

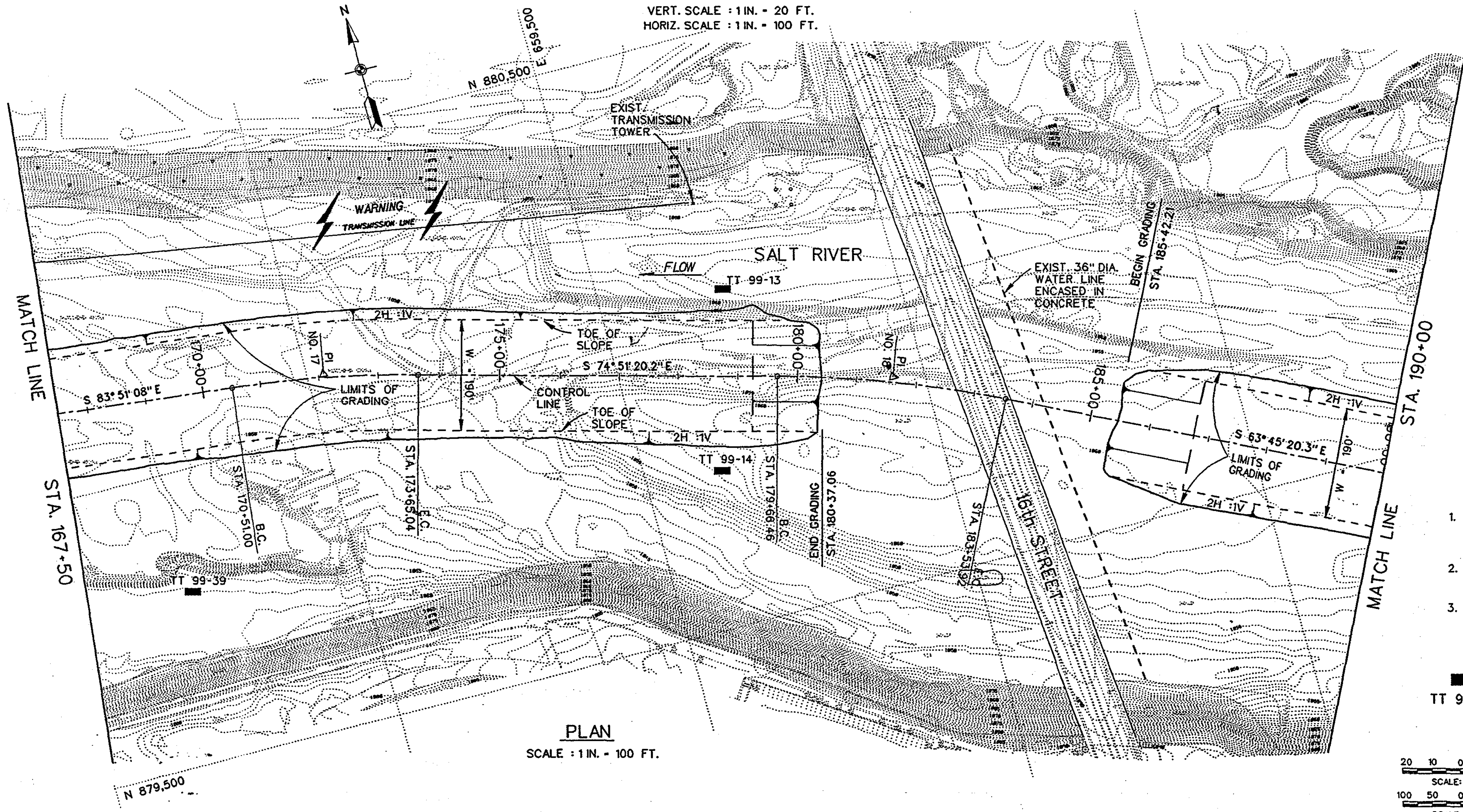
VALUE ENGINEERING PAYS

Figure 21



PROFILE AT CONTROL LINE

VERT. SCALE : 1 IN. = 20 FT.
HORIZ. SCALE : 1 IN. = 100 FT.



PLAN

SCALE : 1 IN. = 100 FT.

℄ CURVE DATA

P.I. NO.	17
NORTHING	880,097
EASTING	659,027
Δ=	8° 59' 47.8"
R=	2,000'
T=	157.34'
L=	314.04'
B.C. STA.	170+51.00
E.C. STA.	173+65.04

℄ CURVE DATA

P.I. NO.	18
NORTHING	879,848
EASTING	659,947
Δ=	11° 05' 59.9"
R=	2,000'
T=	194.34'
L=	387.46'
B.C. STA.	179+66.46
E.C. STA.	183+53.92

NOTES:

1. SEE SHEETS 15 TO 19 FOR LOGS OF EXPLORATION AND UNIFIED SOIL CLASSIFICATION SYSTEM.
2. SEE SHEET 2 FOR TYPICAL SECTION OF EXCAVATION.
3. EXCAVATION SHALL NOT EXCEED THE LIMITS OF GRADING SHOWN.

TT 99-13 — LOCATION, YEAR AND NUMBER OF TEST TRENCH BY CORPS OF ENGINEERS

20 10 0 20 40FT
SCALE: 1"= 20'

100 50 0 100 200FT
SCALE: 1"= 100'

SYMBOL	DESCRIPTIONS	DATE	APPROVAL
REVISIONS			

SALT RIVER, MARICOPA COUNTY, ARIZONA
RIO SALADO, PHOENIX REACH
(19TH AVENUE TO I-10 FREEWAY)

ROUGH GRADING, PLAN AND PROFILE STA. 167+50 TO STA. 190+00

DESIGNED BY: CC / WD
DRAWN BY: WD
CHECKED BY: DC

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

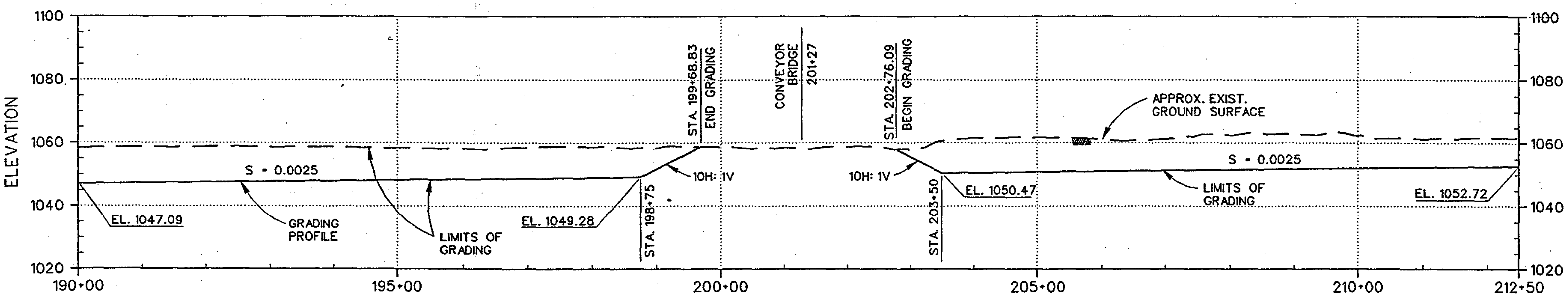
SUBMITTED BY: THOMAS H. SAGE, P.E.
CHIEF, DESIGN BRANCH

DISTRICT FILE NO.: NOT APPLICABLE | SPEC. NO.: NOT APPLICABLE | CADD FILE NAME: 08.dgn

SHEET 19 OF 10 SHEETS

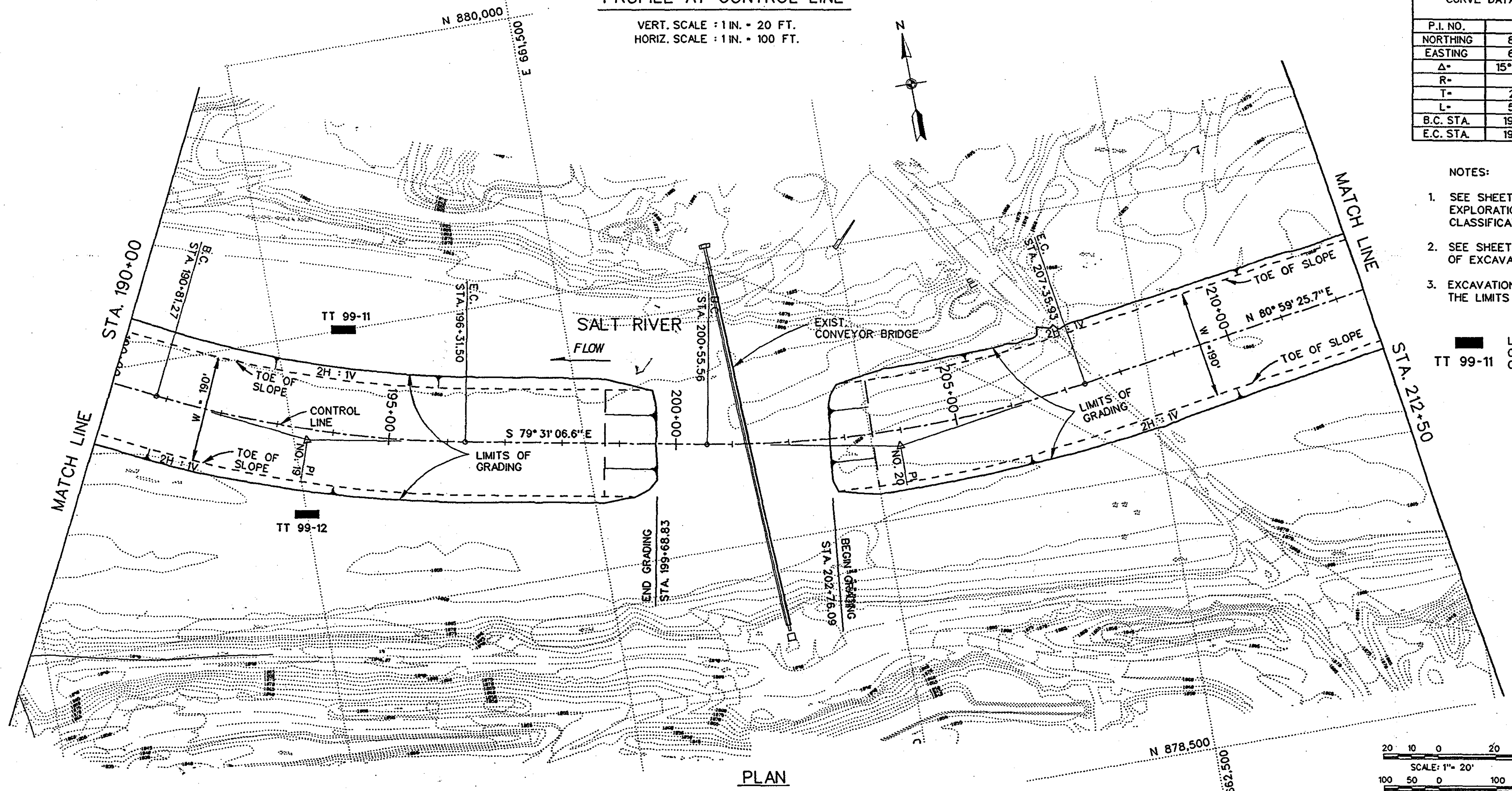
SAFETY PAYS

Figure 22



PROFILE AT CONTROL LINE

VERT. SCALE : 1 IN. = 20 FT.
HORIZ. SCALE : 1 IN. = 100 FT.



PLAN

SCALE : 1 IN. = 100 FT.

20 10 0 20 40FT
SCALE: 1"= 20'
100 50 0 100 200FT
SCALE: 1"= 100'

CURVE DATA AT CONTROL LINE

P.I. NO.	19	20
NORTHING	879,318	879,128
EASTING	661,022	662,049
Δ=	15° 45' 46.4"	19° 29' 27.7"
R=	2,000'	2,000'
T=	276.86'	343.50'
L=	550.23'	680.36'
B.C. STA.	190+81.27	200+55.56
E.C. STA.	196+31.50	207+35.93

NOTES:

1. SEE SHEETS 15 TO 19 FOR LOGS OF EXPLORATION AND UNIFIED SOIL CLASSIFICATION SYSTEM.
2. SEE SHEET 2 FOR TYPICAL SECTION OF EXCAVATION.
3. EXCAVATION SHALL NOT EXCEED THE LIMITS OF GRADING SHOWN.

TT 99-11 — LOCATION, YEAR AND NUMBER OF TEST TRENCH BY CORPS OF ENGINEERS

SYMBOL	DESCRIPTIONS	DATE	APPROVAL
	REVISIONS		

SALT RIVER, MARICOPA COUNTY, ARIZONA
RIO SALADO, PHOENIX REACH
(19TH AVENUE TO I-10 FREEWAY)

ROUGH GRADING, PLAN AND PROFILE
STA. 190+00 TO STA. 212+50

DESIGNED BY: CC / WD
DRAWN BY: WD
CHECKED BY: DC
CADD FILE NAME: s9.dgn

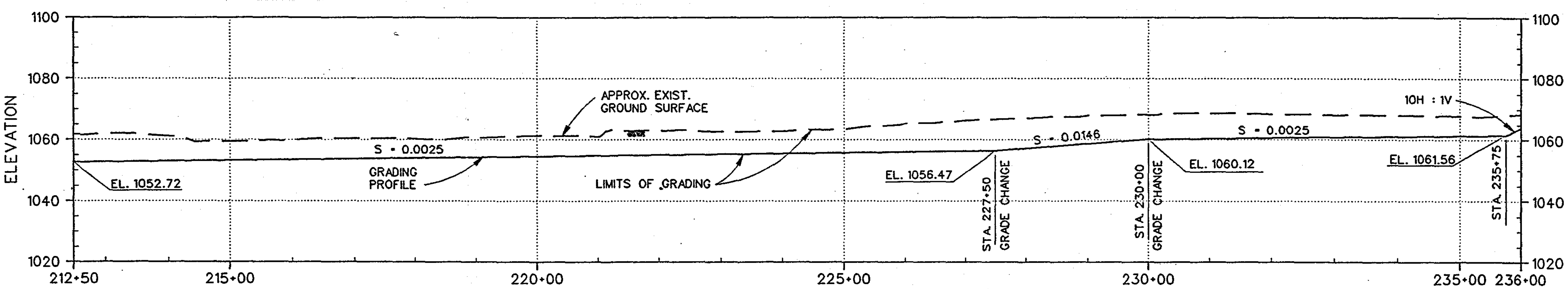
U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SUBMITTED BY:
THOMAS H. SAGE, P.E.
CHIEF, DESIGN BRANCH

DISTRICT FILE NO.: NOT APPLICABLE | SPEC. NO.: NOT APPLICABLE

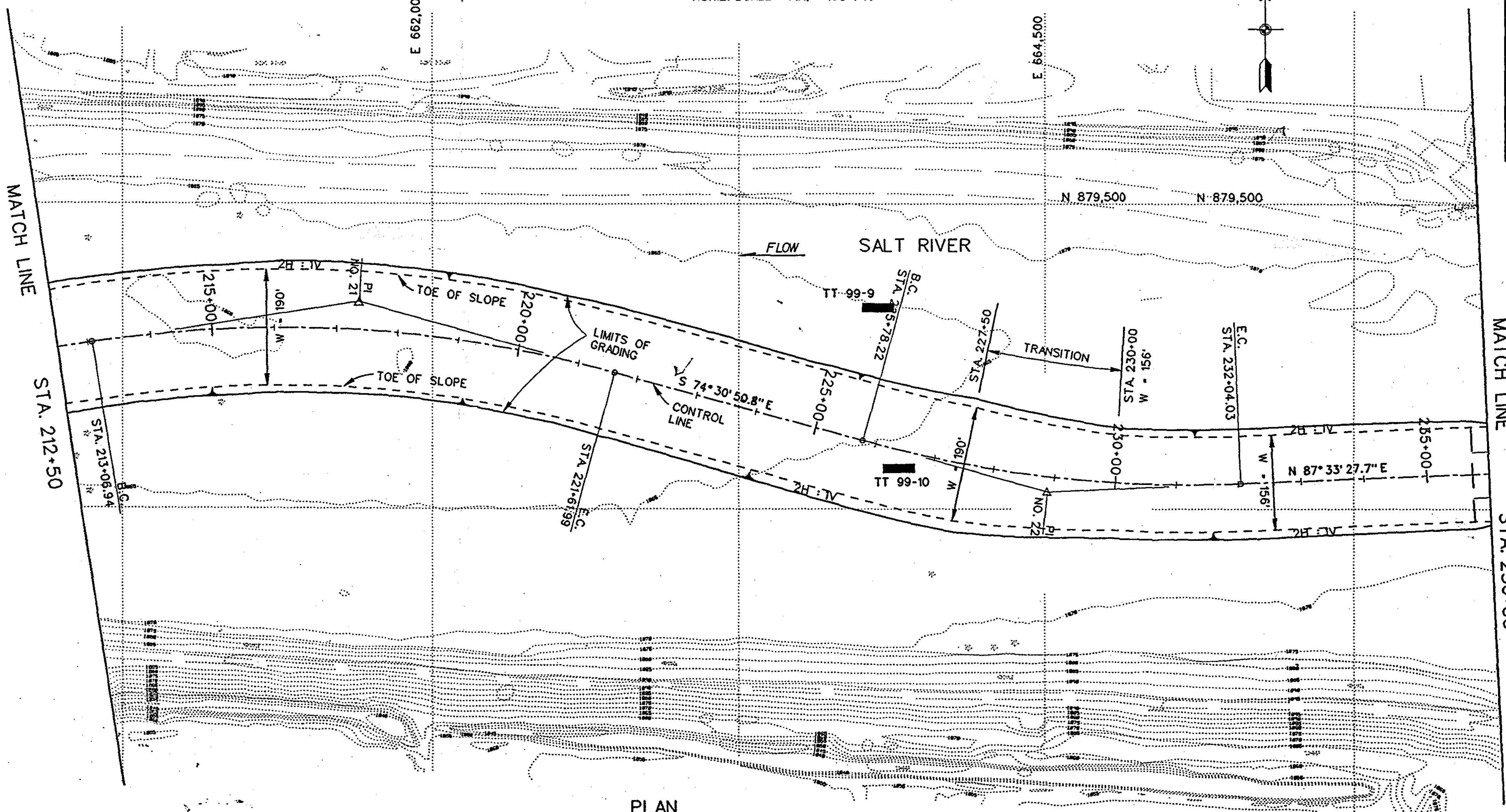
SHEET 11 OF 19 SHEETS

Figure 23



PROFILE AT CONTROL LINE

VERT. SCALE : 1 IN. = 20 FT.
HORIZ. SCALE : 1 IN. = 100 FT.



PLAN

SCALE : 1 IN. = 100 FT.

CURVE DATA AT CONTROL LINE		
P.I. NO.	21	22
NORTHING	879,339.20	879,027.91
EASTING	663,381.03	664,504.58
Δ=	24° 29' 43.5"	17° 55' 41.5"
R=	2,000'	2,000'
T=	434.16'	315.48'
L=	855.05'	625.81'
B.C. STA.	213+06.94	225+78.22
E.C. STA.	221+61.99	232+04.03

NOTES:

1. SEE SHEETS 15 TO 19 FOR LOGS OF EXPLORATION AND UNIFIED SOIL CLASSIFICATION SYSTEM.
2. SEE SHEET 2 FOR TYPICAL SECTION OF EXCAVATION.
3. EXCAVATION SHALL NOT EXCEED THE LIMITS OF GRADING SHOWN.

TT 99-9 — LOCATION, YEAR AND NUMBER OF TEST TRENCH BY CORPS OF ENGINEERS

SCALE: 1" = 20' (20 10 0 20 40FT)

SCALE: 1" = 100' (100 50 0 100 200FT)

REVISIONS — SYMBOL | DESCRIPTIONS | DATE | APPROVAL

SALT RIVER, MARICOPA COUNTY, ARIZONA
RIO SALADO, PHOENIX REACH
(19TH AVENUE TO I-10 FREEWAY)

ROUGH GRADING, PLAN AND PROFILE
STA. 212+50 TO STA. 236+00

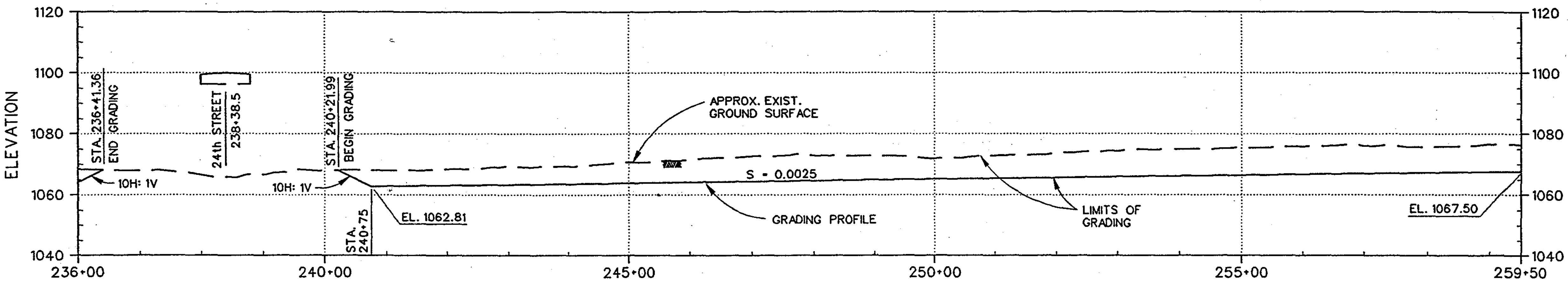
U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SUBMITTED BY: THOMAS H. SAGE, P.E. CHIEF, DESIGN BRANCH

DISTRICT FILE NO.: NOT APPLICABLE | SPEC. NO.: NOT APPLICABLE

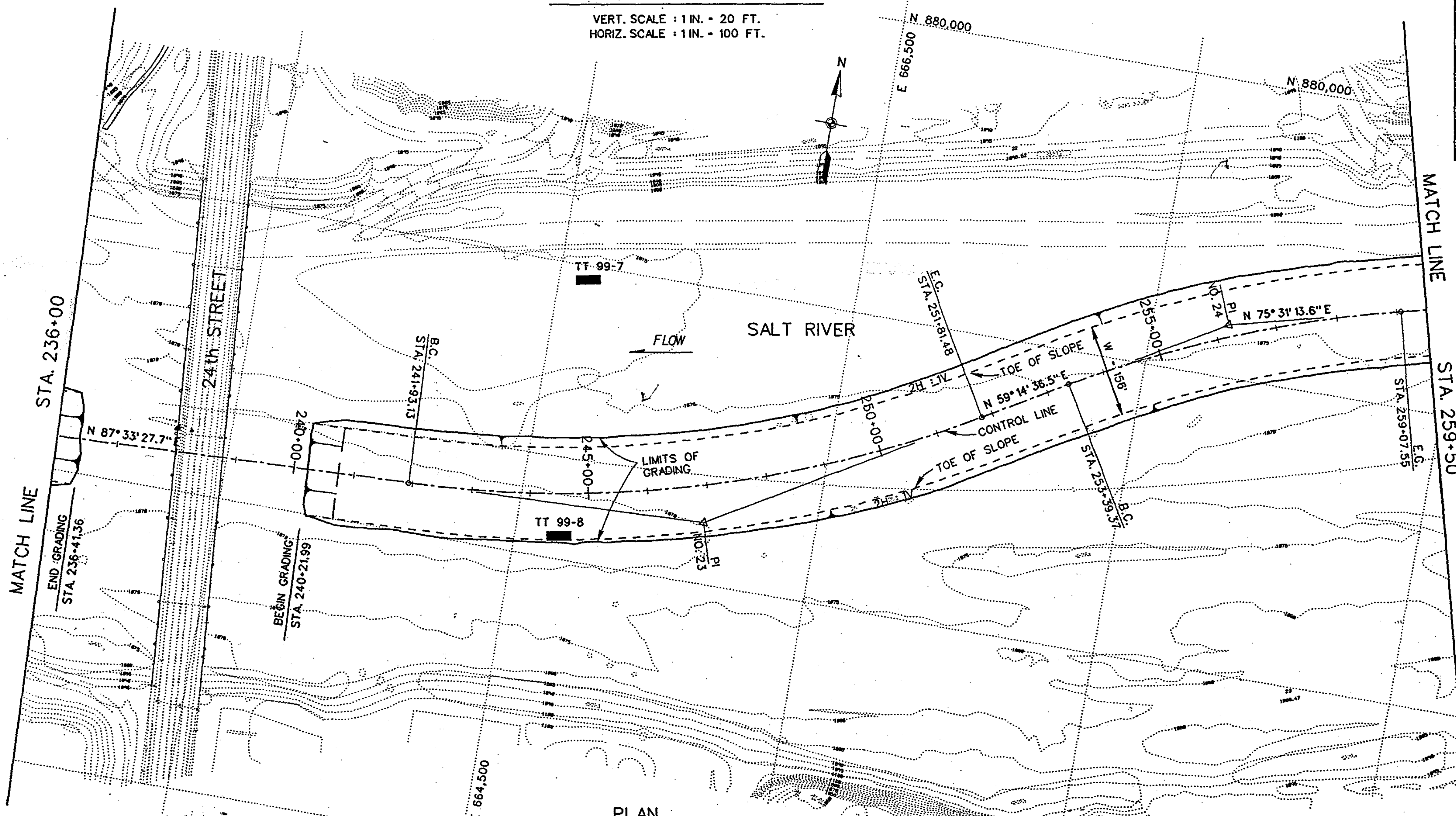
SHEET 19 OF 12 SHEETS

Figure 24



PROFILE AT CONTROL LINE

VERT. SCALE : 1 IN. = 20 FT.
HORIZ. SCALE : 1 IN. = 100 FT.



PLAN

SCALE : 1 IN. = 100 FT.

CURVE DATA AT CONTROL LINE		
P.I. NO.	23	24
NORTHING	879,105	879,590
EASTING	666,312	667,127
Δ=	28° 18' 51.3"	16° 16' 37.2"
R=	2,000'	2,000'
T=	504.49'	286.01'
L=	988.35'	568.17'
B.C. STA.	241+93.13	253+39.37
E.C. STA.	251+81.48	259+07.55

NOTES:

1. SEE SHEETS 15 TO 19 FOR LOGS OF EXPLORATION AND UNIFIED SOIL CLASSIFICATION SYSTEM.
2. SEE SHEET 2 FOR TYPICAL SECTION OF EXCAVATION.
3. EXCAVATION SHALL NOT EXCEED THE LIMITS OF GRADING SHOWN.

TT 99-8 — LOCATION, YEAR AND NUMBER OF TEST TRENCH BY CORPS OF ENGINEERS

20 10 0 20 40FT
SCALE: 1"= 20'

100 50 0 100 200FT
SCALE: 1"= 100'

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

SALT RIVER, MARICOPA COUNTY, ARIZONA
RIO SALADO, PHOENIX REACH
(19TH AVENUE TO I-10 FREEWAY)

ROUGH GRADING, PLAN AND PROFILE
STA. 236+00 TO STA. 259+50

DESIGNED BY: CC / WD
DRAWN BY: WD
CHECKED BY: DC

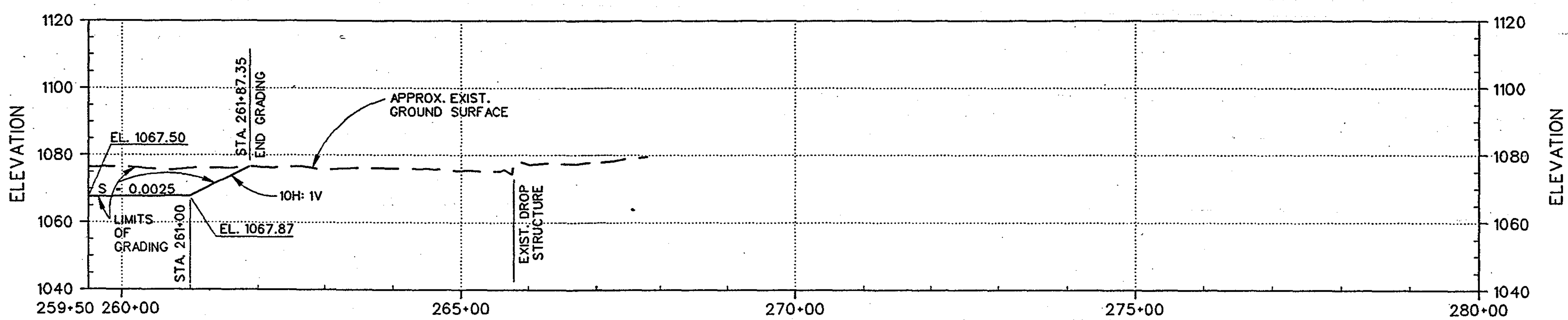
U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SUBMITTED BY:
THOMAS H. SAGE, P.E.
CHIEF, DESIGN BRANCH

DISTRICT FILE NO.: NOT APPLICABLE
SPEC. NO.: NOT APPLICABLE
CADD FILE NAME: C11.dgn

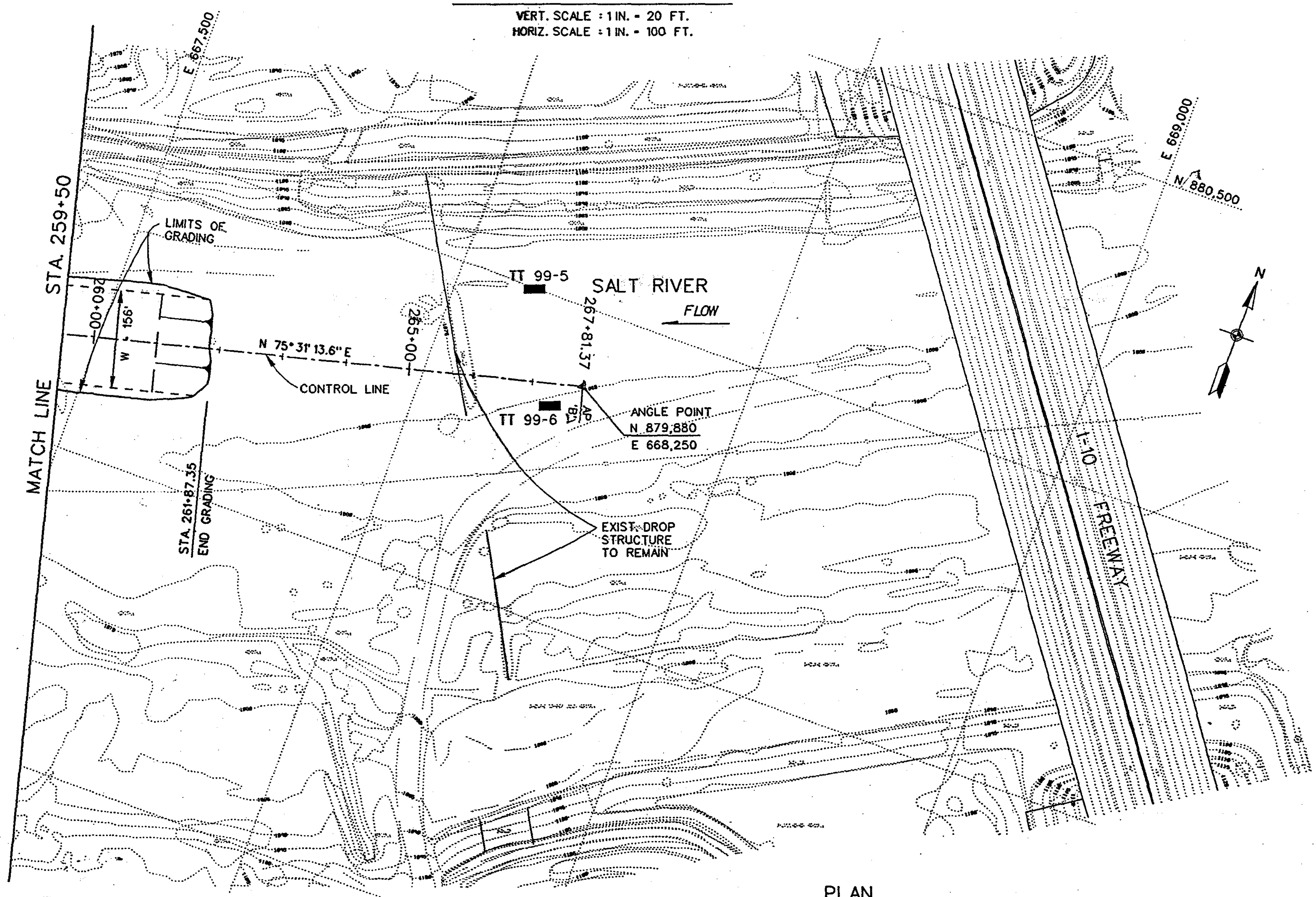
SHEET 13 OF 19 SHEETS

Figure 25



PROFILE AT CONTROL LINE

VERT. SCALE : 1 IN. = 20 FT.
HORIZ. SCALE : 1 IN. = 100 FT.



PLAN

SCALE : 1 IN. = 100 FT.

NOTES:

1. SEE SHEETS 15 TO 19 FOR LOGS OF EXPLORATION AND UNIFIED SOIL CLASSIFICATION SYSTEM.
2. SEE SHEET 2 FOR TYPICAL SECTION OF EXCAVATION.
3. EXCAVATION SHALL NOT EXCEED THE LIMITS OF GRADING SHOWN.

TT 99-5 — LOCATION, YEAR AND NUMBER OF TEST TRENCH BY CORPS OF ENGINEERS

20 10 0 20 40FT
SCALE: 1"= 20'

100 50 0 100 200FT
SCALE: 1"= 100'

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

SALT RIVER, MARICOPA COUNTY, ARIZONA
RIO SALADO, PHOENIX REACH
(19TH AVENUE TO I-10 FREEWAY)

ROUGH GRADING, PLAN AND PROFILE
STA. 259+50 TO STA. 267+81.37

DESIGNED BY: CC / WD
DRAWN BY: WD
CHECKED BY: DC

CADD FILE NAME: c12.dgn

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SUBMITTED BY:
THOMAS H. SAGE, P.E.
CHIEF, DESIGN BRANCH

DISTRICT FILE NO.: NOT APPLICABLE | SPEC. NO.: NOT APPLICABLE

SHEET 14 OF 19 SHEETS

Section B

MATERIALS

RIO SALADO
REPORT ON RCC FOR CONSTRUCTION

1. PURPOSE AND SCOPE
2. EXPLORATION
3. CEMENTITIOUS AND POZZOLANIC MATERIALS
    - 3.1 GENERAL
    - 3.2 PORTLAND CEMENT
        - a. *Types.*
        - b. *Testing Requirements.*
    - 3.3 FLY ASHES
        - a. *Class F.*
        - b. *Testing Requirements.*
    - 3.4 WATER
4. BORROW MATERIALS
    - 4.1 SAMPLING
    - 4.2 FIELD PROCESSING (by The Bureau of Reclamation {BUREC})
    - 4.3 PROCESSING BY TANNER-UNITED METRO
    - 4.4 LABORATORY PROCESSING
5. LABORATORY PROGRAM
    - 5.1 GENERAL
    - 5.2 PHYSICAL PROPERTIES OF AGGREGATES
    - 5.3 MIX DESIGN STUDIES
    - 5.4 CEMENT FLY ASH REPLACEMENT STUDIES
    - 5.5 ABRASION EROSION TEST DATA
    - 5.6 MIX DESIGN EVALUATIONS
6. AGGREGATE PROCESSING COSTS
    - 6.1 COMMERCIALLY AVAILABLE PRICE OF MATERIALS
    - 6.2 ESTIMATED COST OF PROCESSING AGGREGATES
7. DESIGN RECOMMENDATIONS
    - 7.1 AGGREGATE SELECTION
    - 7.2 CEMENT/FLY ASH COMBINATION

RIO SALADO PROJECT
REPORT ON RCC FOR CONSTRUCTION

1. PURPOSE AND SCOPE

The purpose of this report is to supply information and design alternatives for construction of Roller Compacted Concrete (RCC) structures as part of the Rio Salado Restoration Project. The report covers field investigations for potential sources of aggregates, laboratory and economic analysis of materials available, and recommendations for production of RCC for use in the subject project.

2. EXPLORATION

Due to the relative uniformity of the materials available, the relatively shallow and short nature of the structures to be built, explorations, for both the foundation investigations and potential borrow sources for RCC aggregates were carried out at the same time. In conjunction with these studies a detailed study of material types and stratification for a sediment transport study was carried out. Additional fine grained materials suitable to support planting and lining of ponds and channels were desired for construction of the planned project.

The materials encountered during the explorations were generally, cobbles, gravels, and sands. Naturally occurring fine grained materials, eg fine sands and silts, were not found in significant amounts in any of the on-site explorations.

Based on this lack of materials additional surveys of the existing aggregate suppliers in the immediate vicinity of the project were made. These surveys also confirmed that the local sources were short of fine grained materials. Most of the fine grained materials used by the sand and gravel operators is produced from crushing and screening operations.

3. CEMENTITIOUS AND POZZOLANIC MATERIALS

Based on the high cost of cement available, in the area, combinations of cement and fly ash were investigated to determine the most economical proportions of materials for construction. Detailed laboratory results for those studies are reported hereinafter.

3.1 GENERAL

Cementitious and pozzolanic materials needed for the proposed construction will be Portland cement and pozzolanic admixtures such as fly ash. The use of fly ash is recommended based on the cost of cement, approximately $100 per ton and on the widespread availability and quality of fly ashes available in the region.

3.2 PORTLAND CEMENT

Potential sources of Portland cements are indicated on plate 1.

a. *Types.* Type II, low alkali cement conforming to the requirements of ASTM C-150, will be specified. This cement would be available in suitable quantities for any construction anticipated. All of the plants indicated would be capable of producing sufficient cement to meet the proposed construction requirements. The current costs of cement vary from approximately $98 to $105 per ton, from the Phoenix Cement Plant at Clarkdale and the Arizona Portland Cement Co plant at Rillito, Arizona.

b. *Testing Requirements.* Portland cement will be accepted based on the results of tests submitted by the supplier. The government reserves the right to perform Quality Assurance sampling and testing during the execution of any construction contracts.

3.3 FLY ASHES

The primary types of pozzolans available, in this region, are fly ashes. Fly ashes have been used extensively by the Los Angeles District in the past and are readily available in the area. Potential sources of fly ashes are indicated on plate 1.

a. *Class F.* Class F pozzolans, conforming to the requirements of ASTM C-618, will be specified and the special requirements from table 1A shall be invoked. Additionally, from table 2A the following requirements shall be added: (1) the limit on increase of drying shrinkage, and (2) mortar expansion at 14 days. The requirement for mortar expansion at 14 days will be modified so that specimens prepared with the selected fly ash will supply expansions less than or equal to those of specimens prepared using the selected cement alone. The pozzolan would be available in suitable quantities from the sources listed below. The current costs of pozzolan vary from approximately $35 to $40 per ton, from various locations throughout the state.

b. *Testing Requirements.* Fly ash be accepted based on the results of tests submitted by the supplier.

c. The government reserves the right to perform Quality Assurance sampling and testing during the execution of any construction contracts.

3.4 WATER

Water suitable for use in RCC construction would be available from existing city sources.

4. BORROW MATERIALS

Borrow materials proposed for use in production of the RCC will come from the required project excavation. This source has provided suitable quality materials for use in production of concrete and asphaltic aggregates in the past. The project site is currently being exploited by CALMAT and the Tanner-United Metro Co's for production of various classes of aggregates for construction throughout the region.

4.1 SAMPLING

Materials for particle size analysis were obtained from test trenches excavated with a CASE Model 580K, rubber tired backhoe. The depths of materials explored was limited to approximately 15 feet based on the design information available at the time of the exploration. An insignificant difference in material size is anticipated below those depths. Materials larger than 3 inches in size were visibly estimated, and small bag samples were obtained to return to the Los Angeles District Laboratory, for detailed particle size analysis. Materials for preparation of mix design studies were obtained from the United Metro plant at 19th Ave. The materials obtained from the United Metro plant were from existing borrow site in the stream bottom, currently being exploited by United Metro. A review of available data from United Metro and observations of explorations and stockpiles at the United Metro and CALMAT plant indicate that the materials are similar, and should be reasonably respresentative of materials available for borrow throughout the project limits.

4.2 FIELD PROCESSING (by The Bureau of Reclamation {BUREC})

An approximate 8 ton sample was delivered to the BUREC facilities in Phoenix. The sample was a composite sample obtained from TT99-26. A bulk gradation was performed at the BUREC facilities. The results of that gradation are reported in Table 4-1. Based on field observations of other contemporary excavations and examination of working materials pits in the immediate vicinity the gradation indicated should be representative of potential excavation within the project limits.

Table 4.1
Composite Gradation
Test Trench 99-26

SIEVE SIZE	PERCENTAGE PASSING
12"	100
5"	90
3"	75
2"	64
1-1/2"	53
3/4"	45
3/8"	41
No 4	27
No 8	25
No 16	22
No 30	16
No 50	8
No 100	5
No 200	3

4.3 PROCESSING BY TANNER-UNITED METRO

Materials obtained from Tanner-United Metro were materials available from the planned construction site. The materials were excavated and then transported to the Tanner plant. At this location the materials are stockpiled and then fed into a primary crushing system. The system reduces the maximum particle size to approximately 3-inches and the materials are then stockpiled. From this point materials are transported for additional crushing, screening and classification to produce the desired commercial products. A bulk sample representing the materials available in the primary crush stockpile was obtained. Additionally, bulk samples of an Arizona Department of Transportation (ADOT) Class II, road base and an unwashed sand were obtained for additional processing and use in the planned studies. The procedure used for production of aggregates at this plant is similar to procedures used at other plants along the Salt River through the Phoenix area.

4.4 LABORATORY PROCESSING

The samples were transported to the BUREC facility in Denver Colorado, for additional processing and preparation of RCC mixtures for additional testing and analysis. The following materials were delivered to the laboratory for analysis: (1) an aggregate road base, conforming to ADOT standards for ABC was selected and transported to the laboratory; (2) the primary crush product from the United Metro production plant; and (3) an unwashed sand sized material. The primary crushed product from the United Metro Plant was screened, by the BUREC, to produce a 2" X 1-1/2", 1-1/2" X 3/4", 3/4" X No. 4, and a minus No. 4 material. The 1-1/2" X 3/4" and 3/4" X No. 4, were recombined to make the coarse aggregate indicated in Table 5.2. After examination the unwashed fine grained materials were washed to produce a more desirable gradation. The washed fine grained materials were recombined with the coarse aggregates to produce the final gradation used in the mix design RS-9. A complete description of mix design selection and evaluation is included below.

5. LABORATORY PROGRAM

5.1 GENERAL

Laboratory studies were conducted to evaluate the selected materials for production of RCC. All laboratory studies, except bulk gradations, were performed at the BUREC's laboratory facilities in Denver, Colorado.

5.2 PHYSICAL PROPERTIES OF AGGREGATES

Only a minimal number of tests were performed on the aggregates. Tests performed primarily to determine the mixture proportioning properties of the aggregates available. Table 5.1 summarizes physical properties of the aggregates used in the studies. Table 5.2 summarizes aggregate gradations used in the various trials.

Table 5.1
Physical Properties of Aggregates

Material	Sp Gr	Absorption
ABC	2.58	2.05
1-1/2" x No 4	2.62	1.18
Wash Sand	2.61	1.25

Table 5.2
Laboratory Gradations

Sieve Size	Aggregate Gradations				
	ABC	Washed River Sand	ABC+ Coarse Agg	Coarse Agg	Mix RS-9
1-1/2-inch	100	-	100	100	100
3/4-inch	99	-	74	57	74
3/8-inch	61	100	46	17	50
No. 4	38	99	29	2	41
No. 8	32	80	24	0	32
No. 16	26	61	20	0	24
No. 30	19	43	14	0	17
No. 50	11	23	8	0	9
No. 100	6	9	5	0	4
No. 200	4	3	3	0	1

5.3 MIX DESIGN STUDIES

RCC Mix design studies were performed based on the moisture-density relationships. A summary of mix designs and corresponding plastic and hardened properties are supplied in Table 5.3 below. The original studies were laid out based on targeting a compressive strength of approximately 3000 lb/in^2 at 28 days and supplying a Vebe consistency of approximately 30 to 45 seconds. This consistency has proven to be suitable for RCC construction in the past. In order to minimize costs of construction and processing costs a readily available gradation was selected for processing and production. The gradation selected was a gradation conforming to that generally in use for production of Aggregate Base Course (ABC) materials in Maricopa County. Mixes RS-1 to

RS-4 were developed to investigate this initial selection of materials, and to evaluate plastic and hardened properties. Based on the strengths achieved, mix RS-5 was developed to evaluate higher cement contents to achieve higher compressive strengths at comparable Vebe times.

Table 5.3
Summary of RCC Mix Designs and Properties

Mix Name	Lab. No.	Aggregate Quantities		Cementitious Materials									
		0-3/4 In	3/4 To 1-1/2 In	Cement	Pozzolan	Water	W/(C+P)	(Secs)	(Pct)	7-Day	28-Day	56-Day	90-Day
ABC-180	RS-1	3284	-	274	-	165	0.60	180	9.5	1420	1680	1475	2470
ABC-220	RS-2	3414	-	294	-	215	0.73	120	3.1	1660	2015	2490	1560
ABC-260	RS-3	3347	-	296	-	257	0.87	30	2.2	1400	2010	2115	2200
ABC-250	RS-4	3363	-	296	-	246	0.83	33	2.4	1510	2050	2150	2470
ABC-250.6WC	RS-5	3236	-	406	-	244	0.60	54	3.4	2360	3275	3510	3470
ABC1.5-250	RS-6	2537	859	297	-	248	0.83	24	1.9	1300	2195	2350	2520
ABC-250.63WCP	RS-7	3268	-	291	125	261	0.63	120	0.7	2140	2475	-	3690
ABC1.5-250.65WCP	RS-8	2489	842	280	120	252	0.63	50	0.4	1705	2445	-	3125
TAN1.5-200.6WCP	RS-9	1416	2132	234	100	201	0.60	33	0.6	2105	3065	-	3890

As an alternative, mix RS-6 was developed to determine if cement demand and abrasion resistance could be reduced by adding additional coarse aggregates, thereby improving the total aggregate gradation.

Based upon the first six mixtures (RS-1 to RS-6), the projected water content for a 30 to 45 second Vebe time is about 255 lb/yd^3 using the ABC aggregate and about 240 lb/yd^3 using the using the 1-1/2 inch NMSA aggregate. For a W/C of 0.6, the projected cement content would be about 425 and 400 lb/yd^3, respectively for each aggregate size to yield a 3000 lb/in^2 at 28 days age.

The strengths achieved and the estimated costs of production, primarily based on cement contents, was determined to be excessive based on previous Maricopa County experience with soil-cement mixtures. Target compressive strengths at 7 days were selected to be 1000 psi for the armoring of the guide dikes and 2000 psi for the drop structures. Mixes RS-7 to RS-9 were developed to examine the following effects: (1) increasing the maximum nominal coarse aggregate size, (2) substitution of pozzolan for cement, and (3) refine the aggregate gradation in the mix designs. The purpose of these analyses were to reduce the amount of Portland cement necessary to achieve the desired properties.

Prior to selecting pozzolan percentage rates to be used in the mix design studies, mortar cubes were manufactured to select a desired replacement level of cement with pozzolan. The results of that study are reported in section 5.4 below.

Further review indicated the that RCC with compressive strengths of 2000 psi for the grade control structures and 750 psi would be appropriate for armoring the guide dikes and slope protection.

5.4 CEMENT FLY ASH REPLACEMENT STUDIES

Due to the high cost of Portland Cement and the potential for reducing the cost of construction, studies to determine the potential for replacing Portland Cement in the RCC mixtures with fly ash were performed. These studies were completed based on 2-inch cube specimens, manufactured in accordance with ASTM C-109. These specimens were manufactured with various combinations of cement, fly ash, sand, and water. The mixtures were designed to supply approximately the same flows when tested in accordance with procedures outlined in ASTM C-87. The mix design and plastic properties of the various mixtures are reported in table 5.4 below. All mixtures contained 2063 gms (4.54 lbs) of sand.

Table 5.4

MIX ID	PCT Fly Ash Replacement	Batch Quantities (grms)			w/(c+p)	7-Day Strengths Avg	28-Day Strengths Avg
		Cement	Fly Ash	Water			
100C-0FA	0	750	0	355	0.473	5000	5970
90C-10FA	10	675	75	346	0.461	4107	6073
80C-20FA	20	600	150	337	0.449	3127	5253
70C-30FA	30	525	225	324	0.432	2773	3943
60C-40FA	40	450	300	315	0.420	2900	3697

Based on the above information and previous experience, mixtures may be prepared which will substitute substantial amounts of fly ash for cement, for economic reduction in production of the RCC. Target replacements used in the subsequent studies were 30 percent fly ash in substitution of cement.

5.5 ABRASION EROSION TEST DATA

Two separate investigations of abrasion erosion were used in this study. The first study was completed by the Maricopa County Flood Control District (MCFCD) and their consultants, for previous work completed by the MCFCD. The second study was performed by the government (USACE) during the current study. The MCFCD studies investigated abrasion erosion loss, generally in accordance with ASTM C-1138, based on a fixed gradation and varying amounts of cement. The current study examined abrasion erosion loss from a variation in aggregate properties, primarily gradation. The results of both studies have been used to select the optimum blend of aggregates and cementitious materials for use in the planned construction, based on the materials available within the project limits.

Abrasion erosion loss data developed by MCFCD is reported in figure 1. The results generally indicate that for the specific aggregate gradation selected, a minimum of 7 percent cement is recommended for use in soil cement to minimize abrasion erosion loss. Current studies (USACE) are reported in figure 2. The current abrasion-erosion study examined the effects of aggregate size and compressive strength. The current studies indicate that higher compressive strengths and larger NMS coarse aggregates increase abrasion-erosion resistance.

5.6 MIX DESIGN EVALUATIONS

A comparison between the USACE recommended gradation and the previously used MCFCD gradation is shown in figure 3. The decreased cement demand and the increased performance in the abrasion test is most likely attributable to the coarser

nature of the recommended USACE gradation.

Not only does the USACE gradation increase abrasion resistance, but the mixture will most likely be more economical than the previously used gradation. The following table summarizes the cost of cementitious materials for RCC and soil cement. Costs of cement and fly ash were made based on currently available rates in the area. The RCC mixture and attributable costs is from the current (USACE) study. The soil-cement costs reported are based on a report prepared by AGRA Earth and Environmental for MCFCD in 1998.

Mixture	Cement (lbs/yd^3)	Fly Ash (lbs/yd^3)	7-Day Compressive Strength (psi)	Cost per yard Cementitious Materials*
SC (7%)	250	-	1300	$12.50
RCC	234	100	2100	$13.60
SC (10%)	356	-	2060	$17.80

* $100/ton for cement and $38/ton for fly ash.

Assuming approximately the same proportions, the cementitious materials cost of 750 psi RCC would be approxiamtely $9 per cubic yard.

6. AGGREGATE PROCESSING COSTS

6.1 COMMERCIALLY AVAILABLE PRICE OF MATERIALS

A brief survey of the cost of manufacturing the required aggregates from locally available commercial sources was completed. The price of the primary crushed product (the minus 3-inch material indicated above) used in the study would be available from local suppliers at a price of approximately $4 per ton. The specified ABC materials are generally available for $5.50 to $7.50 dollars per ton. A nominal 1-inch MSA would be available for approximately $5.00 per ton. Transportation to the site would be an additional cost not reflected in the prices quoted above.

6.2 ESTIMATED COST OF PROCESSING AGGREGATES

The costs quoted above represent retail costs for bulk purchases. A detailed cost estimate should be prepared for the desired materials specified above, but it can reasonably be concluded that total costs for processing aggregates would amount to $2 to $3 per ton. This would amount to an approximate cost of aggregates (based on mix RS-9) of approximately $3.50 to $5.25 per cubic yard.

7. DESIGN RECOMMENDATIONS

7.1 AGGREGATE SELECTION

Aggregates available from the streambed should be crushed, screened and washed to produce a more desirable gradation. The improvement in gradation will supply a better more uniform material that will require less cement and higher performance for the RCC.

7.2 CEMENT/FLY ASH COMBINATION

The laboratory studies indicate that significant amounts of fly ash may be substituted for cement and still achieve a suitable product. The MCFCD has indicated that generally strengths of 750 psi at 7 days would be suitable for the guide dikes. The Grade Control Structure will require RCC with a 7-day compressive strength of 2000 psi. Detailed laboratory trials during construction could lead to even lower quantities of cement and higher fly ash replacement rates. These alternatives should be developed in more detail during the actual construction laboratory trials.

RIO SALADO

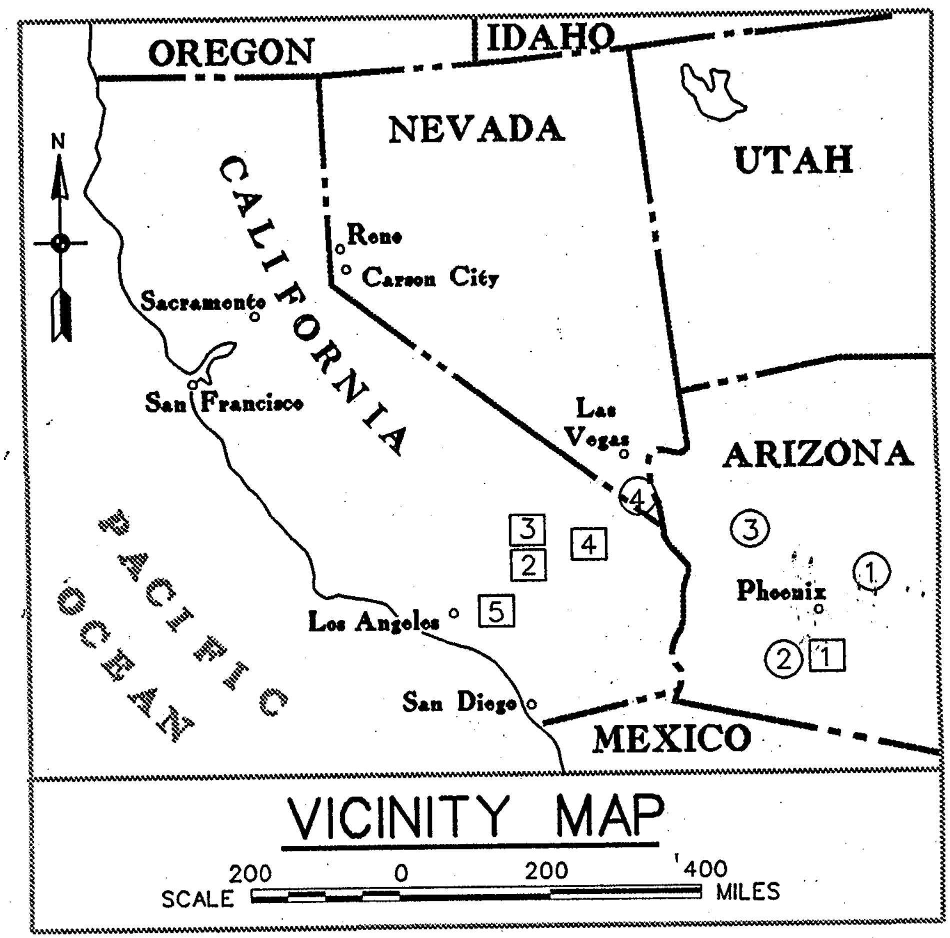
SOURCES OF CEMENTS AND POZZOLANS

SOURCES OF CEMENT

[1] ARIZONA PORTLAND CEMENT, RILLITO, ARIZONA
[2] SOUTHWESTERN PORTLAND CEMENT CO., VICTORVILLE, CALIFORNIA
[3] RIVERSIDE CEMENT CO., ORO GRANDE, CALIFORNIA
[4] MITSUBISHI CEMENT CO., LUCERNE VALLEY, CALIFORNIA
[5] CALIFORNIA PORTLAND CEMENT CO., COLTON, CALIFORNIA

SOURCES OF POZZOLAN

(1)
(2) ARIZONA PORTLAND CEMENT, RILLITO, ARIZONA
(3) PHOENIX PORTLAND CEMENT, JOSEPH CITY, ARIZONA
(4) BORAL MATERIALS, LAUGHLIN, NEVADA



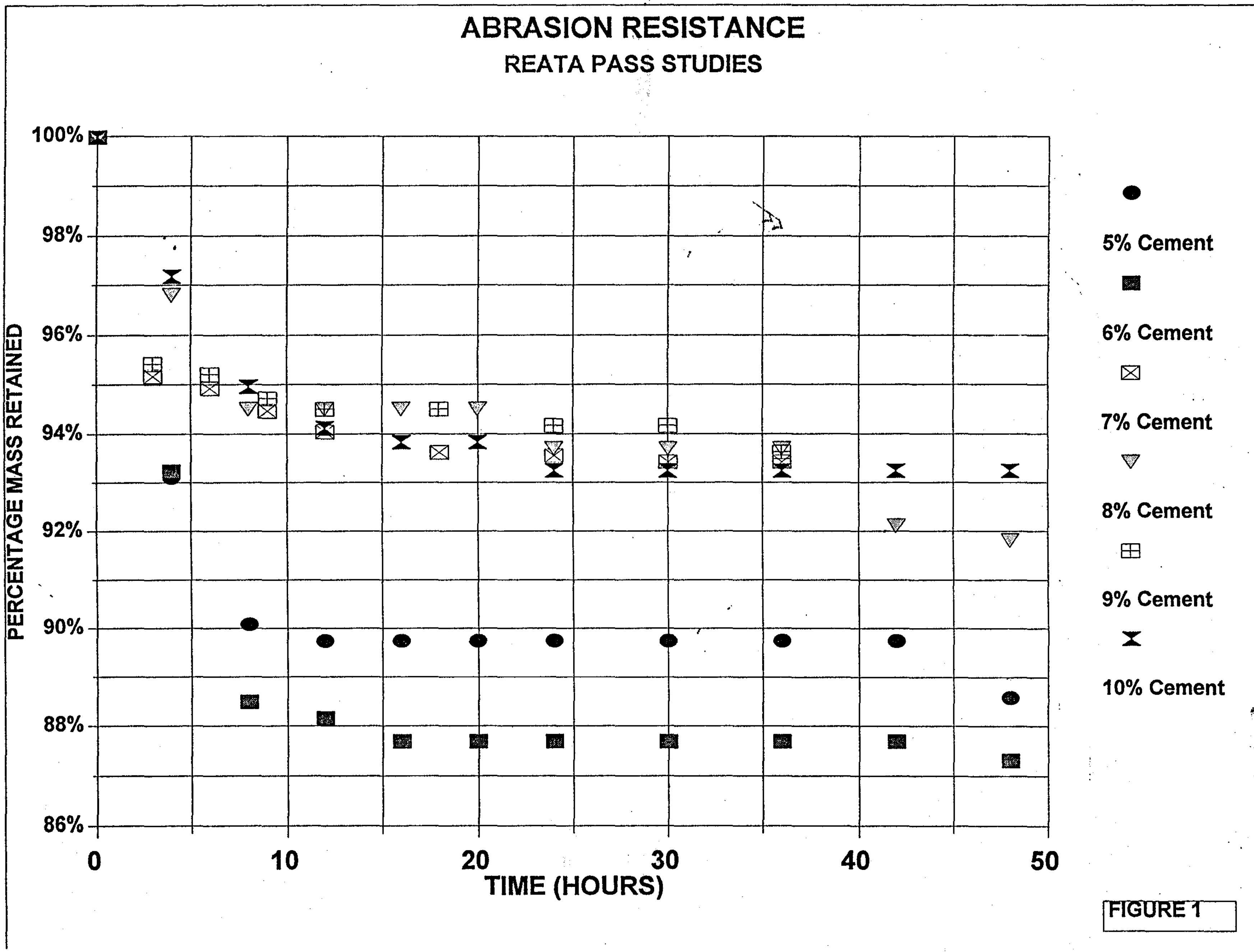

ABRASION RESISTANCE
REATA PASS STUDIES
PERCENTAGE MASS RETAINED
100%
98%
96%
94%
92%
90%
88%
86%
0
10
20
30
40
50
TIME (HOURS)
5% Cement
6% Cement
7% Cement
8% Cement
9% Cement
10% Cement

FIGURE 1

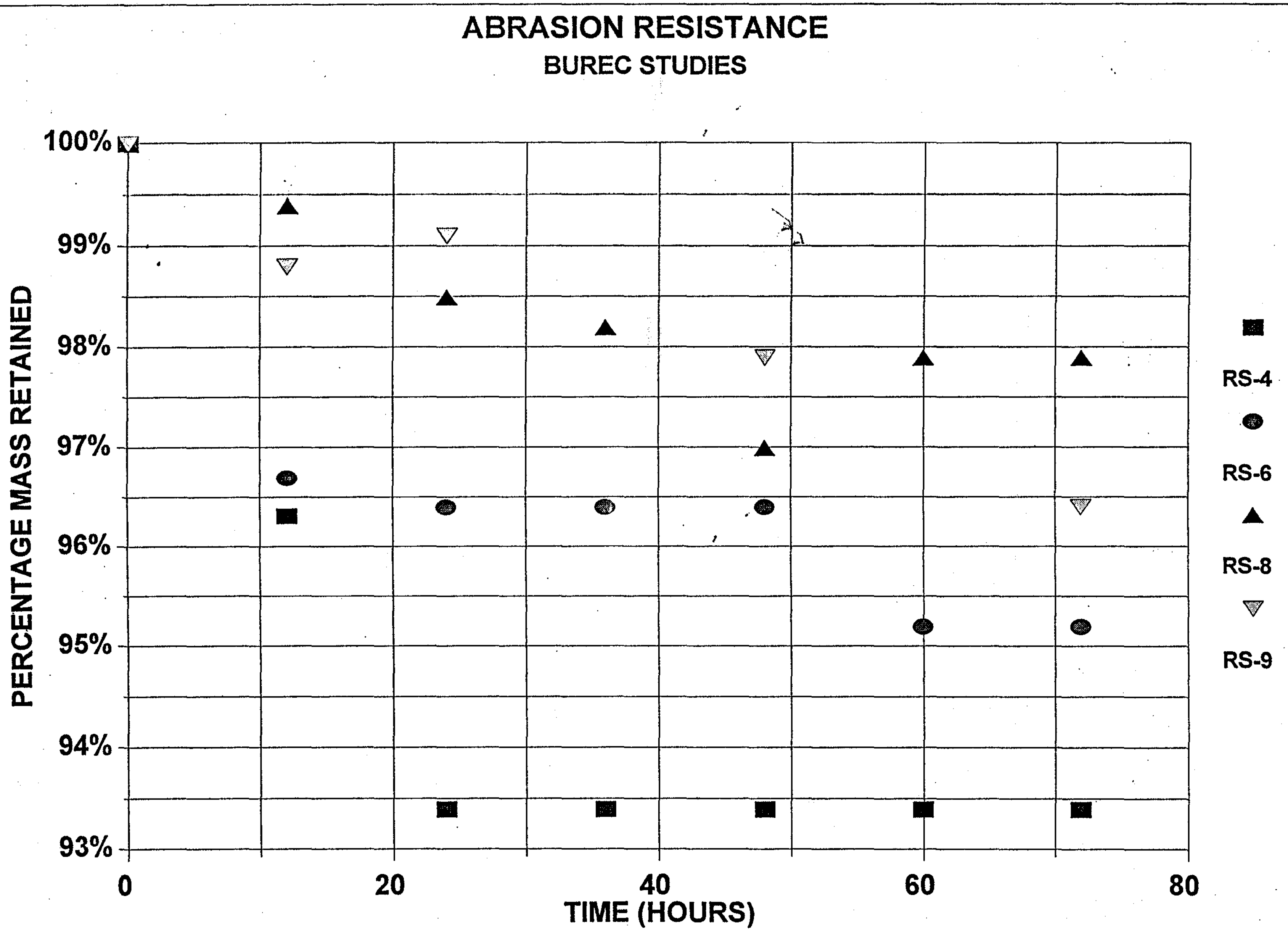

ABRASION RESISTANCE
BUREC STUDIES
PERCENTAGE MASS RETAINED
100%
99%
98%
97%
96%
95%
94%
93%
0
20
40
60
80
TIME (HOURS)
RS-4
RS-6
RS-8
RS-9

FIGURE 2

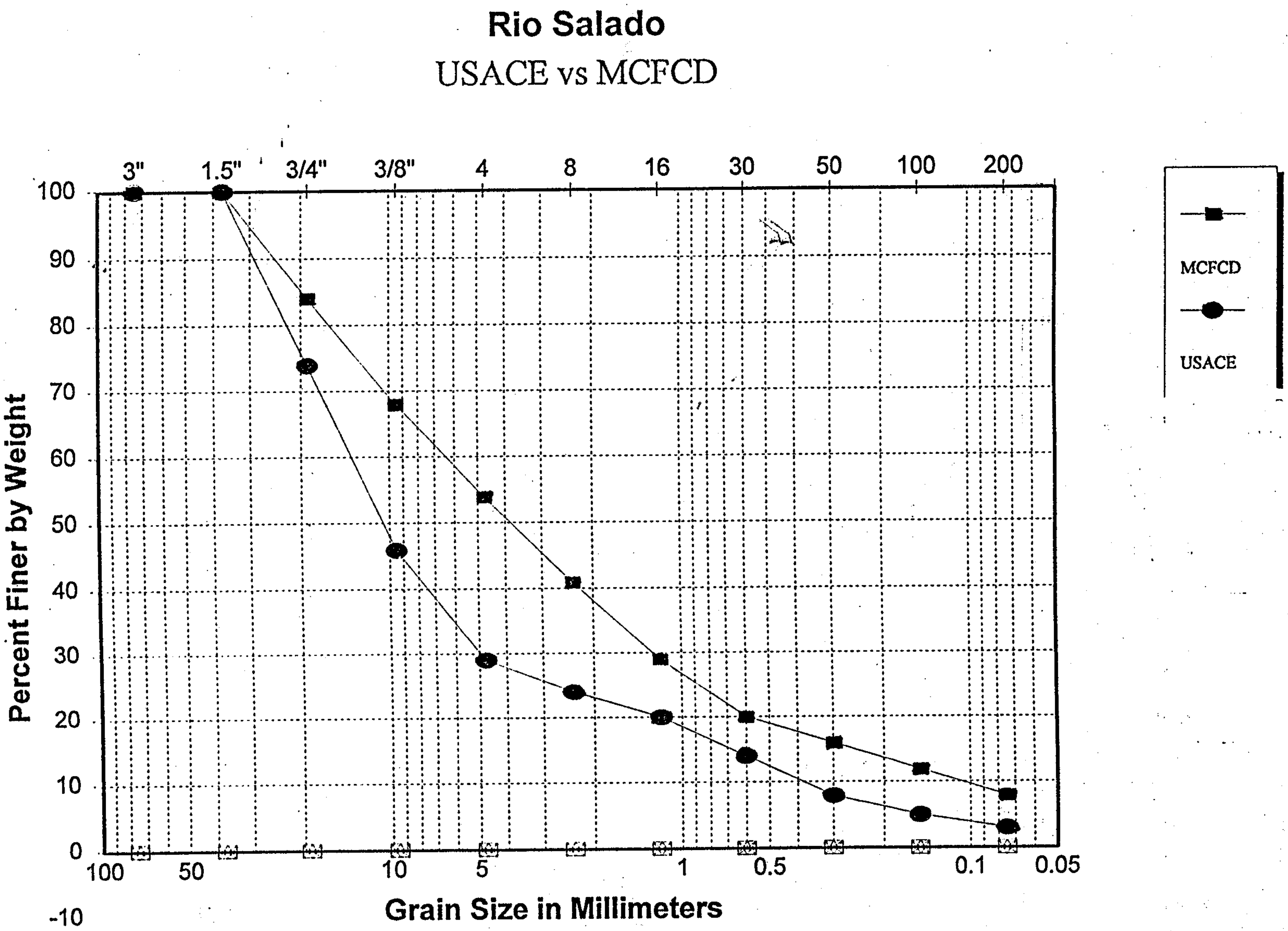

Rio Salado
USACE vs MCFCD
3"
1.5"
3/4"
3/8"
4
8
16
30
50
100
200
100
90
80
70
60
50
40
30
20
10
0
-10
Percent Finer by Weight
100
50
10
5
1
0.5
0.1
0.05
Grain Size in Millimeters
MCFCD
USACE

FIGURE 3