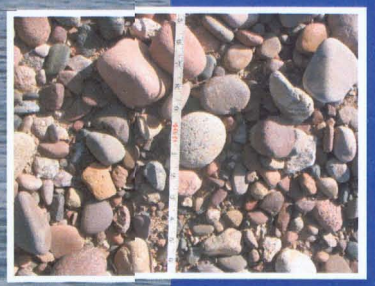
GILA RIVER SEDIMENT PROGRAM
PHASE 1 - BED MATERIAL SAMPLING PLAN MEMORANDUM

JUNE 2009

Flood Control District of Maricopa County

Contract FCD 2007C017
Stantec Project Number 182000565



Stantec

Memo

Stantec

To:	John Hathaway, PE	From:	George Sabol, PhD, PE Stephanie Gerlach, PE
	Flood Control District of Maricopa County		Stantec Consulting Inc.
File:	182000565	Date:	June 30, 2009

Reference: Gila River Sediment Program
Phase I - Bed Material Sampling Plan Memorandum

Attached is a memorandum of the Gila River Sediment Program. It contains the analysis of all available bed material size gradation data and recommendations. This is the work project for Phase 1 of that project.

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LIST OF ATTACHMENTS

Attachment A – CD of Geodatabase, Spreadsheet and MRPP Program
Attachment B – Right-of-Entry Docs., SHPO Clearance Letter & Floodplain Use Permit
Attachment C – Photographs of Sample Sites
Attachment D – Test Pit Logs
Attachment E – AMEC Laboratory Reports
Attachment F – MRPP Report by Julien, Mielke and Paris

Reference: Gila River Bed Material Sampling and Size Gradation Analysis and Recommendations

INTRODUCTION

PURPOSE

The purpose of this project is to characterize bed material size gradation of the Gila River between 115th Avenue and State Route 85 (SR85),for the Flood Control District of Maricopa County (District).

The major elements of the project include:

- selecting, identifying and inspecting bed material sampling sites in the project study area,
- obtaining bed material samples and documenting the sample sites,
- performing size gradation analyses of samples,
- developing a statistical analysis procedure (MRPP) to classify bed material samples (performed by Dr. Pierre Julien and Dr. Paul Mielke),
- performing statistical analyses of the size gradation data.
- using the statistical analysis procedure to evaluate bed material samples that were collected by others,
- analyzing the data to identify spatial trends, if any,
- to the extent practical, characterize the bed material of the Gila River in the study area, and
- preparing a memorandum of project results.

LOCATION

The study limits extend approximately 20 miles upstream from SR85 to Avondale Boulevard (115th Avenue) (see Figure 1 and Plate 1). There are five bridges within the study area; Bullard Avenue, Estrella Avenue, Cotton Lane, Tuthill and SR85. Two major washes enter the river within the study area, Agua Fria River and Waterman Wash. The Salt River and Gila River confluence is just upstream of 115th Avenue.

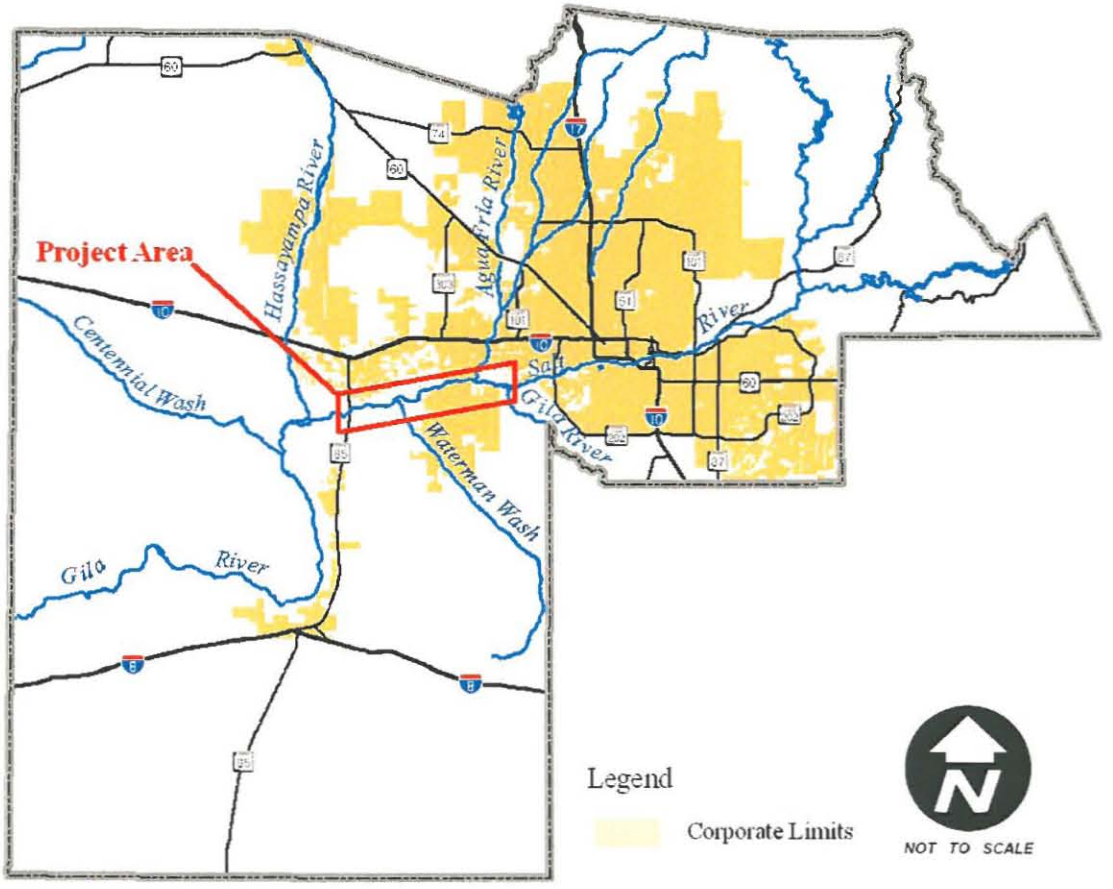


Figure 1

Vicinity Map

BACKGROUND

INTRODUCTION

The Gila River within the project area is the subject of several recent large scale hydrologic, hydraulic and sediment studies. The studies include Salt – Gila River Floodplain Delineation Study, Hydraulic Design of Tres Rios North Levee, El Rio Watercourse Master Plan and Cotton Lane Bridge. Also several sand and gravel operators have collected bed material samples in the Gila River. Data from the following were incorporated into this project for the District.

SALT – GILA RIVER FLOODPLAIN DELINEATION RESTUDY

The floodplain delineation study was initiated by the District and performed by Michael Baker, Jr., Inc (Michael Baker Jr., 1999). The purpose of the study was to produce a Letter of Map Revision or a Physical Map Revision to revise the 100-year floodplain and floodway along the Gila River from 1.4 miles downstream of SR85 to the confluence with the Salt River. The study also included the Salt River from the Gila River confluence to just downstream of the Granite Reef Diversion Dam. Project specific 4-foot contour topographic mapping was used. An HEC-RAS model was developed to delineate the floodplain and floodway.

PED HYDRAULIC DESIGN OF TRES RIOS NORTH LEVEE

The study was prepared for the U.S. Army Corps of Engineers by WEST Consultants, Inc. (WEST, 2004). The purpose of the study was to provide results of the hydraulic, sediment and scour analysis for the design of the North Levee on the north bank of the Salt and Gila Rivers. The limits of the study were from the Agua Fria River confluence with the Gila River to 91st Avenue alignment on the Salt River (approximately 8.7 miles long). As part of the study, samples were collected in the Salt and Gila Rivers. Plates 2 and 2.3 show the location of the samples and Figure 2 shows the results of the sieve analysis for samples collected in the Gila River.

EL RIO WATERCOURSE MASTER PLAN

Prepared by Stantec Consulting Inc. for the District (Stantec Consulting Inc., 2005). The purpose of the study was to document the existing river and the desired form and function of the river in the future. The focus of the plan is to maintain and enhance the natural functions of the Gila River through flood control management strategies. The limits of the study were from SR85 to the confluence with the Agua Fria River. As part of the study, sediment analyses of the existing condition and the selected alternative were conducted. The sediment analyses were performed for the purpose of the following:

- Develop an understanding of the fluvial process of sedimentation within the project area for the period of record and for the 100-year flood.

- Qualitatively identify tendencies for sedimentation that may occur in reaches of the study watercourse.
- Quantifying magnitudes of sedimentation that may occur.
- Develop a sediment transport model that can be used to evaluate various structural and nonstructural flood management alternatives.

Sediment samples were collected as part of the project. The locations of the samples are shown on Plates 2, 2.1, 2.2, and 2.3 and the sieve analysis results are shown on Figure 3.

COTTON LANE BRIDGE GEOTECHNICAL AND FOUNDATION REPORT

Richer-Atkinson-McBee & Associates, Inc. (RAM) prepared the report for Michael Baker Jr., Inc. (RAM, 2005). The purpose of the study was to review available geotechnical data, perform an initial field exploration program, complete laboratory analysis and geotechnical engineering evaluation for the new Cotton Lane Bridge over the Gila River. Several test borings were drilled along the alignment of the bridge and samples were collected for sieve analysis. Sieve analysis results of samples that were collected between the ground surface and 15 feet below ground surface are shown on Figure 4. Locations of the samples are shown on Plates 2 and 2.2.

COTTON LANE BRIDGE CLOMR

Prepared by River Research & Design Inc. for Maricopa County Department of Transportation (River Research & Design, Inc. 2008). The purpose of the report was for a CLOMR submittal package for a new bridge at Cotton Lane and associated roadway across the floodplain. The study area is approximately 3 miles long and extends from Estella Road Bridge to approximately 1 mile downstream of Cotton Lane Bridge. The bridge and associated abutments were incorporated into the HEC-RAS model developed as part of the Norte Vista / King Ranch project. A sediment model was developed and sediment samples were collected for the model. The sampling locations are shown on Plates 2, 2.2, and 2.3 and the sieve analysis results are shown on Figure 5.

OTHER BED MATERIAL SAMPLING

Sand and gravel operators have provided to the District results of sieve analyses including the following:

- Construction Inspection & Testing Co. for Burlingame sampled on 22 January 2008. (Plate 2.3 and Figure 6)
- Terracon – Gila River at Airport Crossing sampled during December 2006. (Plates 2.1 and 2.2 and Figure 7)

The sampling locations are shown on Plates 2, 2.1, 2.2, and 2.3.

GILA RIVER SEDIMENT PROGRAM

For this project for the District, extensive bed material sampling was conducted of the study reach of the Gila River. A summary of currently available bed material size gradation data is provided in Table 1.

Table 1
Summary of Gila River Bed Material Size Gradation Data

Source of Samples (1)	No. of Samples (2)
1. For this District project by Stantec:	
Used by Julien and Mielke to develop MRPP	29
Used by Julien and Mielke to test MRPP	18
Used by Stantec to classify samples	12
	59
2. For the El Rio WMP by Stantec	12
3. For Burlingame by Construction Inspection & Testing Co.	8
4. For the Gila River at Airport Road crossing by Terracon	13
5. For the Cotton Lane Bridge CLOMR by River Research & Design	4
6. For Cotton Lane Bridge by Richer-Atkinson-McBee & Associates for Michael Baker Jr., Inc.	7
7. For Tres Rios North Levee by WEST Consultants, Inc.	7
	110

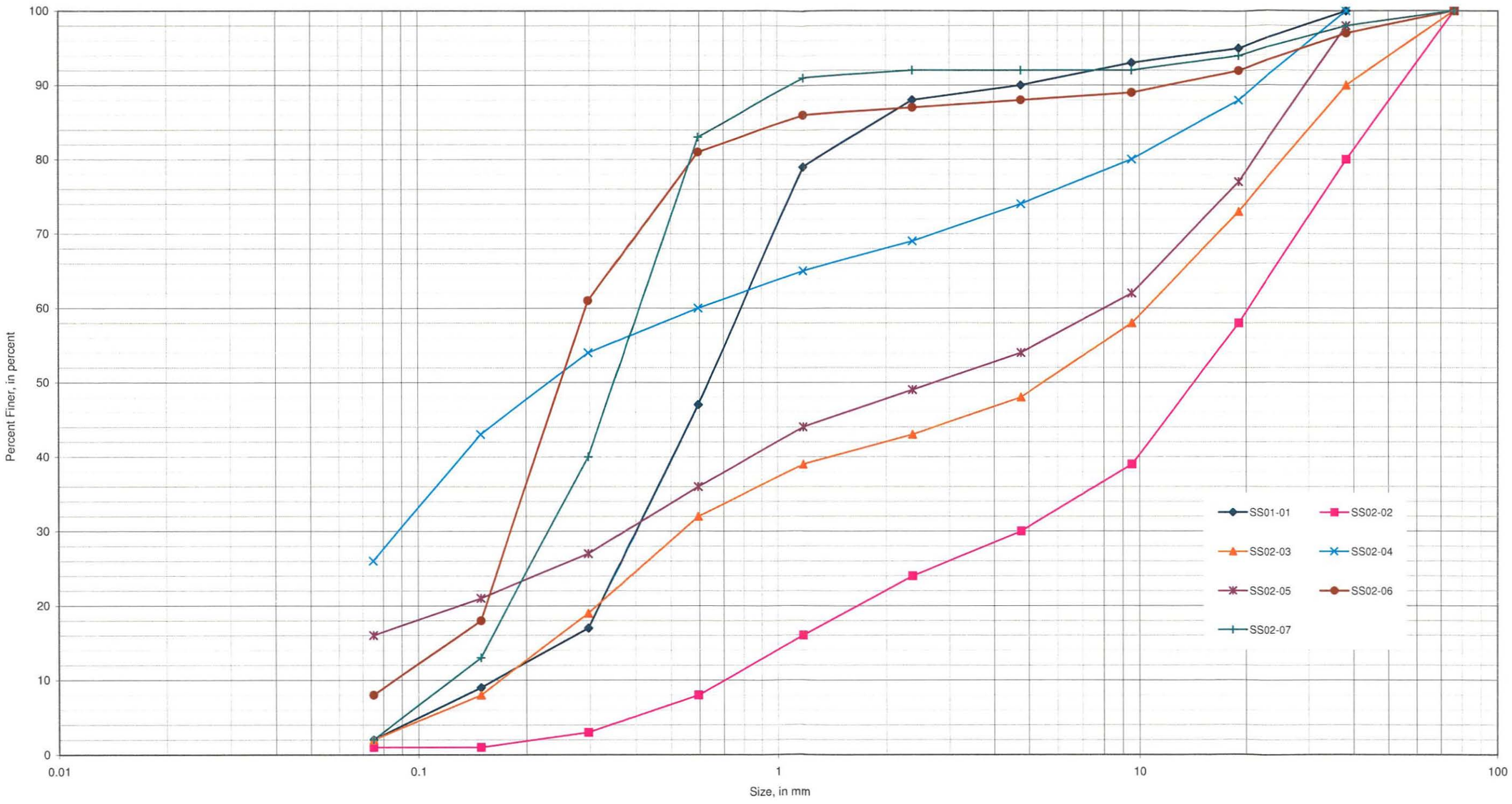
GEODATABASE

A geodatabase was created that includes the following information for each sample collected previously and as part of this project:

- Sample Name
- Sampling Date
- Sampled By
- Owner
- Project Name
- Latitude and Longitude
- Sieve analysis results for the sample and for the project

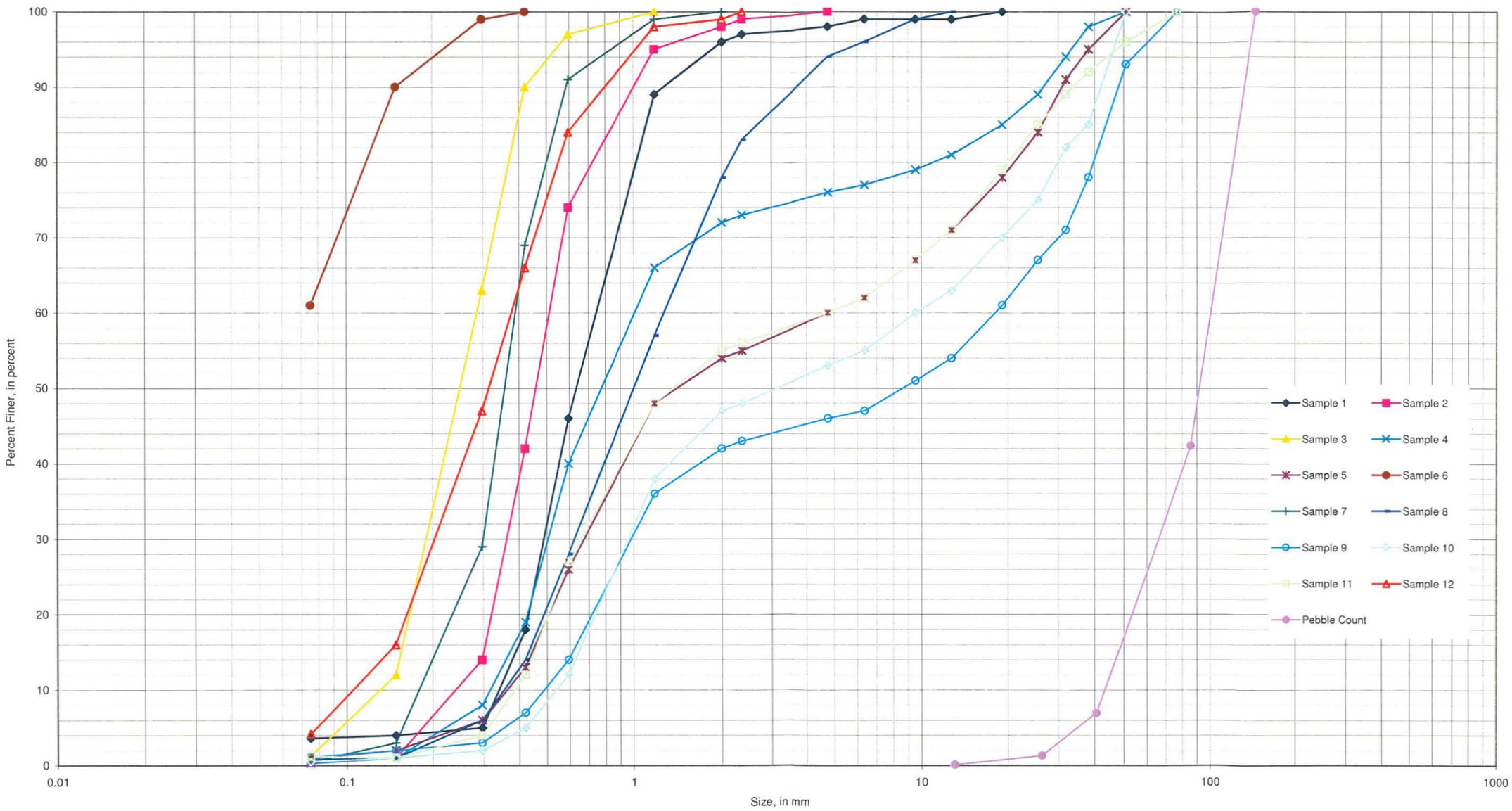
A copy of the database is included in Attachment A.

Figure 2
Size Gradation of Samples from the PED Hydraulic Design of Tres Rios North Levee Project



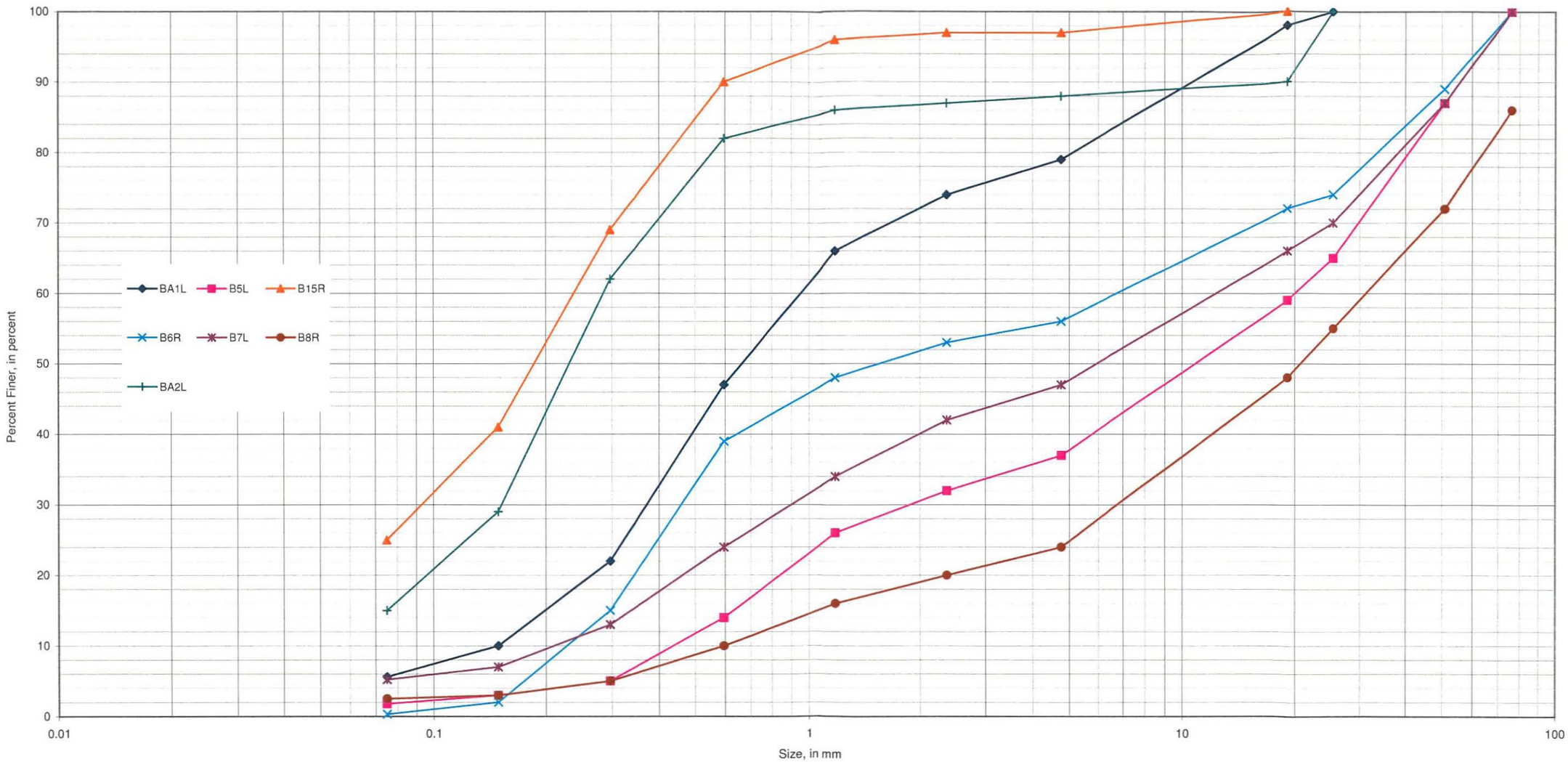
Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Very Fine Gravel	Fine Gravel	Medium Gravel	Coarse Gravel	Very Coarse Gravel	Small Cobbles

Figure 3
Size Gradation of Samples from the El Rio Study of the Gila River



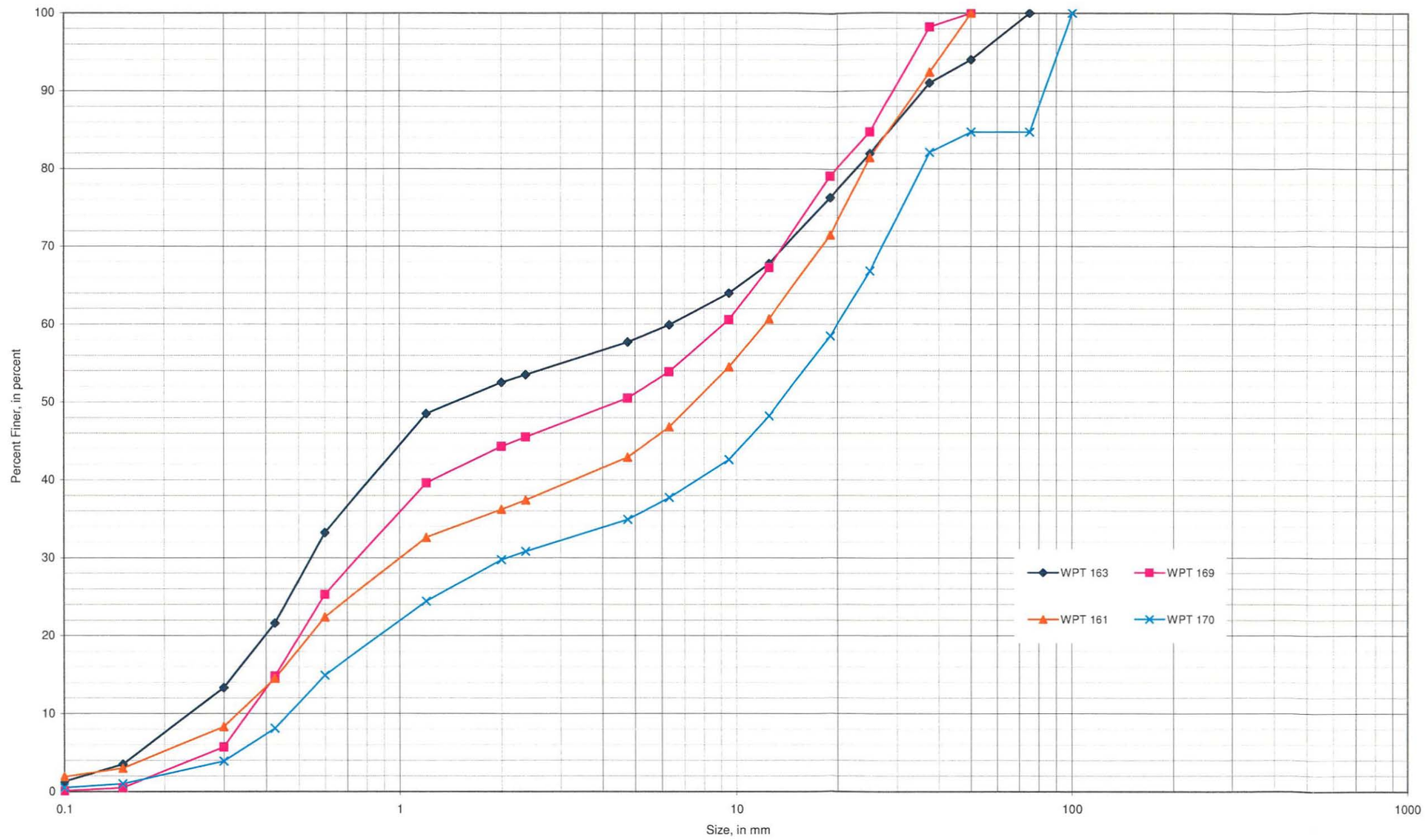
Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Very Fine Gravel	Fine Gravel	Medium Gravel	Coarse Gravel	Very Coarse Gravel	Small Cobbles	Large Cobbles	Small Boulders

Figure 4
Size Gradation of Samples from the Cotton Lane Bridge Geotechnical & Foundation Report



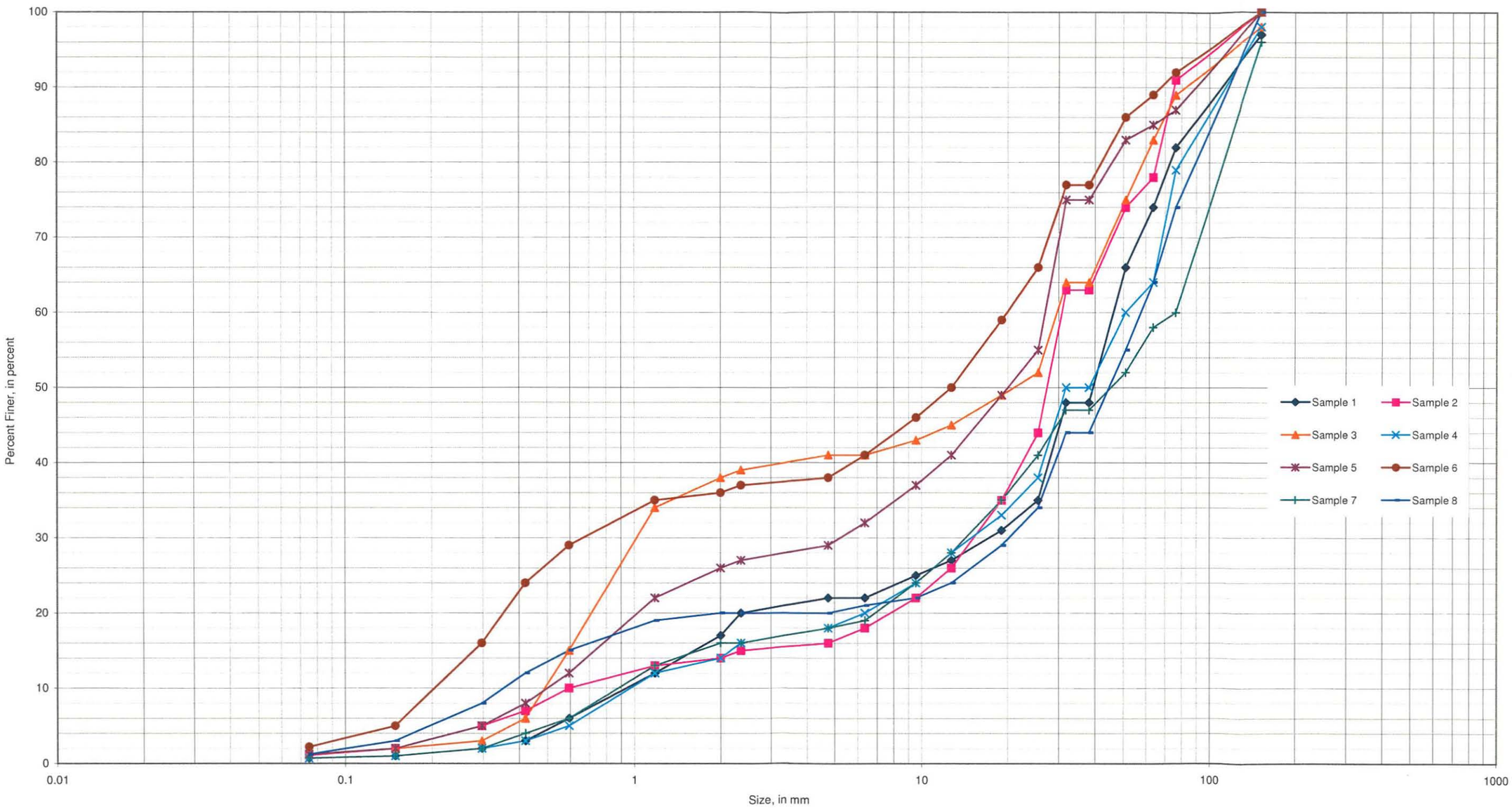
Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Very Fine Gravel	Fine Gravel	Medium Gravel	Coarse Gravel	Very Coarse Gravel	Small Cobbles

Figure 5
Size Gradation of Samples from the Cotton Lane Bridge Floodplain Redelineation CLOMR



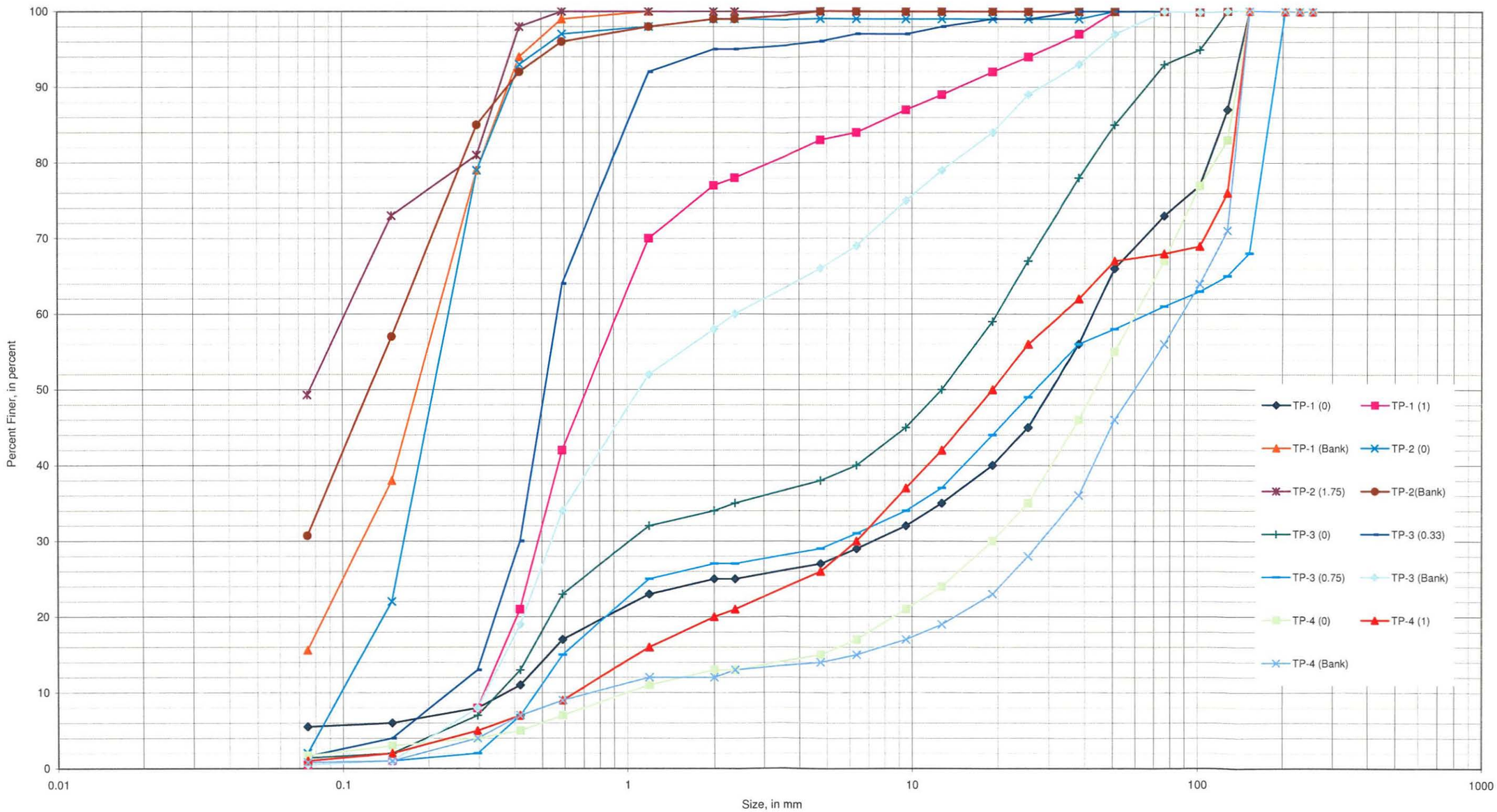
Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Very Fine Gravel	Fine Gravel	Medium Gravel	Coarse Gravel	Very Coarse Gravel	Small Cobbles	Large Cobbles	Small Boulders	Medium Boulders

Figure 6
Size Gradation of Samples from Construction Inspection & Testing Co. for Burlingame



Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Very Fine Gravel	Fine Gravel	Medium Gravel	Coarse Gravel	Very Coarse Gravel	Small Cobbles	Large Cobbles	Small Boulders

Figure 7
Size Gradation of Samples from Terrecon for the Gila River at Airport Crossing



Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Very Fine Gravel	Fine Gravel	Medium Gravel	Coarse Gravel	Very Coarse Gravel	Small Cobbles	Large Cobbles	Small Boulders

CHARACTERISTICS OF THE GILA RIVER

GENERAL

The Gila River basin at its confluence with the Colorado River near Yuma is approximately 58,200 square miles in size and encompasses the majority of southern Arizona as well as parts of New Mexico west of the continental divide and a small portion of northern Mexico. The major tributaries to the Gila River are listed in Table 2.

Table 2

Major Tributaries of the Gila River

Tributary	Contributing Area sq. miles
Salt and Verde Rivers	13,700
Santa Cruz River	8,600
San Pedro River	4,500
San Francisco River	2,800
San Simon River	2,200
Agua Fria River	2,000
Centennial Wash	1,800
Hassayampa River	1,462
San Carlos River	1,027
Waterman Wash	420

The Gila River basin at the study area is approximately 46,000 square miles in size. Hydrometeorologic and physiographic characteristics of the watershed are highly varied. The upper reaches of the watershed (northern and northeastern portions) consist of rugged, mountainous terrain with incised or canyonized watercourses, many of which have perennial flow. Elevations in these areas are generally greater than 5,000 feet and the climate ranges from semi-arid to cool and humid with annual precipitation reaching as much as 30 inches. The lower reaches of the watershed can be characterized as a basin and range physiographic region with braided, alluvial watercourses of intermittent flow. Elevations in these areas are generally less than 1,200 feet in the basins with the mountain ranges typically not exceeding 4,000 feet. The climate is mostly semi-arid with annual precipitation as low as 4 inches.

The Gila River study limits extend approximately 20 miles upstream from SR85 (approximately 5 miles upstream of the Hassayampa River) to 115th Avenue and is shown in relation to the Gila River basin on Plate 3. Flooding along the Gila River study

limits is controlled, to a certain degree, by the numerous dams within the watershed. Many of the dams have flood control as a primary or secondary purpose, however only a few have a significant impact on flooding within the study reach. The most significant dams, in regard to flooding within the study limits, are the Salt River Project dams, Coolidge Dam and New Waddell Dam. The locations of these dams are shown in Plate 3. The drainage area controlled by each of these dams as well as the total available storage capacity is listed in Table 3. The total area controlled by these dams is approximately 24,000 square miles, nearly half of the total watershed area at the study limits. Significant streamflow in the upper region (upstream of the dams) is generally produced in the winter months (December through March) as a result of frontal or convergence storm activity of large areal extent lasting several days and is usually associated with some degree of snowmelt. Significant streamflow in the lower region is generally produced during the summer months (June through October) as a result of convective storm activity of lesser areal extent and duration than frontal or convergence storm activity. Streamflow produced in these two regions is, therefore, not coincident. Based on the nature of the hydrometeorological conditions of the watershed, flooding events of significance within the study limits occur during the winter months from streamflow produced in the upper region.

Table 3
Major Dams within the Gila River Watershed Upstream of the Study Area

Dam	Total Storage Capacity acre-feet	Dedicated Flood Pool Capacity acre-feet	Contributing Area sq. miles	Purpose
Roosevelt	2,100,000	557,000	5,830	Irrigation/Power
Horse Mesa	245,000	---	5,935	Irrigation/Power
Mormon Flat	58,000	---	6,095	Irrigation/Power
Stewart Mtn.	70,000	---	6,221	Irrigation/Power
Horseshoe	131,000	---	5,657	Irrigation
Bartlett	249,700	71,700	5,872	Irrigation
Coolidge	1,100,000	---	12,886	Irrigation/Power
New Waddell	1,108,000	---	1,459	Irrigation

Source: *Section 7 Study for Modified Roosevelt Dam, Arizona, Hydrologic Evaluation of Water Control Plans, Salt River Project to Gila River at Gillespie Dam* (COE 1996).

HISTORIC FLOODS

A time line representing the recorded flood history for the study area is shown on Figure 8. The data shown on that figure consists of mean daily and instantaneous discharge records for the gaging station at the Gila River below Gillespie Dam (09519500). This station is used to represent the flood history for the study reach because it is the closest station to the study area with the longest period of record. In general, streamflow in the

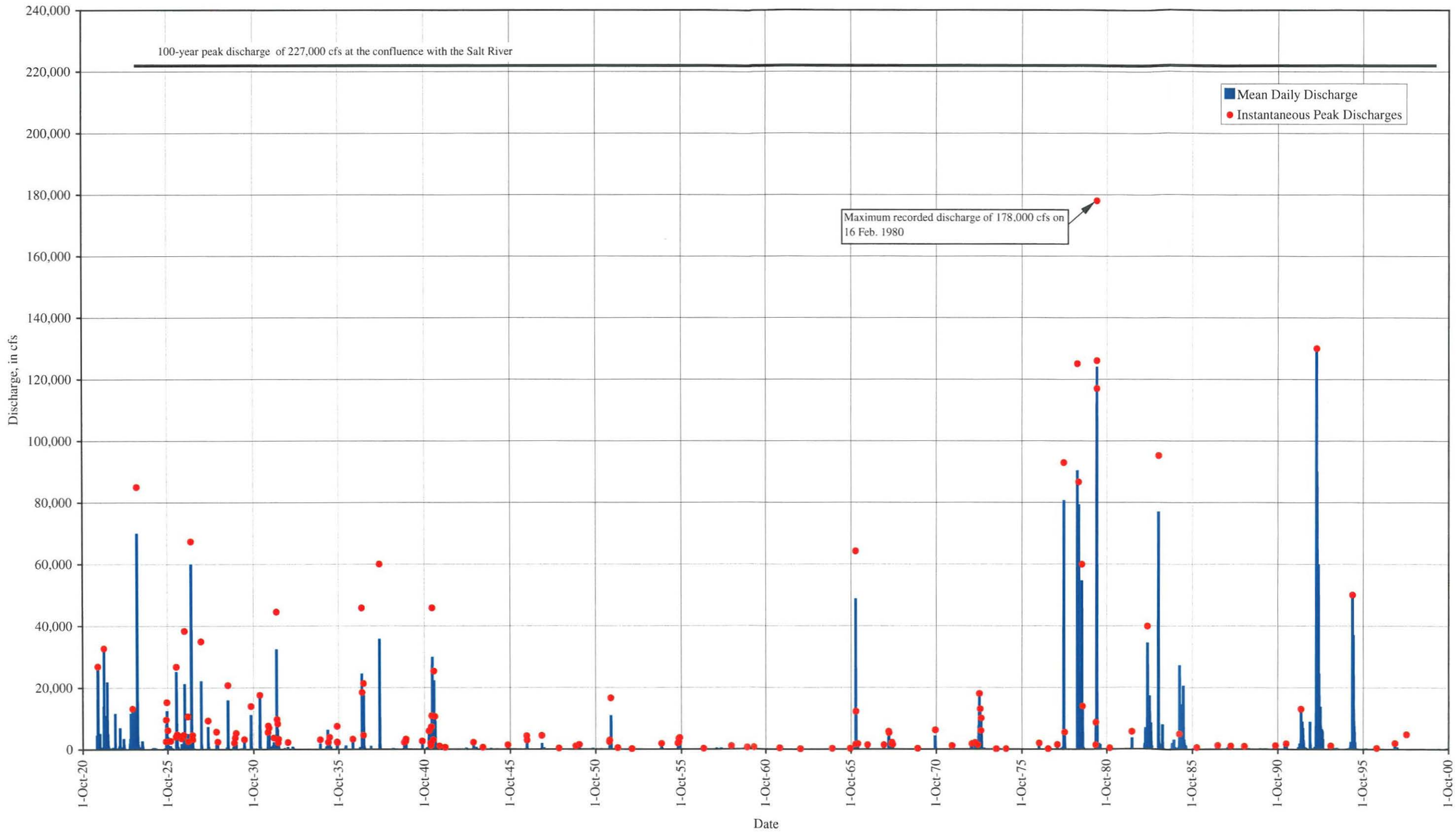
study area occurs after long duration rainfall events of large aerial extent. The three most significant recorded events occurred in December 1978, February 1980 and January 1993. The flooding of 1978 resulted from a tropical storm that moved across the state dumping large quantities of rainfall over a period of several days. The major reservoirs in the watershed were already near capacity from the unusually wet 1977 – 78 season and large releases were necessary. The maximum discharge recorded at Gillespie Dam (09519500) for this storm was 125,000 cfs. The flooding of 1980 was a result of a series of tropical storms that moved across the state dumping as much as 13 inches of rainfall in the upper portion of the watershed over a ten-day period. The maximum recorded discharge at Gillespie Dam for this storm was 178,000 cfs, which is the largest recorded discharge for the period of record. The flooding of 1993 was a result of a series of winter storms beginning in December 1992 that resulted in record breaking snowpack throughout the state. In January 1993, 15 days of rainfall combined with the rapidly melting snow to fill the major reservoirs that were already near capacity. The maximum estimated discharge at Gillespie Dam for this storm was 130,000 cfs. Based on a flood frequency analysis the return period was estimated to be 33 years, that is, floods with peak discharges in excess of the 1993 flood would be expected only once every 33 years on the average (Stantec, 1997).

GILA RIVER FLOODPLAIN AND FLOODWAY

The floodplain and floodway limits shown on Plates 1 and 2 were obtained from the following studies:

- Gila River Floodplain Redelineation Study for the area between Airport Road and Bullard Avenue (Stantec, 2008)
- Salt – Gila River Floodplain Delineation Restudy for the area downstream of Airport and upstream of Bullard Avenue (Michael Baker Jr., 1999)

Figure 8
Annual Peak Discharge for the Gila River Study Area



DATA COLLECTION

RIGHT OF ENTRY, UTILITY CLEARANCE AND ENVIRONMENTAL PERMITTING

The District obtained right of entry (ROE) permits from private landowners and government agencies to obtain the sediment samples. Attachment B includes a copy of the ROEs. A clearance letter from the State Historic Preservation Office and Floodplain Use Permit from the District was obtained and is included in Attachment B.

Blue Stake was contacted to clear the locations of the underground utilities prior to starting subsurface investigations. The following ticket numbers were obtained to cover all the sampling sites:

- Sampling conducted during March 2009 - 2009031300185, 2009031300209, 2009031300253 and 2009031300314.
- Sampling conducted during May 2009 – 2009042400486 and 2009042400510

The District dust control block permit was used and District provided a water truck to assist with dust control during field operations.

SAMPLE COLLECTION

During March 18 through 27 and May 4 through 5, 2009, Stantec conducted field data collection. The following were performed:

- Excavation of trenches by backhoe
- Collection of bed material samples
- Pebble count of bed material grain size
- Documentation of sediment characteristics by photographs and logs.

Thirty-two test pits were excavated in the Gila River to depths ranging from 2 to 10 feet below ground surface (bgs) using a backhoe (see Plate 1). The test pits were located to obtain bed material along the length and width of the river. They were also located such that a backhoe could access the site. The maximum depth for the excavation was set to 10 feet bgs for safety reasons. Excavations were stopped when groundwater was encountered or for safety reasons. The test pits were backfilled with the material excavated from the pits. In some excavations the groundwater was as shallow as 2 feet bgs. At least one grab sample (approximately 1 cubic foot) from the backhoe bucket was collected in each test pit. Additional samples were collected at changes in soil type or at the bottom of the test pit. For instance, in Test Pit 8 one sample was collected at 1 foot bgs and at the bottom of the pit at 8 feet bgs. The excavation was stopped at 8 ft bgs for safety reasons. The soil encountered in the test pits were examined, visually classified, photographed and logged. Photographs of each sample site and test pit are

included in Attachment C. The test pit logs are included in Attachment D. Fifty-nine samples at various depths were collected for laboratory analysis. Total sieve analyses were conducted by AMEC and the laboratory reports are included in Attachment E. Figure 9 shows the results of the sieve analysis. A spreadsheet summarizing the data is included in Attachment A.

The sieve sizes used for the analyses are:

Sieve	Size, in mm
#200	0.075
#100	0.149
#50	0.297
#40	0.42
#30	0.595
#16	1.18
#10	2.00
#8	2.36
#4	4.75
¼ inch	6.35
3/8 inch	9.52
½ inch	12.70
¾ inch	19.05
1 inch	25.40
1 ¼ inch	31.75
1 ½ inch	38.10
2 inch	50.80
3 inch	76.20
6 inch	152.39

For the purpose of hydraulic analyses of sediment, 0.062 mm is used as the demarcation between silt and very fine sand. For these mechanical sieve analyses, the ASTM sieve #200 is used as the upper size limit of silt. The composition of fine material, silt and clay, is not important when characterizing bed material. In this study, 0.075 mm is used to define fine sediment material.

In areas where the surface material consisted of coarse gravel and cobbles, pebble counts were conducted. The pebble count data were collected by first laying a tape across the channel. A sampling interval was selected so that 50 to 75 measurements were taken at the section with a sampling interval larger that the visual estimate of the D_{50}. The intermediate axis of each sediment grain under the sampling interval was measured. For sediment grains too small to be measured, a sand grain sizing folder was used to estimate the sediment size. Photographs of the bed material for each pebble count site are included in Attachment C. Measurements of the sediment grains were converted to a percent smaller size fraction. Figure 10 shows the results of the pebble count analyses.

Figure 9
Size Gradation of Samples from the Gila River Sediment Program Test Pits - All Data

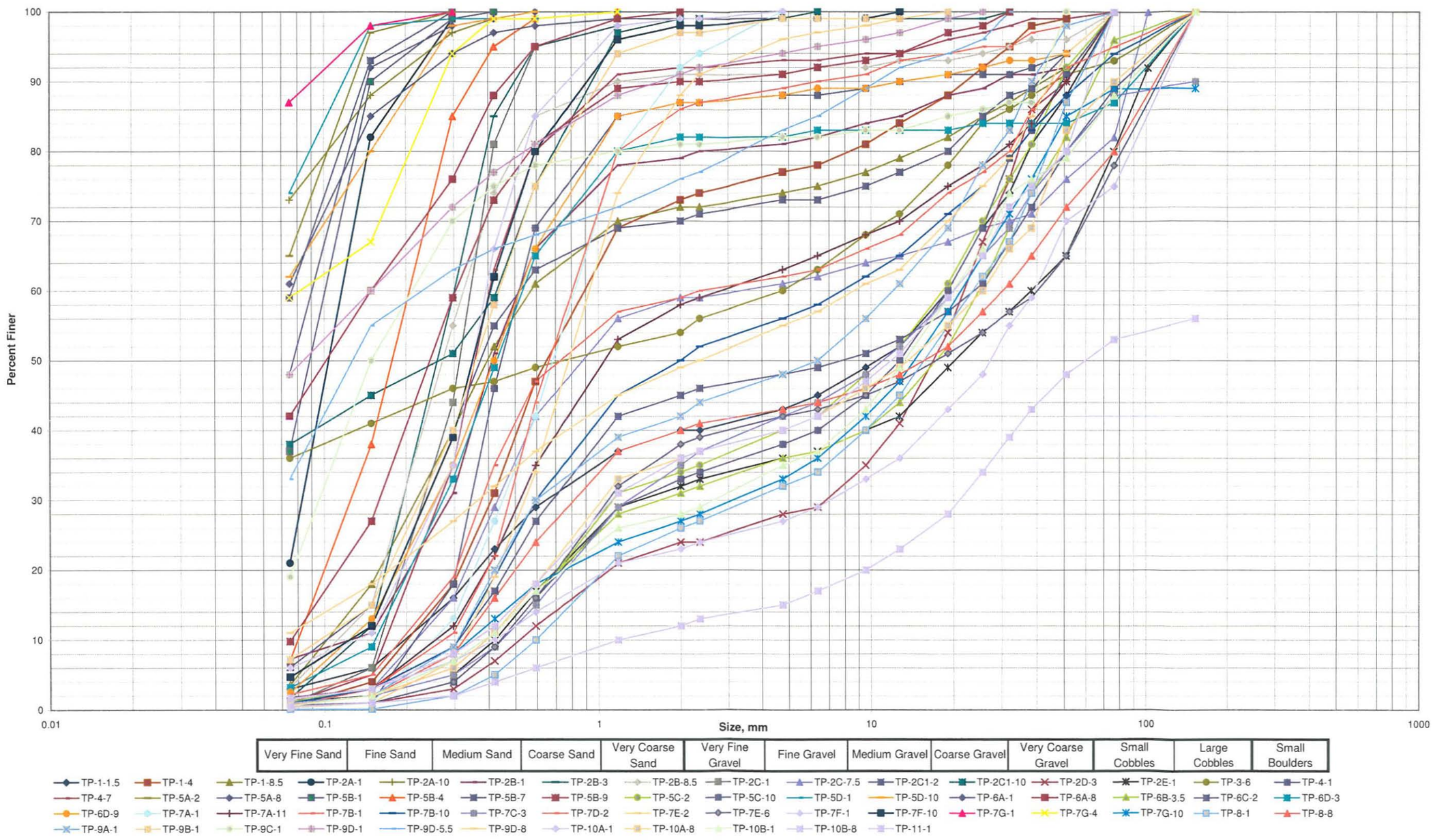
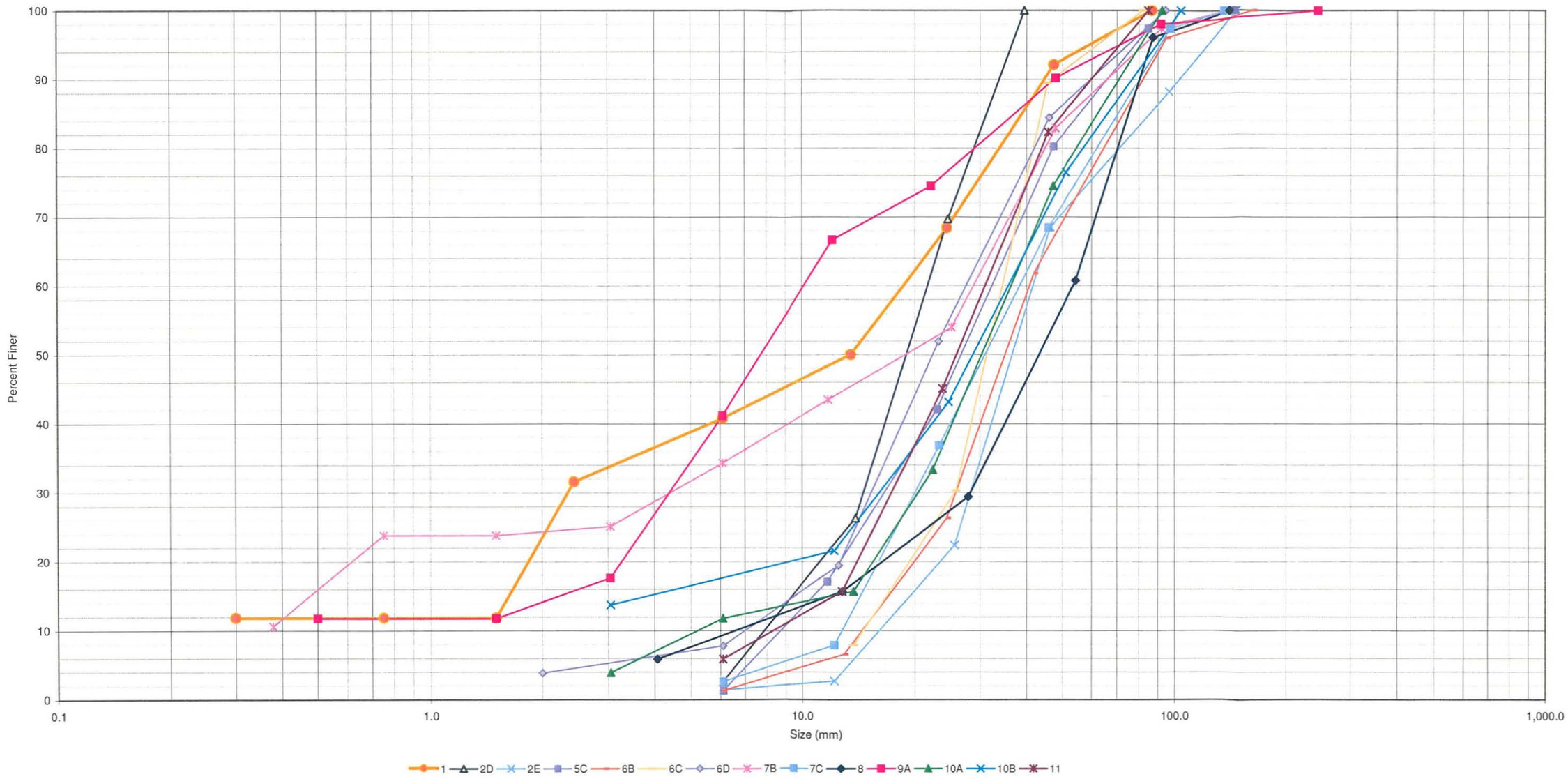


Figure 10
Gila River Sediment Program Pebble Count Data



Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Very Fine Gravel	Fine Gravel	Medium Gravel	Coarse Gravel	Very Coarse Gravel	Small Cobbles	Large Cobbles	Small Boulders

ANALYSES AND RESULTS

Overview of the Analyses

This project for the District began in May 2008. However, obtaining rights of entry and environmental compliance issues delayed the start of field data collection until March 2009. During March 18-27, 2009, 47 samples were obtained; but at that time not all rights of entry were available. Subsequently, some sample sites were changed to facilitate obtaining rights of entry. Upon resolution of those issues, a second field data collection program was undertaken during May 4-5, 2009, during which an additional 12 samples were obtained. In total, this project collected and analyzed 59 bed material samples. Due to the need to complete this project, including the analyses and report, by June 30, 2009, the data analyses were initiated prior to the collection of all data.

Stantec was assisted in the statistical analysis of the data by Dr. Pierre Julien, Dr. Paul Mielke, and Dr. Anne Paris of Colorado State University. Their report is provided in Attachment F. Using some of the data, they wrote a fortran program, MRPP, that can be used to classify bed material size gradation samples into one of three types. That program was subsequently used to classify the currently available bed material size gradation data, summarized in Table 1, into those types. A description of the program and executable file is provided in Attachment F. The results of the MRPP program are contained in this memorandum. In the future, any additional bed material samples from the Gila River can be analyzed by the MRPP program to determine the bed material type classification.

Review of the data collection and analyses was to be performed by Dr. Tony Thomas of Mobile Boundary Hydraulics. However, due to the shortened project schedule and other project commitments by Dr. Thomas, his review was not possible.

The analysis was conducted in the following steps:

1. Size gradation data and statistics from the 47 samples obtained during March 18-27, 2009 were sent to Julien and Mielke. They selected data from 29 of those samples to develop a statistical test program, MRPP. They used the data from the remaining 18 samples to test the MRPP program. The results of the statistical testing and the MRPP program are presented later in this memo.

2. The size gradation data obtained during May 4-5, 2009 were subjected to testing using the MRPP program. That testing was performed by Stantec.

3. The other size gradation data (items number 2 through 7 in Table 1) were subjected to testing by Stantec using the MRPP program.

4. The results of steps 1 through 3 provided a classification of the bed material samples identified in Table 1 into three types: Type A, Type B and Type C. That classification is described later. Using those results, Stantec performed an

inspection of the spatial distribution of those bed material types in the study reach of the Gila River.

Upon visual inspection of the initial set of 47 size gradation graphs (see Figure 9 for all 59 graphs), the following was noted;

1. There is a wide range of size gradation variability from fine particle sizes (less than 0.075 mm) to large cobbles (greater than 128 mm).

2. There are samples where more than 50 percent is silt and clay (finer than 0.075 mm).

3. There are samples where more than 50 percent is gravel and cobble (larger than 2.0 mm).

4. There are samples that are predominantly sand (between 0.075 mm and 2.0 mm).

From the data set of 47 samples that were sent to Julien and Mielke, and noting the above observations, 29 samples were selected that represent three distinct groups of size gradation: Group A, Group B and Group C. It is noted that the term "Group" is used with A, B or C to distinguish the 29 samples that were used to develop the statistical program, MRPP, while "Type" is used with A, B or C to classify any sample as to its size gradation character. Using the statistics from that data set, Mielke wrote the Fortran code for MRPP. Size gradation graphs of those 29 samples are provided in Figure 11. It is evident from Figure 11 that Group A is predominantly silt and clay, Group B is predominantly sand, and Group C is predominantly gravel. Upon completion of the MRPP code, Julien and Mielke tested the program using the remaining 18 samples. The size gradation graphs of those samples are provided in Figure 12.

The 12 samples that were collected by Stantec in May were tested using MRPP and the classification of the bed material was determined. The size gradation graphs of those samples are provided in Figure 13.

The results of the classification of the 59 bed material samples from this sampling program are provided in Table 4. In that table, each sample is identified by a sample number, the sample statistics used by MRPP to classify the bed material (d_{50} and d_{84}), and the classification as to Type A, Type B or Type C is provided

Of the 59 samples from this project, the size gradations graphs of the 12 samples that are Type A are shown in Figure 14, the 21 samples that are Type B are shown in Figure 15, and the 26 samples that are Type C are shown in Figure 16. MRPP was also used to classify the 51 bed material samples from sources 2 through 7 of Table 1. The results of that classification are provided in Table 4.

Table 4
Results of MRPP for Type of Each Sample

Sample Number	Sample Depth	d_{50}	d_{84}	Type	Range Index d_{50}	Range Index d_{84}	Composite Range Index
	ft	mm	mm		%	%	%
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Source of Sample:1. This data collection project							
TP-1-1.5	1.5	10.58	43.54	C	100	100	100
TP-1-4	4	0.67	12.7	C	100	26	63
TP-1-8.5	8.5	0.4	23.28	C	100	21	61
TP-2A-1	1	0.11	0.17	A	84	100	92
TP-2A-10	10		0.13	A *			
TP-2B-1	1	0.41	9.52	B	100	29	65
TP-2B-3	3	0.27	0.42	B	100	94	97
TP-2B-8.5	8.5	0.28	0.58	B	100	100	100
TP-2C-1	1	0.32	0.46	B	100	100	100
TP-2C-7.5	7.5	0.93	79.02	C	27	100	64
TP-2C1-2	2		0.13	A *			
TP-2C1-10	10	0.27	0.83	B	100	100	100
TP-2D-3	3	17.1	36.83	C	100	100	100
TP-2E-1	1	20.32	84.66	C	100	100	100
TP-3-6	6	0.79	25.4	C	26	70	48
TP-4-1	1	0.45	1.14	B	100	100	100
TP-4-7	7	0.36	0.81	B	100	100	100
TP-5A-2	2		0.12	A *			
TP-5A-8	8	0.08	0.14	A	100	100	100
TP-5B-1	1	0.09	0.14	A	100	100	100
TP-5B-4	4	0.19	0.44	B	100	100	100
TP-5B-7	7	0.38	24.13	B	100	21	61
TP-5B-9	9	0.26	0.81	B	100	100	100
TP-5C-2	2	11.11	41.56	C	100	100	100
TP-5C-10	10	12.7	39.69	C	100	100	100
TP-5D-1	1		0.11	A *			
TP-5D-10	10		0.18	A *			
TP-6A-1	1		0.15	A *			
TP-6A-8	8	0.11	0.38	A	84	25	54
TP-6B-3.5	3.5	17.46	54.43	C	100	100	100
TP-6C-2	2	7.94	62.09	C	100	100	100
TP-6D-3	3	0.43	25.4	B	100	21	60
TP-6D-9	9	0.42	1.15	B	100	100	100
TP-7A-1	1	0.7	1.5	B	100	100	100
TP-7A-11	11	1.1	38.1	C	29	100	65
TP-7B-1	1	0.7	1.7	B	100	100	100

* Type selected by inspection.

Table 4 Cont.
Results of bed material classification by MRPP

Sample Number	Sample Depth	d_{50}	d_{84}	Type	Range Index d_{50}	Range Index d_{84}	Composite Range Index
	ft	mm	mm		%	%	%
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TP-7B-10	10	2	40.6	C	39	100	69
TP-7C-3	3	11.11	63.5	C	100	100	100
TP-7D-2	2	0.77	35.98	C	26	100	63
TP-7E-2	2	0.83	1.77	B	100	100	100
TP-7E-6	6	17.46	96.98	C	100	100	100
TP-7F-1	1	0.36	0.59	B	100	100	100
TP-7F-10	10	0.36	0.74	B	100	100	100
TP-7G-1	1			A *			
TP-7G-4	4		0.24	A *			
TP-7G-10	10	14.6		C *			
TP-8-1	1	15.87	47.87	C	100	100	100
TP-8-8	8	15.87	91.44	C	100	100	100
TP-9A-1	1	6.35	32.66	C	100	100	100
TP-9B-1	1	0.37	0.87	B	100	100	100
TP-9C-1	1	0.149	15.87	B	75	24	50
TP-9D-1	1	0.09	0.85	B	50	100	75
TP-9D-5.5	5.5	0.13	5.55	B	66	38	52
TP-9D-8	8	2.36	37.04	C	42	100	71
TP-10A-1	1	27.21	103.63	C	100	100	100
TP-10A-8	8	13.76	54.43	C	100	100	100
TP-10B-1	1	13.33	64.91	C	100	100	100
TP-10B-8	8	60.96		C *			
TP-11-1	1	11.91	55.88	C	100	100	100

* Type selected by inspection.

Source of Sample: 2. El Rio WMP

1	0	0.65	1.11	B	100	100	100
2	0	0.46	0.87	B	100	100	100
3	0	0.26	0.39	B	100	85	93
4	2	0.82	17.46	C	26	48	37
5	0	1.45	25.4	C	33	70	51
6	0	0.054	0.13	A	100	100	100
7	0	0.36	0.54	B	100	100	100
8	0	1.04	2.58	B	78	65	71
9	0	8.73	43.18	C	100	100	100
10	0	3.32	35.98	C	53	100	76
11	0	1.41	24.34	C	33	66	49
12	0	0.32	0.60	B	100	100	100

Table 4 Cont.
Results of bed material classification by MRPP

Sample Number	Sample Depth	d_{50}	d_{84}	Type	Range Index d_{50}	Range Index d_{84}	Composite Range Index
	ft	mm	mm		%	%	%
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Source of Sample: 3. Burlingame							
1	0	39.51	86.36	C	66	100	83
2	0	27.41	69.36	C	99	100	100
3	0	21.17	65.62	C	100	100	100
4	0	31.75	96.25	C	83	100	91
5	0	20.11	57.15	C	100	100	100
6	0	12.7	47.98	C	100	100	100
7	0	45.72	126.99	C	58	74	66
8	0	45.03	105.5	C	59	97	78
Source of Sample: 4. Terracon - Gila river at Airport Road Crossing							
TP-1 (0)	0	31.17	119.38	C	84	30	82
TP-1 (1)	1	0.76	6.35	B	100	35	68
TP-1 (Bank)	0	0.19	0.34	B	100	73	86
TP-2 (0)	0	0.22	0.34	B	100	73	86
TP-2 (1.75)	1.75	0.08	0.32	A	100	30	65
TP-2 Bank	0	0.13	0.29	A	74	35	54
TP-3 (0)	0	12.7	48.99	C	100	100	100
TP-3 (0.33)	0.33	0.52	1.02	B	100	100	100
TP-3 (0.75)	0.75	27.21	177.8	C	100	52	76
TP-3 (Bank)	0	1.12	19.1	C	30	52	41
TP-4 (0)	0	43.74	128.49	C	61	73	67
TP-4 (1)	1	19.1	135.47	C	100	68	84
TP-4 (Bank)	0	60.96	138.39	C	47	67	57
Source of Sample: 5. Cotton Lane Bridge CLOMR							
WPT 163	0	1.5	27.88	C	34	78	56
WPT 169	0	4.51	24.25	C	68	66	67
WPT 161	0	7.63	27.95	C	100	79	89
WPT 170	0	13.64	46.63	C	100	100	100
Source of Sample: 6. Cotton Lane Bridge							
BA1L	5' - 10'	0.69	8.51	B	100	31	65
B5L	10' - 15'	13.2	47.34	C	100	100	100
B15R	0' - 5'	0.2	0.51	B	100	100	100
B6R	0' - 5'	1.65	42.33	C	35	100	68
B7L	5' 10'	7.01	46.32	C	100	100	100
B8R	10' - 15'	20.86	72.57	C	100	100	100
BA2L	0' - 5'	0.24	0.89	B	100	100	100

Table 4 Cont.
Results of bed material classification by MRPP

Sample Number	Sample Depth	d_{50}	d_{84}	Type	Range Index d_{50}	Range Index d_{84}	Composite Range Index
	ft	mm	mm		%	%	%
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Source of Sample: 7. Tres Rios North Levee							
SS01-01	0	0.65	1.84	B	100	95	97
SS02-02	0	15.04	45.72	C	100	100	100
SS02-03	0	5.7	31.38	C	87	94	90
SS02-04	0	0.24	14.29	B	100	25	63
SS02-05	0	2.84	25.4	C	47	70	59
SS02-06	0	0.26	0.95	B	100	100	100
SS02-07	0	0.37	0.67	B	100	100	100

Figure 11
Size Gradation of 29 Samples Used to Develop MRPP

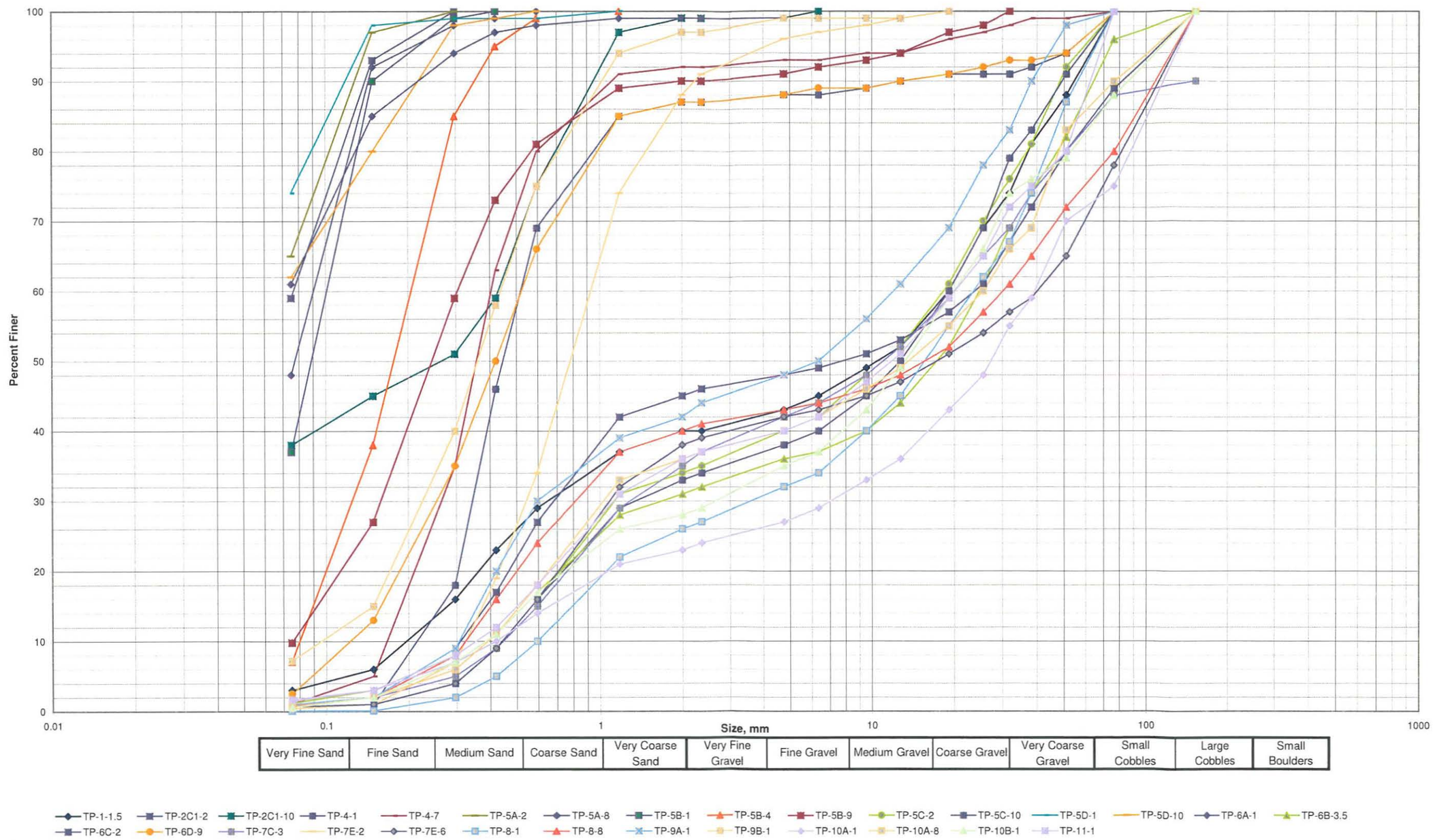


Figure 12
Size Gradation of 18 Samples Used By Julien and Mielke to Test MRPP

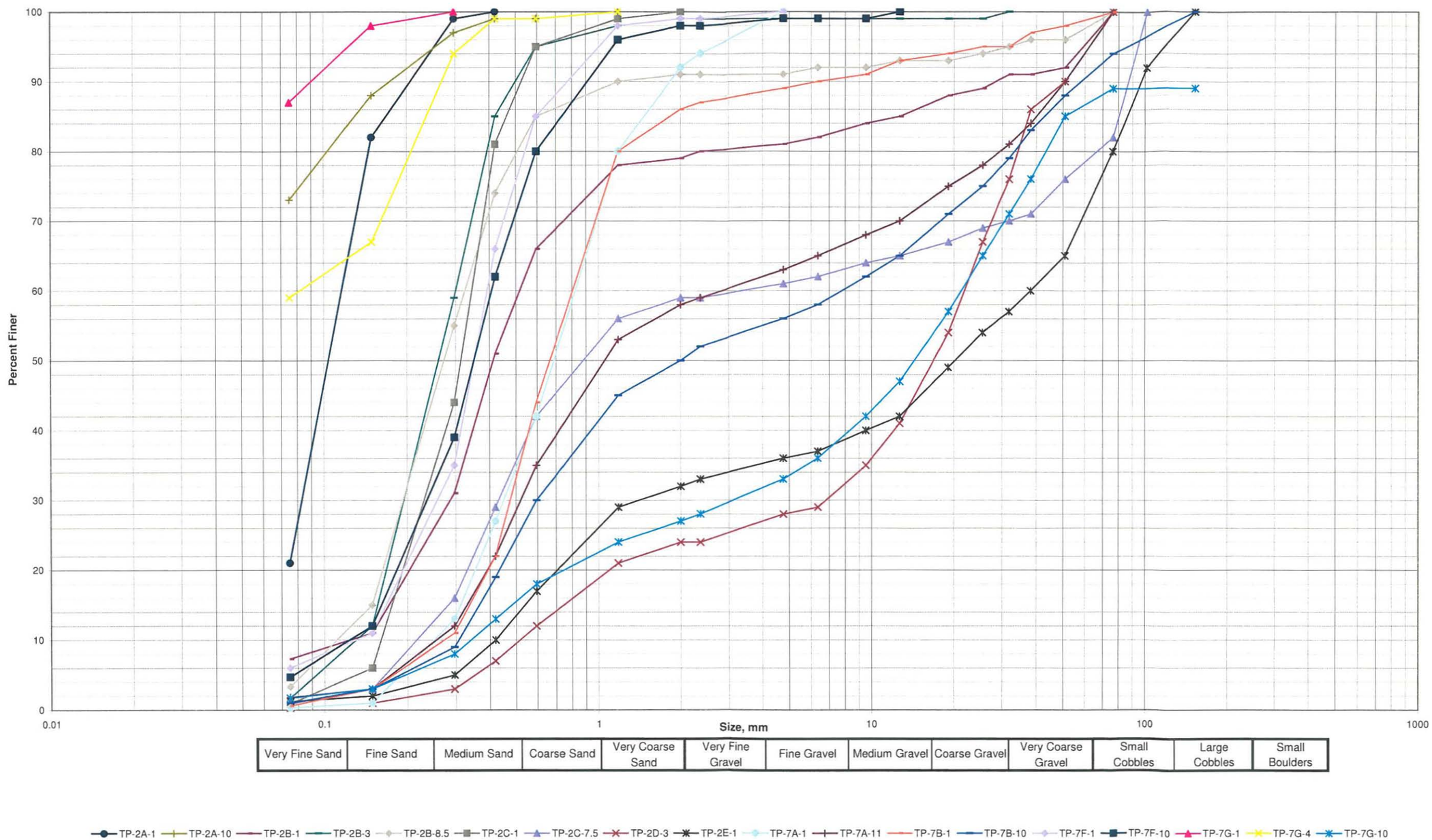


Figure 13
Size Gradation of 12 Samples Classified By Stantec Using MRPP

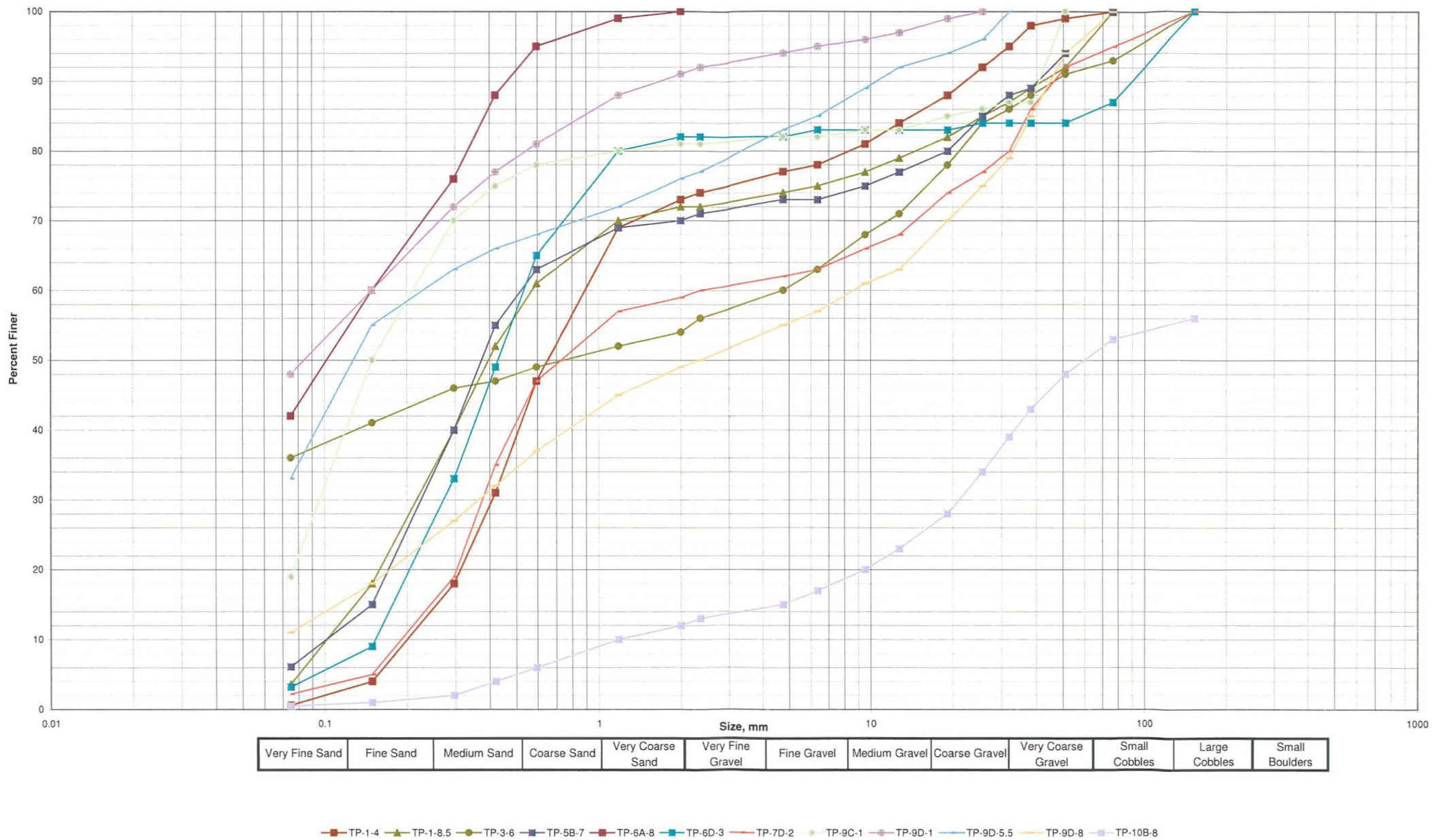


Figure 14
Size Gradation of Samples from the Gila River Sediment Program Test Pits - Type A

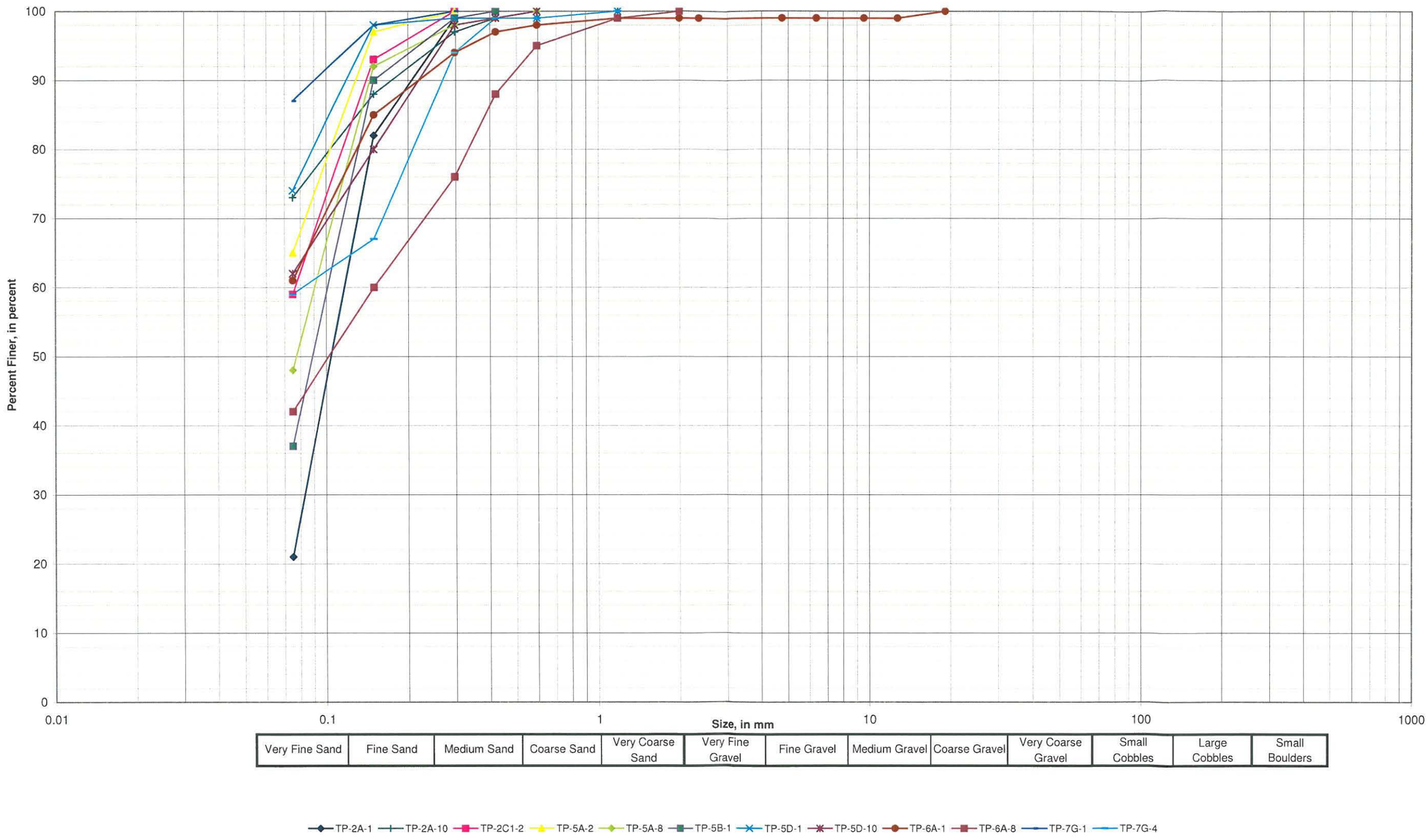


Figure 15
Size Gradation of Samples from the Gila River Sediment Program Test Pits - Type B

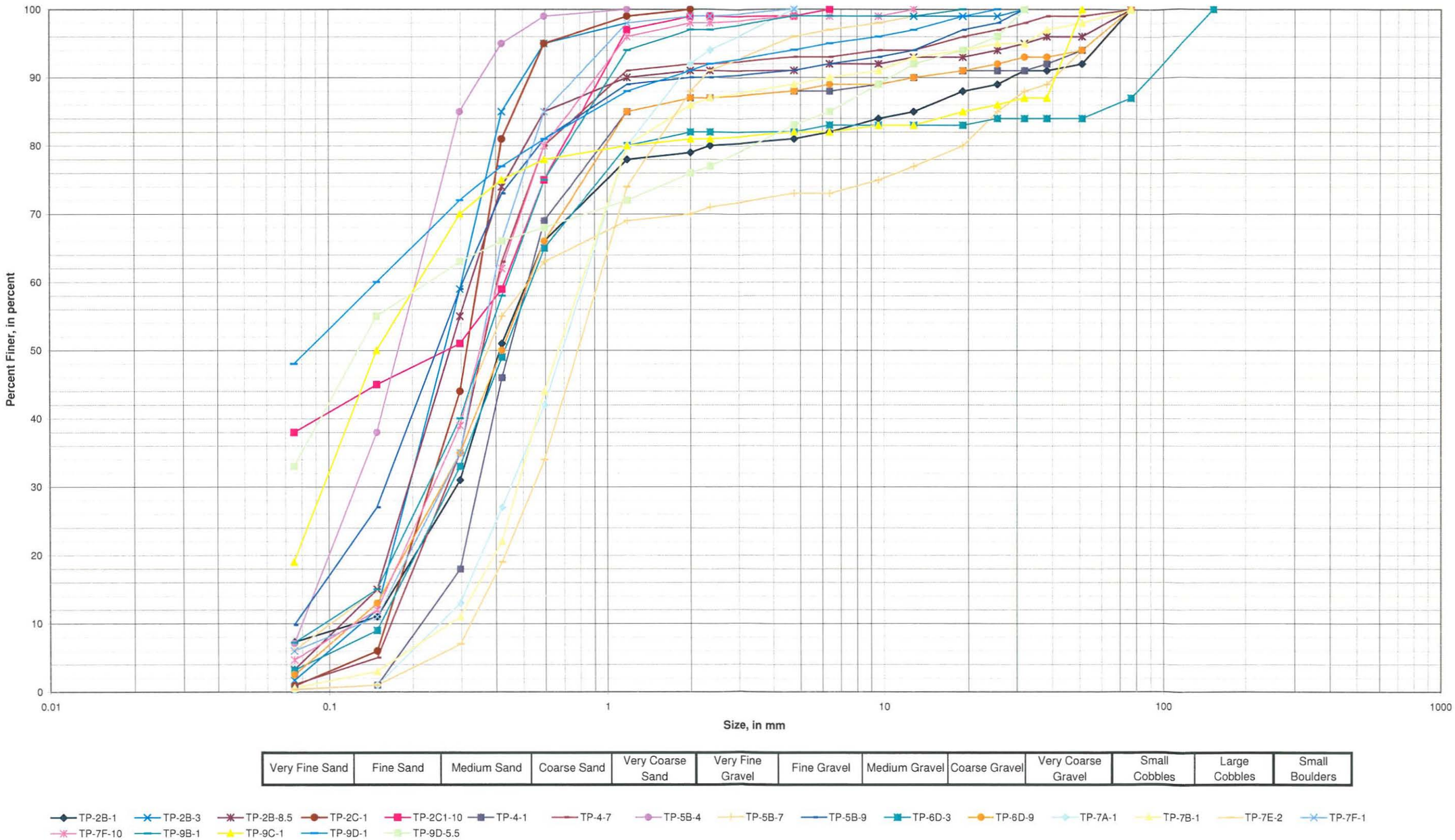
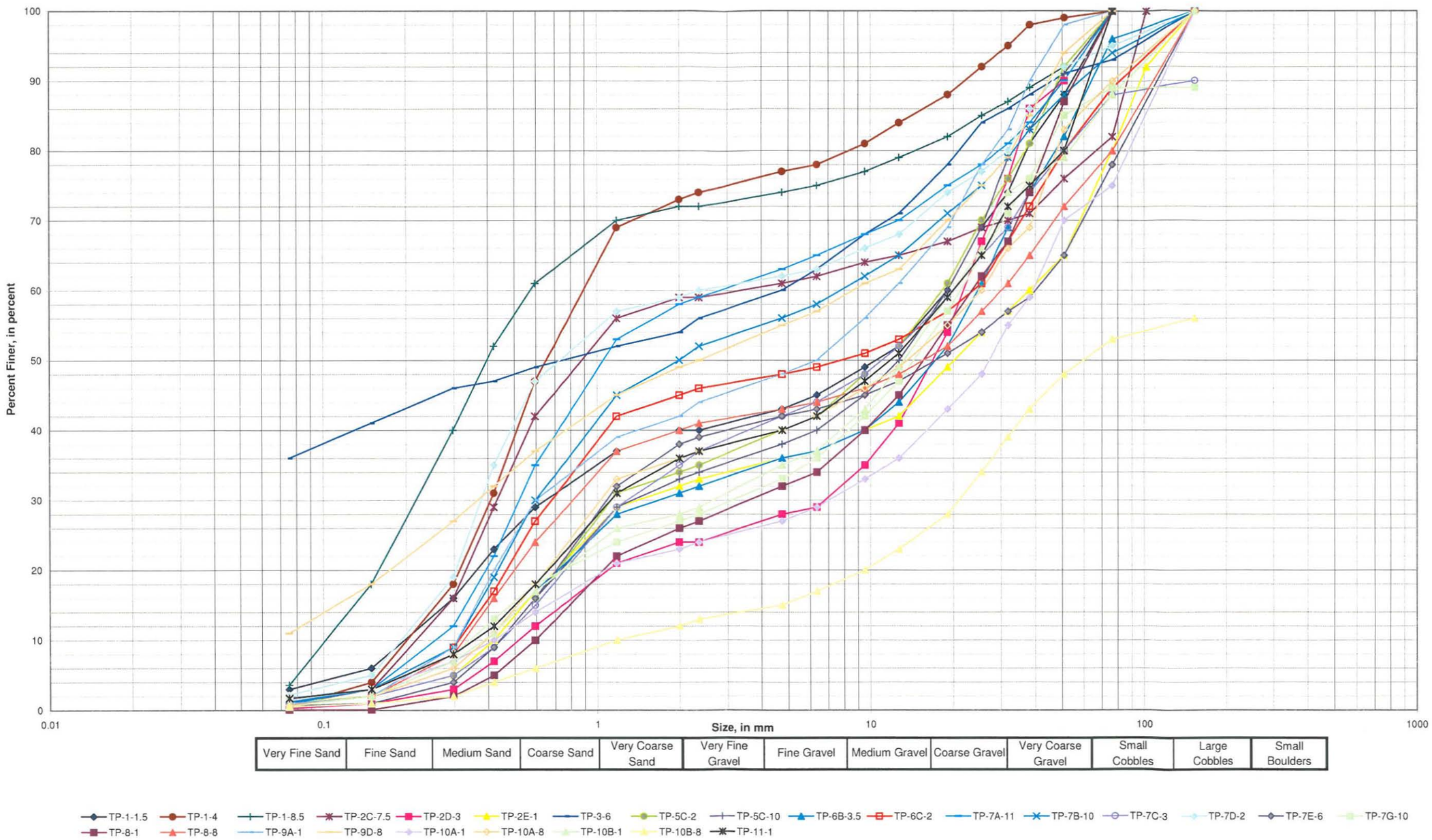


Figure 16
Size Gradation of Samples from the Gila River Sediment Program Test Pits - Type C



The spatial occurrence of those three soil types was investigated. To investigate the occurrence of soil type with depth, the 59 samples from the current project were used. In Figure 17, the depth of sample from each test pit is plotted along with its class Type A, B or C. Figure 17 shows the excavated depth of each pit and the depth to groundwater, if encountered in the pit. Figure 17 also indicates whether the soil in the pit was uniformly Type A, B or C, or if it was a mix of soil types.

To investigate aerial spatial distribution, the type of each sample is located on an aerial photograph of the study area in Plate 1. In that plate, the sample number and Type A, B or C is shown for the 110 samples. To facilitate the interpretation of that data, Plate 4 shows the soil type of each sample plotted on the aerial photograph with a color code to distinguish the soil type. The following is noted concerning the data depicted on Plate 4:

1. The study area from the confluence of the Salt River with the Gila River downstream to Tuthill Bridge has a greater density of sampling than the study area from Tuthill Bridge downstream to SR85.

2. Based on the sampling that is currently available, bed material Type C is the dominant bed material from the confluence of the Salt and Gila Rivers to Tuthill Bridge. However, the lack of comparable sampling frequency downstream of Tuthill Bridge may not adequately represent the occurrence of Type C in that reach.

3. Type B bed material occurs with about the same frequency throughout the study area.

4. Type B and C bed material generally occur in less densely vegetated sections of the river and in near-term active braids of the river.

5. Type A soil generally occurs in densely vegetated overbank areas of the floodplain.

6. Using data from Table 4, where there is a mix of soil type that includes Type A (Test Pits 2C1, 5B and 7G). Type A soil overlays bed material Type B or C.

The number of times Type A, B or C material occurs relative to depth of sample is provided in Table 5. The data for all samples (Column 16) is plotted versus sample depth in Figure 18. From that analysis, it is noted that more than 50 percent of all samples were obtained at a depth of 3 feet or less. It is noted that this statistic is biased due to operational factors in that a sample is almost always (30 of 32 pits) extracted from the top 3 feet of the pit, but deeper samples are not necessarily obtained, or are distributed between 3 and 11 feet.

A similar frequency graph was prepared using the data for material Types A, B and C of Table 5, and those results are presented in Figure 19. In Figure 19, it is noted that the frequency of encountering either Type B or C material is about the same regardless of depth.

Table 5
Occurrence of Samples According to Soil Type and Depth

	Soil Type A			Soil Type B			Soil Type C			All Samples		
Depth of Sample	Number of Occurrences	Cum. Number Occurrences	Percent of Total Number of Samples	Number of Occurrences	Cum. Number Occurrences	Percent of Total Number of Samples	Number of Occurrences	Cum. Number Occurrences	Percent of Total Number of Samples	Number of Occurrences	Cum. Number Occurrences	Percent of Total Number of Samples
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
0												
0.5		0	0		0	0		0	0	0	0	0
1	5	5	42	9	9	43	6	6	23	20	20	34
1.5		5	42		9	43	1	7	27	1	21	36
2	2	7	58	1	10	48	3	10	38	6	27	46
2.5		7	58		10	48		10	38	0	27	46
3		7	58	2	12	57	2	12	46	4	31	53
3.5		7	58		12	57	1	13	50	1	32	54
4	1	8	67	1	13	62	1	14	54	3	35	59
4.5		8	67		13	62		14	54	0	35	59
5		8	67		13	62		14	54	0	35	59
5.5		8	67	1	14	67		14	54	1	36	61
6		8	67		14	67	2	16	62	2	38	64
6.5		8	67		14	67		16	62	0	38	64
7		8	67	2	16	76		16	62	2	40	68
7.5		8	67		16	76	1	17	65	1	41	69
8	2	10	83		16	76	4	21	81	6	47	80
8.5		10	83	1	17	81	1	22	85	2	49	83
9		10	83	2	19	90		22	85	2	51	86
9.5		10	83		19	90		22	85	0	51	86
10	2	12	100	2	21	100	3	25	96	7	58	98
10.5		12	100		21	100		25	96	0	58	98
11		12	100		21	100	1	26	100	1	59	100

Figure 17
Comparison of Soil Type in Each Pit and Depth of Sample

Data taken log of test pit sheets.

Figure 18
Frequency of Sample with Depth

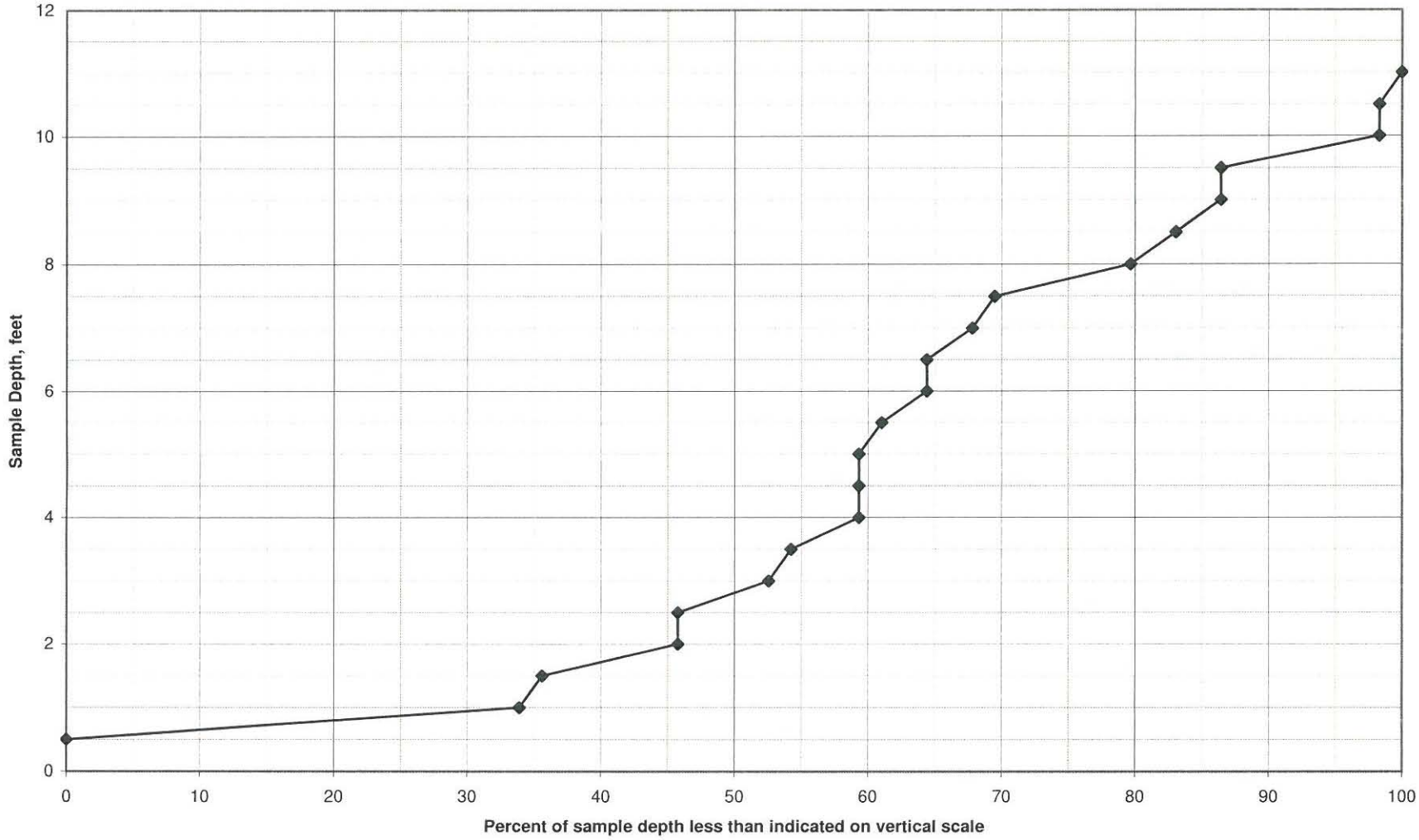
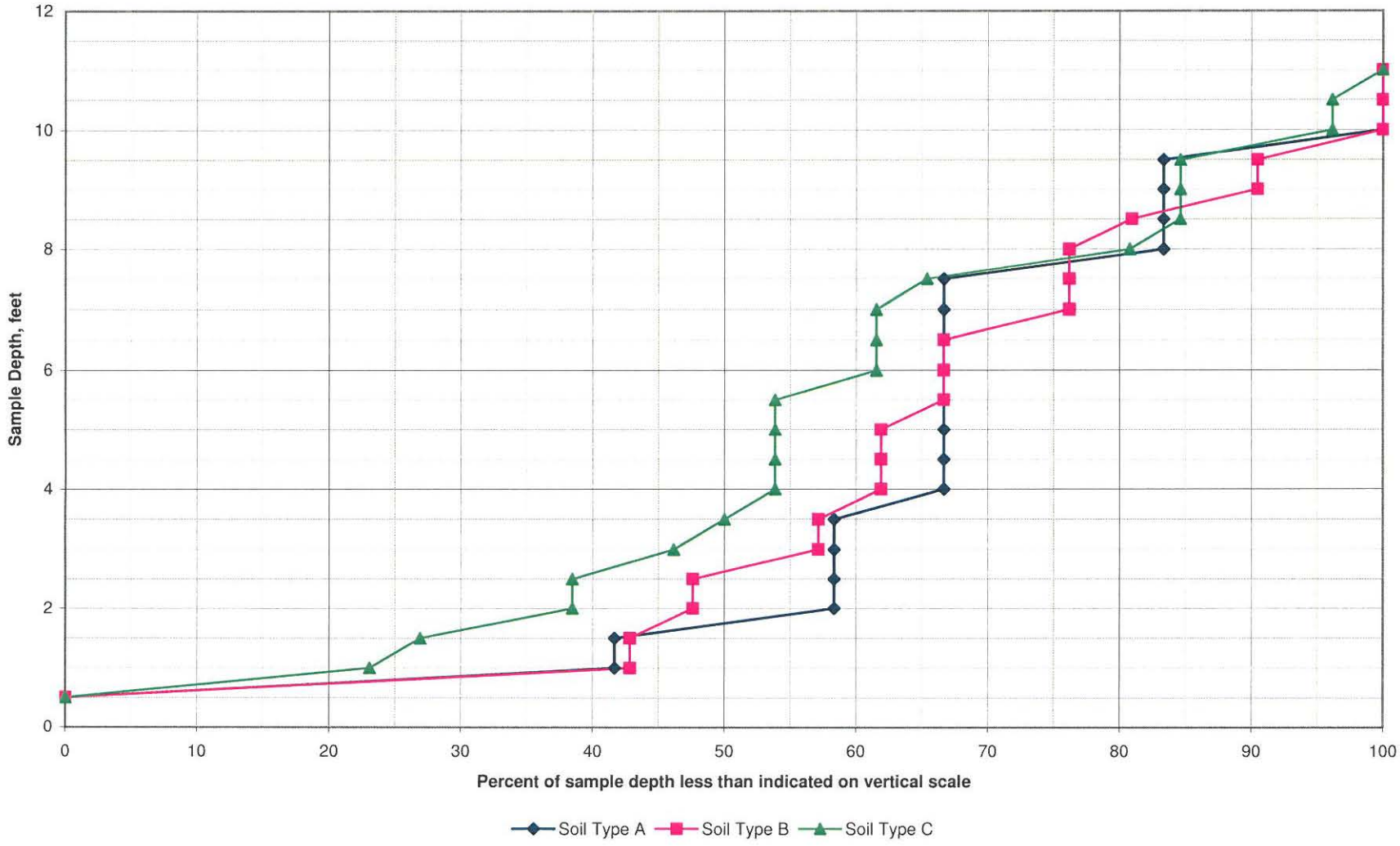


Figure 19
Frequency of Sample with Depth for Soil Types A, B & C



An analysis was performed of the uniformity of material in the pits. Uniformity is a measure of consistency of material type in a test pit. A pit of high uniformity contains all one material type. The results are presented in Table 6 and illustrate that about 75 percent of the pits contained only one material type and that 25 percent of the pits contain two material types. None of the pits contained three material types.

Table 6
Analysis of Uniformity of Bed Material in the Test Pits
(all pits)

Soil Type	Test Pits	No. in Group	Percent of Total
"A"	2A, 5A, 5D, 6A	4	13%
"B"	2B, 4, 6D, 7F, 9B, 9C	6	19%
"C"	1, 2D, 2E, 3, 5C, 6B, 6C, 7C, 7D, 8, 9A, 10A, 10B, 11	14	44%
"A" & "B"	2C1, 5B	2	6%
"B" & "C"	2C, 7A, 7B, 7E, 9D	5	16%
"A" & "C"	7G	1	3%

Although 11 of the 32 pits had only one sample that does not bias the results. If the pit, regardless of the depth, would have indicated nonuniformity of material, additional samples would have been obtained. Therefore, a pit with only one sample contained uniform bed material of one type.

Surface deposits of coarse material were sampled in the field by pebble count. The size gradation results are presented in Figure 10. Comparison of the size gradation graphs of Figures 9 and 10 clearly shows that the size gradations of surface deposits (Figure 10) are not represented in the bed material of the river (Figure 9). The mean grain size of those sporadic surface deposits is generally in the 20 to 50 mm range and about 5 to 30 percent of the material is cobble (larger than 64 mm). Those deposits are generally only one or two grains thick with underlying bed material of Type B or Type C. The occurrence of surficial gravel and cobble deposits with underlaying bed material of Type B and C is clearly shown in photographs (Attachment C) of pits at sites 5C, 6B, 6C, 6D, 7C and 8. In none of the pits was the coarse surface veneer representative of the mobile bed material beneath that layer.

The classification of bed material into Type B and Type C removes much of the variability in size gradation that is illustrated in Figure 9. However, there remains considerable variability within each type, and even variability at a location. Test Pit 8 is used to illustrate this. Review of the photographs (Attachment C) of Test Pit 8 shows a surface that is predominantly gravel, an upper layer that contains considerable gravel, and a deeper layer that appears to be sand. One sample (TP-8-1) was taken in the upper 1 foot of material and a second sample (TP-8-8) was taken at the bottom of the pit, 8 feet bgs. Comparative statistics for those two samples are:

	Grain Size, in mm		
	d_{16}	d_{50}	d_{84}
TP-8-1	0.84	16	48
TP-8-8	0.40	16	83

According to soil classification, the samples contain the following:

	Sand & Finer	Gravel	Cobble
TP-8-1	26%	68%	6%
TP-8-8	40%	37%	23%

The upper layer does contain a higher percent of gravel (as the photographs in Attachment C indicate) and the lower layer does contain a higher percent of sand. The lower layer also contains a larger percent of cobble; however, this may be explained if the sample from the lower layer contained a large cobble(s) that dominated the analysis. That vagary is inherent in the sampling procedure and the reason why numerous samples are obtained. Regardless of that uncertainty, both of those samples are Type C and indicate a statistical uniformity in bed material size at that location. This illustrates that surface deposits are not reliable indicators of the bed material and that visual assessment of size gradation may be misleading.

CONCLUSIONS

1. Soil in the Gila River overbanks (see Plates 1 and 4) is typically composed of very fine sand, silt and clay sized particles. The source of that material is fine, suspended load during overbank flooding that settles on the floodplain due to low velocity (energy) flows as a result of high flow resistance from dense vegetation. That material is classified as Type A in this study. It represents "wash load" that enters the river during upland watershed runoff. The source of that sediment is predominantly watershed soil erosion and some amount of river bank erosion. That material is not bed material and it does not represent the active channel bed material size gradation. That material is susceptible to reintrainment as suspended load during floods if the vegetation is removed or as a result of lateral migration of braids in the Gila River. That material, once entrained in the flow, will remain in suspension until the velocity (energy) is low enough to allow settling of the suspended particles.

2. The bed material of the Gila River in the study area is represented by two general size distributions. Type B is composed mostly of fine to coarse sand. Type C is composed of mostly very coarse sand, gravel and some small cobbles.

3. Type B, sandy, bed material is less frequent than Type C throughout the study area, although current data tends to indicate a greater frequency of it occurring downstream of Tuthill Bridge compared with upstream of that bridge.

4. Type C, gravely, bed material is the dominant bed material between the confluence of the Salt River with the Gila River downstream to Tuthill Bridge. This conclusion may be biased by the greater frequency of sediment sampling in that reach of river.

5. Generally, the sediment in the Gila River floodplain can be classified with confidence as Type A, B or C. A composite mix of two or more of those types is not strongly indicated. Occasionally, two of those sediment types occur at the same location at different depths. Where that stratification occurs and Type A material is present, the Type A soil is the upper most material.

6. Sampling to depths of up to 10 feet did not necessarily provide additional information as to the bed material size gradation. In nearly 75 percent of the pits the material was essentially of uniform grain size throughout the depth, although this conclusion is biased due to the frequency of pits at 3 feet deep, or less.

7. The source and distribution within the river bed of the two distinct bed materials is not known. Two postulates are offered; either the two bed materials are derived from different upland sources, or it is the result of selective transport of finer grain sizes during floods and subsequent deposition of that material during flood recession. In the first case, it is possible that the finer grain size material (Type B) is introduced from the Gila River, while the coarser material (Type C) is delivered from the Salt River system. Alternatively, it is possible that segregation of Type B material from parent Type C material could be the result of winnowing of finer bed material during floods. However, that process would be expected to produce more of a graded mix of Type B and Type C material. The size gradation graphs of Figures 15 and 16 do not strongly suggest that process. Regardless of the source of Type B and Type C bed material, those materials clearly comprise the vast majority of the bed material of the Gila River in the study area. Those materials are interbedded deposits. There is a greater occurrence of Type C material upstream near the confluence of the Salt and Gila Rivers. The materials are randomly segregated downstream of the Agua Fria River confluence.

8. Surface deposits of gravel and cobbles occur throughout the Gila River study area. The size gradation of those deposits was determined by pebble count. The results are shown in Figure 10. Those gravel deposits do not represent the bed material of the river. Rather those deposits are the result of selective transport of finer bed material leaving a veneer of coarser gravel and cobble. Due to the extreme range of discharges in the Gila River, those surficial deposits zones are transitory and will be subject to mobilization during episodic floods.

That thin veneer of gravel deposit does not constitute a stable armouring of the bed of the river or provide any reasonable degree of protection against bed scour or bank erosion.

RECOMMENDATIONS

1. The bed material of the Gila River in the study area is represented by material of size gradation as depicted by Type B and Type C. For sediment transport modeling purposes, the input of bed material data should represent those size gradations. There is evidence to suggest the use of coarser bed material size gradation in the upper reach of river and a finer size gradation in the lower reach.

2. The occurrence of Type B and Type C bed material cannot be predicted based on the presently available data. For sediment transport modeling and estimate of scour depths, the use of the finer bed material size gradation, Type B, may be justified to obtain maximum scour depths. Sensitivity analyses of size gradation could provide informative results by using both Type B and Type C data.

3. Based on this limited data collection program, it does not appear that obtaining bed material samples at depths greater than 3 feet provides more reliable data. Therefore, field data collection by hand dug holes rather than by backhoe appears to be justified. However, only limited data is available and more data, at depth, is encouraged when such sampling is viable.

4. Soil in densely vegetated overbanks is predominantly deposited wash load. It is not representative of bed material. That soil is susceptible to erosion and entrainment as suspended load during overbank floods. Dense vegetation, particularly salt cedar, contributes to the deposition and removal of that vegetation (by floods or by other means) exposes that material to erosion.

5. The data collection was limited to the near-surface bed material that is potentially mobilized during floods. The size gradation at greater depths at specific locations could vary appreciably from these results. For example, these results may not be applicable for bridge scour studies. In those cases, a sampling program, such as borehole, may be appropriate to collect the necessary size gradation data. Similarly, this data collection program is not intended to represent the sand and gravel deposits at depths that are normally mined for mineral extraction.

6. The cause of two distinct bed material size gradation is not known. Bed material sampling of the Gila and Salt Rivers upstream of the confluence and the Agua Fria River may assist in explaining the bi-modal nature of the bed material of the Gila River in the study area.

7. Sediment sampling of the Gila River in the study area for the purpose of determining bed material size gradation should generally yield results that represent Type B or Type C. The MRPP program can be used to classify those samples as to type. Graphical comparison of sample data to size gradation graphs of Figures 15 and 16 provides useful information.

8. Additional bed material sampling between Tuthill Bridge and SR85 is recommended to better define the occurrence of Type B and Type C material in that reach of the river.

LIST OF REFERENCES

COE, 1996, Section 7 Study for Modified Roosevelt Dam, Arizona, Hydrologic Evaluation of Water Control Plans, Salt River Project to Gila River at Gillespie Dam.

Michael Baker Jr., 1999, Salt-Gila Floodplain Delineation Restudy Submitted to the Flood Control District of Maricopa County, dated May 1999.

Ricker-Atkinson-McBee & Associates, Inc., 2005. Final Geotechnical and Foundation Report, Cotton Lane Bridge Over the Gila River, prepared for Michael Baker Jr., Inc., dated 2 December 2005.

River Research & Design, Inc., 2008, Cotton Lane Bridge Floodplain Redelineation Gila River, Goodyear, Arizona Conditional Letter of Map Revision, dated February 2008.

Stantec Consulting Inc. (SFC Engineering Company), 1997, Flood Hydrology and Sediment Analysis of the 1993 Flood on the Gila River in Regard to the Breach of Gillespie Dam, dated January 20, 1997.

Stantec Consulting Inc., 2005, El Rio Watercourse Master Plan, Prepared for the Flood Control District of Maricopa County, dated December 2005.

Stantec Consulting Inc., 2008, Gila River Floodplain Redelineation Study, Maricopa County, Technical Data Notebook, for the Flood Control District of Maricopa County (FCDMC), dated March 2008.

WEST Consultants, Inc., 2004, PED Hydraulic Design of Tres Rios North Levee, Pre-Final Project Analysis Final Report, Prepared for U.S. Army Corps of Engineers Las Angeles District, dated April 2004.

Plates

Flood Control District of Maricopa County

Legend

- SAMPLE LOCATION WITH SOIL TYPE
- 100-YR PROJECT FLOODWAY
- 100-YR PROJECT FLOODPLAIN
- SAND & GRAVEL SITE

Client/Project

Flood Control District of Maricopa County
Gila River Sediment Program

Figure No.

Plate 1

Title

Location of Test Pit Sites

Legend

Samples from Previous Projects

- Burlingame
- Cotton Lane Bridge Floodplain Redelination CLOMR
- Cotton Lane Bridge over Gila River
- El Rio Watercourse Master Plan (2006)
- Gila River at the Airport Road Crossing
- Tres Rios North Levee PED (2004)
- 100-YR PROJECT FLOODWAY
- 100-YR PROJECT FLOODPLAIN
- SAND & GRAVEL SITE

Client/Project

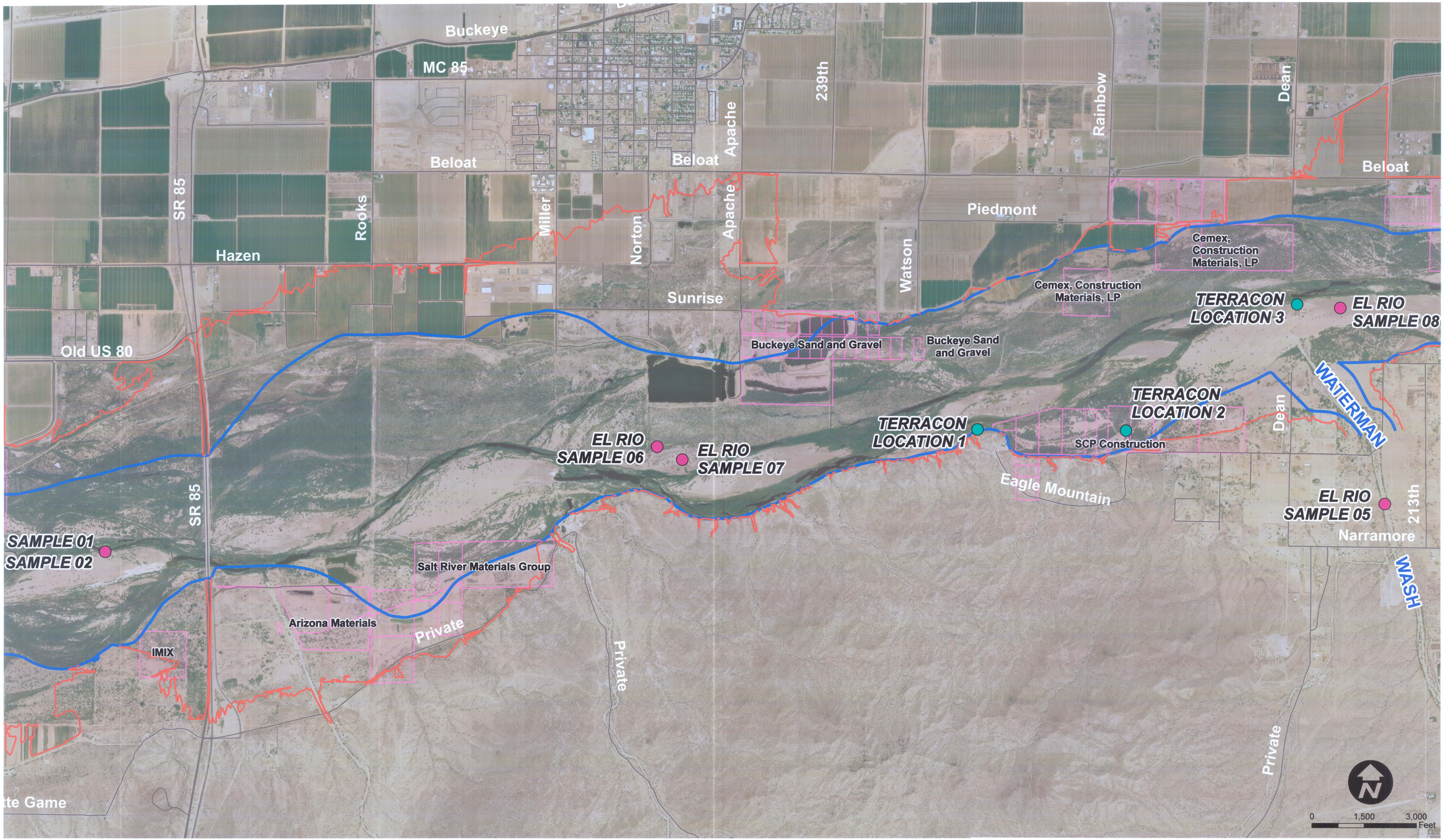
Flood Control District of Maricopa County
Gila River Sediment Program

Figure No.

Plate 2

Title

Location of Previous Sample Sites



Flood Control District of Maricopa County

Legend

Samples from Previous Projects

- Burlingame
- Cotton Lane Bridge Floodplain Redelination CLOMR
- Cotton Lane Bridge over Gila River
- El Rio Watercourse Master Plan (2006)
- Gila River at the Airport Road Crossing
- Tres Rios North Levee PED (2004)
- 100-YR PROJECT FLOODWAY
- 100-YR PROJECT FLOODPLAIN
- SAND & GRAVEL SITE

Client/Project

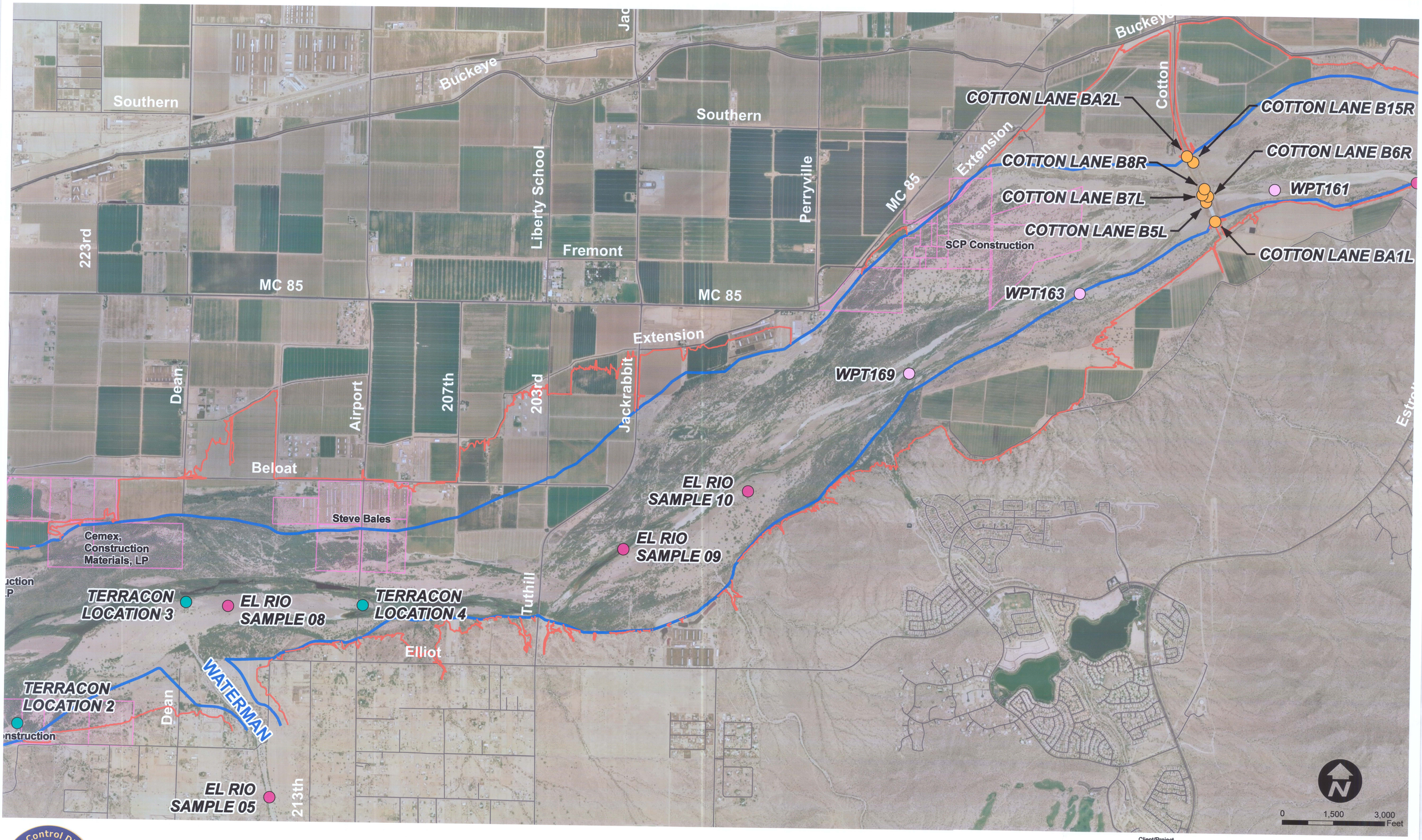
Flood Control District of Maricopa County
Gila River Sediment Program

Figure No.

Plate 2.1

Title

Location of Previous Sample Sites West Section



Flood Control District of Maricopa County

Legend

Samples from Previous Projects

- Burlingame
- Cotton Lane Bridge Floodplain Redelination CLOMR
- Cotton Lane Bridge over Gila River
- El Rio Watercourse Master Plan (2006)
- Gila River at the Airport Road Crossing
- Tres Rios North Levee PED (2004)
- 100-YR PROJECT FLOODWAY
- 100-YR PROJECT FLOODPLAIN
- SAND & GRAVEL SITE

Client/Project

Flood Control District of Maricopa County
Gila River Sediment Program

Figure No.

Plate 2.2

Title

Location of Previous Sample Sites
Central Section

Pioneer
Victory
Dunlap
Elwood
Estrella
Trocar
Broadway
Estrella
Bullard
Buckeye
AGUA FRIA RIVER
Vermeersch
Dysart
Broadway
El Mirage
Lower Buckeye
Winslow
Miami
Avondale
Buckeye Irrigation District
Buckeye
Southern
EL RIO SAMPLE 03
EL RIO SAMPLE 04
WEST SS2
COTTON LANE B15R
CI&T SAMPLE 01
COTTON LANE B6R
WPT170
CI&T SAMPLE 02
EL RIO SAMPLE 11
WPT161
Vineyard
Rio Grande Materials West
Vulcan
Vulcan
Vulcan
Bill Lueck
CI&T SAMPLE 03
WEST SS1
CI&T SAMPLE 05
WEST SS7
WEST SS5
WEST SS6
COTTON LANE BA1L
EL RIO SAMPLE 12
CI&T SAMPLE 04
CI&T SAMPLE 07
Buckeye Irrigation District
Spartan Industries
WEST SS4
Avondale
Spartan Industries
CI&T SAMPLE 06
CI&T SAMPLE 08
WEST SS3
Estrella
Old Baseline
N
0
1,500
3,000
Feet

Flood Control District of Maricopa County

Legend

Samples from Previous Projects

- Burlingame
- Cotton Lane Bridge Floodplain Redelination CLOMR
- Cotton Lane Bridge over Gila River
- El Rio Watercourse Master Plan (2006)
- Gila River at the Airport Road Crossing
- Tres Rios North Levee PED (2004)
- 100-YR PROJECT FLOODWAY
- 100-YR PROJECT FLOODPLAIN
- SAND & GRAVEL SITE

Client/Project

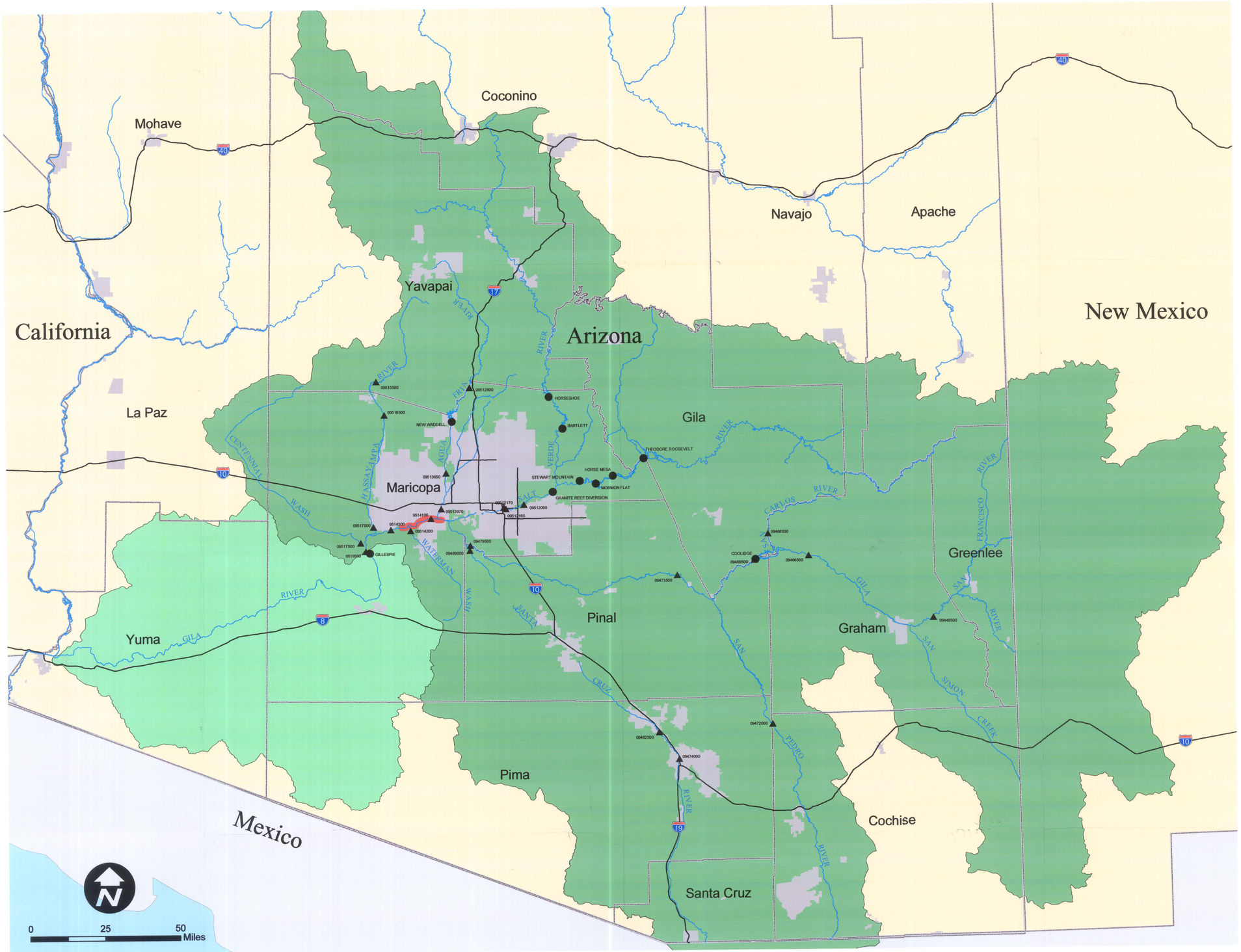
Flood Control District of Maricopa County
Gila River Sediment Program

Figure No.

Plate 2.3

Title

Location of Previous Sample Sites East Section



Legend

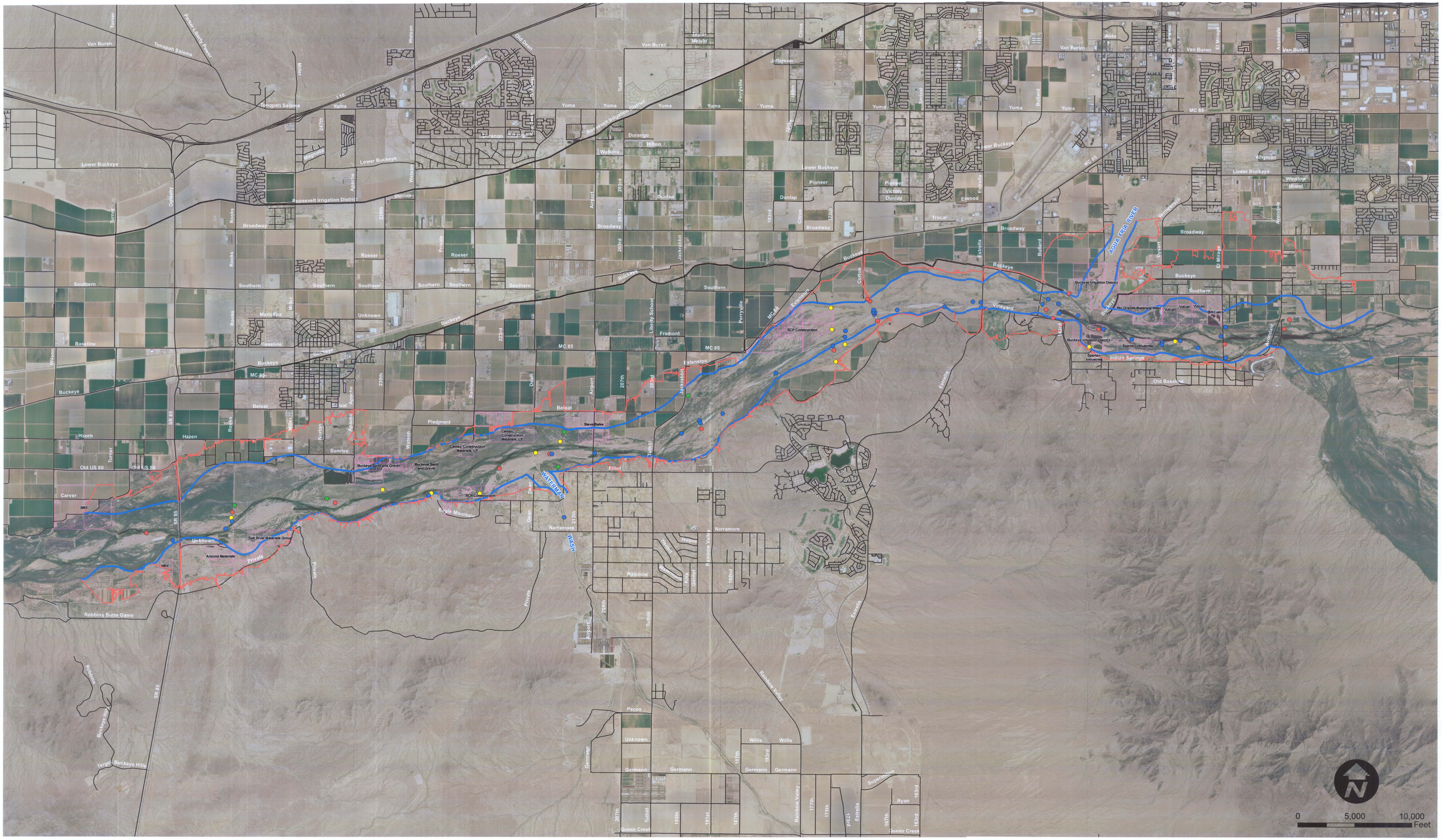
- USGS Gaging Station
- Dam
- River
- Interstate
- State Line
- Counties
- City
- Project Area
- Watershed Boundary Downstream of Gillespie Dam
- Watershed Boundary Upstream of Gillespie Dam

Client/Project

Flood Control District of Maricopa County
Gila River Sediment Program
FCD 2007C017

Figure No. **Plate 3**

Title **Watershed Map**



Legend

- SOIL TYPE A
- SOIL TYPE B
- SOIL TYPE C
- MIXED SOIL TYPE
- 100-YR PROJECT FLOODWAY
- 100-YR PROJECT FLOODPLAIN
- SAND & GRAVEL SITE

Client/Project

Flood Control District of Maricopa County
Gila River Sediment Program

Figure No.

Plate 4

Title

Spatial Distribution of Samples by Soil Type

Attachment A

CD of Geodatabase, Spreadsheet and MRPP Program

Attachment B

Right-of Entry Documents, SHPO Clearance Letter & Floodplain Use Permit

Maricopa County

Public Works

2901 W. Durango St
Phoenix, AZ 85009
Phone: 602-506-2055
Fax: 602-506-4161
www.maricopa.gov

US Stone and Gravel LLC
~~75 Manhattan Drive, Suite 203~~ 2975 Valmont Road #230
~~Boulder, CO 80303~~ Boulder, CO 80301

August 5, 2008

Subject: Project Control No. 126.05.20 – Gila River Sediment project

Dear Sirs:

The Flood Control District of Maricopa County [District] is in the process of collecting sediment samples from various locations along the Gila River bed from SR 85 on the west to approximately Avondale Blvd. on the east. The purpose of the sample collections is to characterize the bed material size gradations along this reach of the Gila River. A backhoe will be used to collect the samples and the sites are located so that the backhoe can reach them.

Our records indicate that it is necessary to cross properties owned by you in order to access three of the proposed locations. I have enclosed for your records a map and a table detailing the location.

This* Letter Form Right-of-Entry *grants the District and its agents a temporary right of ingress & egress across your property.

The District is offering a payment of **One Hundred and no/100 Dollars** [$100.00] to each property owner within the Project. We consider this payment to be "just compensation" for the minimal right requested.

To be valid, this **Letter Form Right-of-Entry** must have the Owner's, or legal representative's written acceptance granting the District and its agents the herein described right. If the Letter is satisfactory to you, please sign and date at the bottom right of this letter and return in the enclosed self addressed stamped envelope. Please retain the copy of this letter marked "Owner's Copy" for your records.

The District herein agrees to be liable for damages caused by itself or its agents upon your property.

Should you have any questions regarding this matter, please feel free to contact me at 602.506.4650, or e-mail me at patmertz@mail.maricopa.gov.

Respectfully,

J. Patrick Mertz

J. Patrick Mertz, SR/WA
Right of Way Agent
Public Works Real Estate Division
Enclosure

US Stone and Gravel LLC
~~75 Manhattan Drive, Suite 203~~ 2975 Valmont Road #230
~~Boulder, CO 80303~~ Boulder, CO 80301

Approved:

By: _____
US Stone and Gravel LLC
Leed Weinstein

Its: Mgr.

3/23/08
Date

Maricopa County
Public Works

2901 W. Durango St
Phoenix, AZ 85009
Phone: 602-506-2055
Fax: 602-506-4161
www.maricopa.gov

ACKA No. 7 Limited Partnership
5340 W. Luke Ave.
Glendale, AZ 85301

August 26, 2008

Subject: Project Control No. 126.05.20 – Gila River Sediment project

Dear Sirs:

The Flood Control District of Maricopa County [District] is in the process of collecting sediment samples from various locations along the Gila River bed from SR 85 on the west to approximately Avondale Blvd. on the east. The purpose of the sample collections is to characterize the bed material size gradations along this reach of the Gila River. A backhoe will be used to collect the samples and the sites are located so that the backhoe can reach them.

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The District herein agrees to be liable for damages caused by itself or its agents upon your property.

Should you have any questions regarding this matter, please feel free to contact me at 602.506.4650, or e-mail me at patmertz@mail.maricopa.gov.

Respectfully,

J. Patrick Mertz

J. Patrick Mertz, SR/WA
Right of Way Agent
Public Works Real Estate Division
Enclosure

ACKA No. 7 Limited Partnership
5340 W. Luke Ave.
Glendale, AZ 85301

Approved:

By: _____ Douglas W. STECKER
ACKA No. 7 Limited Partnership

Its: PARTNER

_____
Date August 28, 2008

Maricopa County
Public Works

2901 W. Durango St
Phoenix, AZ 85009
Phone: 602-506-2055
Fax: 602-506-4161
www.maricopa.gov

Airport Road Mining Co., LLC
20600 W. Beloat Road
Buckeye, AZ 85326

August 5, 2008

Subject: Project Control No. 126.05.20 – Gila River Sediment project

Dear Sirs:

The Flood Control District of Maricopa County [District] is in the process of collecting sediment samples from various locations along the Gila River bed from SR 85 on the west to approximately Avondale Blvd. on the east. The purpose of the sample collections is to characterize the bed material size gradations along this reach of the Gila River. A backhoe will be used to collect the samples and the sites are located so that the backhoe can reach them.

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Should you have any questions regarding this matter, please feel free to contact me at 602.506.4650, or e-mail me at patmertz@mail.maricopa.gov.

Respectfully,

J. Patrick Mertz

J. Patrick Mertz, SR/WA
Right of Way Agent
Public Works Real Estate Division
Enclosure

Airport Road Mining Co., LLC
20600 W. Beloat Road
Buckeye, AZ 85326

Approved:

By: Steve Baker
Airport Road Mining Co., LLC

Its: MANAGER

8-22-08
Date

Maricopa County
Public Works

2901 W. Durango St
Phoenix, AZ 85009
Phone: 602-506-2055
Fax: 602-506-4161
www.maricopa.gov

Mr. and Mrs. Jose Paredes
21305 W. Beloat Road
Buckeye, AZ 85326

August 5, 2008

Subject: Project Control No. 126.05.20 – Gila River Sediment project

Dear Sirs:

The Flood Control District of Maricopa County [District] is in the process of collecting sediment samples from various locations along the Gila River bed from SR 85 on the west to approximately Avondale Blvd. on the east. The purpose of the sample collections is to characterize the bed material size gradations along this reach of the Gila River. A backhoe will be used to collect the samples and the sites are located so that the backhoe can reach them.

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Should you have any questions regarding this matter, please feel free to contact me at 602.506.4650, or e-mail me at patmertz@mail.maricopa.gov.

Respectfully,

J. Patrick Mertz

J. Patrick Mertz, SR/WA
Right of Way Agent
Public Works Real Estate Division
Enclosure

Mr. and Mrs. Jose Paredes
21305 W. Beloat Road
Buckeye, AZ 85326

Approved:

By: _____
Mr. and Mrs. Jose Paredes

~~Its:~~ _____

8-8-08
Date

Maricopa County
Public Works

2901 W. Durango St
Phoenix, AZ 85009
Phone: 602-506-2055
Fax: 602-506-4161
www.maricopa.gov

Buckeye Water Conservation and Drainage District
Buckeye Irrigation District
PO Box 726
Buckeye, AZ 85326

August 5, 2008

Subject: Project Control No. 126.05.20 – Gila River Sediment project

Dear Sirs:

The Flood Control District of Maricopa County [District] is in the process of collecting sediment samples from various locations along the Gila River bed from SR 85 on the west to approximately Avondale Blvd. on the east. The purpose of the sample collections is to characterize the bed material size gradations along this reach of the Gila River. A backhoe will be used to collect the samples and the sites are located so that the backhoe can reach them.

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Respectfully,

J Patrick Mertz

J. Patrick Mertz, SR/WA
Right of Way Agent
Public Works Real Estate Division
Enclosure

Buckeye Water Conservation and Drainage District
Buckeye Irrigation District
PO Box 726
Buckeye, AZ 85326

Approved:

By: Ed Gerak
Buckeye Water Conservation and Drainage District
Buckeye Irrigation District

Its: General Manager

8/8/08
Date

Maricopa County
Public Works

2901 W. Durango St
Phoenix, AZ 85009
Phone: 602-506-2055
Fax: 602-506-4161
www.maricopa.gov

Phoenix Speedway Corp.
125 S. Avondale Blvd., Suite 200
Avondale, AZ 85323

August 5, 2008

Subject: Project Control No. 126.05.20 – Gila River Sediment project

Dear Sirs:

The Flood Control District of Maricopa County [District] is in the process of collecting sediment samples from various locations along the Gila River bed from SR 85 on the west to approximately Avondale Blvd. on the east. The purpose of the sample collections is to characterize the bed material size gradations along this reach of the Gila River. A backhoe will be used to collect the samples and the sites are located so that the backhoe can reach them.

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The District herein agrees to be liable for damages caused by itself or its agents upon your property. The District further agrees that access across your property shall not be permitted on the following dates: Oct 13th to November 15, 2008 and March 25 to April 28th, 2009.

Should you have any questions regarding this matter, please feel free to contact me at 602.506.4650, or e-mail me at patmertz@mail.maricopa.gov.

Respectfully,

J. Patrick Mertz, SR/WA
Right of Way Agent
Public Works Real Estate Division
Enclosure

Phoenix Speedway Corp.
125 S. Avondale Blvd., Suite 200
Avondale, AZ 85323

Approved:

By: _____
Phoenix Speedway Corp.

Its: President

8-13-08
Date

Maricopa County
Public Works

2901 W. Durango St
Phoenix, AZ 85009
Phone: 602-506-2055
Fax: 602-506-4161
www.maricopa.gov

Tran Holdings
3411 S. Siesta Lane
Tempe, AZ 85282

August 5, 2008

Subject: Project Control No. 126.05.20 – Gila River Sediment project

Dear Sirs:

The Flood Control District of Maricopa County [District] is in the process of collecting sediment samples from various locations along the Gila River bed from SR 85 on the west to approximately Avondale Blvd. on the east. The purpose of the sample collections is to characterize the bed material size gradations along this reach of the Gila River. A backhoe will be used to collect the samples and the sites are located so that the backhoe can reach them.

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Respectfully,

J. Patrick Mertz

J. Patrick Mertz, SR/WA
Right of Way Agent
Public Works Real Estate Division
Enclosure

Tran Holdings
3411 S. Siesta Lane
Tempe, AZ 85282

Approved:

By: _____
Tran Holdings

Its: Owner/Manager

08/12/08
Date

OFFICIAL RECORDS OF
MARICOPA COUNTY RECORDER
HELEN PURCELL
2008-0865960 10/07/2008 08:31a
BkFrVgtn_1260420-3-1-1-- Yorkm

Date: September 3, 2008

When recorded, Interoffice Mail to:
Flood Control District
of Maricopa County [ls]

EXEMPT ARS § 11-1134, A3

Resolution FCD 2006G001

TEMPORARY RIGHT-OF-ENTRY
EASEMENT AND AGREEMENT FOR FLOOD CONTROL PURPOSES

Project: Buck Fire Re-Vegetation Project
PCN: 126.04.20

This Right-of-Entry Easement and Agreement is made this 1st day of October, 2008, by and between the following parties, and shall become effective upon the acceptance by the Board of Directors of the Flood Control District.

GRANTOR: **ARLINGTON CANAL COMPANY,** an Arizona corporation.

GRANTEE: **FLOOD CONTROL DISTRICT OF MARICOPA COUNTY**, a municipal corporation and political subdivision of the State of Arizona, its agents, contractors, successors, and assigns.

FOR AND IN CONSIDERATION of the sum of **Five Hundred Dollars ($500.00)**, and other valuable consideration, the receipt and sufficiency of which are hereby acknowledged, **GRANTOR** does hereby grant and convey to **GRANTEE**, a Right-of-Entry Easement and Agreement for the following purpose:

The right of ingress and egress, over the existing right of way of the Arlington Canal Company located between the Miller Road alignment and the Rooks Road alignment located in the S2S2 of Section 7, Township 1 South, Range 3 West of the Gila and Salt River Base and Meridian, Maricopa County, Arizona.

Agreement terms shall be as follows:

The right of ingress and egress shall remain in force for up to ten (10) years from date of execution of Agreement, for the continued monitoring of the vegetation growth.

To the extent permitted by law, **GRANTEE** agrees to indemnify **GRANTOR** for all direct damages to the real property, personal property, or physical injury to persons on the property of **GRANTOR**, caused by or arising from the proximate result of the activities of **GRANTEE**, its officers, employees, agents or contractors in the exercise of **GRANTEE'S** rights pursuant to the terms of this Right-of-Entry Easement and Agreement.

Dated this 10 day of Sept, 2008.

Gary P. Gable President

Grantor

Grantor

STATE OF ARIZONA)
)ss.
COUNTY OF MARICOPA)

Before me, BLANCA VILLAREAL, Notary Public in and for said County, State of Arizona, on this day personally appeared GARY P. GABLE and _____, known to me to be the person(s) whose name(s) is subscribed to the foregoing instrument as Board Member(s) of the Arlington Canal Company, an Arizona Corporation described in the foregoing instrument, and as such he/she/ acknowledged to me that he/she executed the same for said Corporation, for the purpose and consideration therein expressed, as its free act and deed and by each of them voluntarily executed.

Given under my hand and seal of office, this 10TH day of September, 2008.

My Commission Expires FEB-01-2010

Notary Public (signature)

OFFICIAL SEAL
BLANCA G. VILLAREAL
NOTARY PUBLIC - ARIZONA
MARICOPA COUNTY
My Commission Expires Feb 1, 2010

RECOMMENDED FOR APPROVAL:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

9/25/08

Timothy S. Phillips, P.E. Date
Chief Engineer and General Manager

9/24/08

Michael D. Wilson Date
Manager
Public Works Real Estate Division

APPROVED AND ACCEPTED:

BOARD OF DIRECTORS OF FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

Chairman of the Board

ATTEST:

ASSISTANT DEPUTY Clerk of the Board

Date: OCT 01 2008

FLOOD CONTROL DISTRICT of Maricopa County
2801 West Durango Street
Phoenix, Arizona 85009
Office (602) 506-1501 – Fax (602) 372-6232

FLOODPLAIN USE PERMIT: FAC09-009 - Excavate Sediment Sampling for Analysis @ Address - Varies

STANDARD STIPULATIONS:

1. Development to be in compliance with the Resource Sample Site List dated on 2/17/09.
2. Applicant shall submit a Warning and Disclaimer of Liability Notice.
3. Flood Control District approval is for Floodplain purposes only, based upon how the proposed development affects the effective floodplain.
4. This permit may be declared null and void if substantial progress of development does not occur within one year of approval or for any substantial deviation from the approved plan or for any violation of the Floodplain Regulation or any stipulations or other terms or agreement in connection with approval of this permit.
5. Approval of this permit does not convey any property rights, either real estate or material, and is not to be construed as consent, approval or authorization to cause any injury to property or invasion of rights or the infringement of any Federal, State or other local laws, rules or regulations nor does it obviate the requirement to obtain other permits. Furthermore, the plan review by the District has been solely for the purpose of determining that your application conforms with the written requirements of the Floodplain Regulation for Maricopa County and is not to be taken as a warranty that structural plans and specifications meet engineering requirements or standards or are free from failure to perform as described or designed in the application, reports or plans as submitted. Approval does not imply that the total drainage concept for the site has been reviewed or approved by our office.

ADDITIONAL STIPULATIONS:

6. The plan for Sediment Sampling for an analysis test, approximately 10'x10'x8' deep pits, shall be required to include a plan of reclamation to leave the land when the approved use is terminated in such a condition as to maintain stability of the floodway by backfilling, contouring, leveling, revegetation, removal of equipment and materials or other appropriate means.
7. Applicant must secure property rights from all owners prior to any excavation.
8. The applicant shall be responsible for being informed of any flooding that may be imminent and for removing portable equipment and stockpile of materials in the floodplain during development.
9. The applicant shall be responsible to maintain historical drainage or tributary flow of the channel or watercourse.
10. The applicant shall obtain all approvals necessary prior to any development.

Applicant _____ **Date** 2/27/09

Floodplain Administrator Kelly A. Serfield **Date** Feb 27, 2009

FOR INSPECTION CALL (602) 506-0228 / 24 HOUR RECORDING NUMBER
Or visit our website at www.fcd.maricopa.gov

Base Floodplain Elevation
FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
Floodplain Administration

Application Information

Number FAC09-009 Category One (1) Date 2/18/2009 Type Use Permit

Request Excavate Sediment Sampling for Analysis

Elevation Certificate 404 ADEQ Other

Status PENDING Expiration Date Fee $0.00

Approved By Action Date Report Date

Reviewed By DJL Reference Receipt No. EXEMPT

Applicant Information

Applicant FCDMC - John Hathaway

Mailing Address 2801 W. Durango Street

City, State, ZIP Code Phoenix, AZ 85009

Phone 602-506-0503

Consultant Stantec Consulting, Inc

Property Information

Property Address Non-assigned Parcel Various

1/4 Section Section, Township, Range Various--

Floodplain Salt/Gila River MP Community 040037 - Maricopa County; 040039 -Buckeye

FIRM 2505H, 2510G Floodplain Map FCD92-01 Zone AE/X/FW BFE Varies

Synopsis RFE: Varies

Flood Control District
of Maricopa County

APPLICATION TO FLOODPLAIN ADMINISTRATOR

(Completed by Applicant or Agent)

Applicant: John Hathaway - Flood Control District of Maricopa County

Mailing Address: 2801 W. Durango St City Phoenix State AZ ZIP 85009

Phone Number: 602-506-0503 Business Phone Number (if applicable) _____

Assessor Book Number See Attached Map Number _____ Parcel Number _____

Property Address See Attached

¼ Section " Section " Township " Range "

Consultant Stephanie Gerlach - Stantec Consultants Phone No. 602-707-4630

Purpose of Application Sediment sampling an analysis under contract to the Flood Control District - Gila River (El Rio)

Applicant Statement (justification or hardship if variance; grounds for appeal) Excavate test pits approx. 10'x10'x8' deep, collect approx. 1 ft³ sample and re fill pit. Total disturbance < 0.1 Acre.

APPLICANT SIGNATURE _____ DATE 2/17/09

For Flood Control District use only

FAC09-009 ☒ Use Permit ☐ Variance ☐ Appeal Supervisory Dist 5 Fee N/A

Floodplain SALT/GILA RIVER MP Flood Map FCD 92-01 FIRM 2505H 2510G Zone AE/X/FW Date _____

Map Date _____ FIRM BFE VARIES Regulatory Flood Elevation VARIES

Additional Documentation: ☐ Notification of Variance ☐ 404 ☐ ADEQ ☐ Surety

☐ Elevation/Floodproofing Certificate ☒ Warning and Disclaimer of Liability

☐ Recorded Notice ☐ Flood Damage Statement ☐ Coordination _____ Agency

For Floodplain Administrator's use only

Approved subject to attached stipulations _____ Floodplain Administrator 2/27/2009 Date

For Board of Review use only

ACTION TAKEN: Approved _____ Date Denied _____ Date Continuance _____ Date

BOARD ACTION CONFIRMED: _____ **DATE** _____

FCDMC Rev. 6/2007

Flood Control District
of Maricopa County

WARNING AND DISCLAIMER OF LIABILITY

A Floodplain Regulation for Maricopa County has been in force since February 25, 1974. The current version of the Floodplain Regulation for Maricopa County, Arizona was adopted on August 4, 1986, and amended March 23, 1987, April 6, 1988, September 18, 1989, September 3, 1991, December 15, 1993, November 1, 2000, and December 20, 2006. Its intent is to prevent the dangerous and expensive misuse of floodplains in Maricopa County

A Floodplain as defined in the Regulations is the areas adjoining the channel of a watercourse including areas where drainage is or may be restricted by man-made structures which have been or may be covered partially or wholly by floodwater from the 100-year flood.

Depending on the location of your property it could possibly be inundated by greater frequency flood events (those occurring more often). A flood greater in magnitude than the 100-year flood could also occur.

The review your use has undergone is solely for the purpose of determining if your application conforms with the written requirements of the Floodplain Regulation for Maricopa County. It is not to be taken as a warranty. Compliance with this Regulation does not insure complete protection from flooding. The Floodplain Regulation meets established standards for floodplain management, but neither this review nor the Regulation take into account such flood related problems as natural erosion, streambed meander or man-made obstructions and diversions all of which may have an adverse affect in the event of a flood. You are advised to consult your own engineer or other expert regarding these considerations.

In consideration for the issuance of the requested permit the applicant, owner, agent, engineer and their successors agree to hold the District harmless from any onsite or offsite damages of any kind arising from the development of the subject property in accordance with their submittals as outlined in the attached permit

I have read and understand the above WARNING AND DISCLAIMER OF LIABILITY.

FA 09-009		2/27/09
Permit No.	Owner or Agent	Date

2801 West Durango Street, Phoenix, Arizona 85009 (602) 506-1501 Fax (602) 372-6232

"Managing and conserving Arizona's natural, cultural and recreational resources"

Arizona State Parks

No historic properties affected

February 10, 2009

Diana Stuart
Environmental Program Manager
Flood Control District of Maricopa County
2801 West Durango Street
Phoenix AZ 85009

RE: Gila River Channel Sediment Sampling Program, El Rio Watercourse Master Plan Implementation; MCFCD
SHPO-2008-1992 (38873)

Dear Ms. Stuart:

Thank you for consulting with us about the above referenced program and for providing the additional information we requested. All of the sampling will occur with the Gila River channel and 100-year floodplain which has been repeatedly scoured by floods.

I concur that no significant cultural resources would be disturbed by the proposed program.

We appreciate the District's continuing efforts to consider the potential impacts to Arizona's cultural resources that might result from the agency's actions.

Sincerely,

Jo Anne Medley
Compliance Specialist/Archaeologist
State Historic Preservation Office

Janice K. Brewer
Governor

State Parks Board Members

Chair
Reese Woodling
Tucson

Arlan Colton
Tucson

Tracey Westerhausen
Phoenix

William C. Cordasco
Flagstaff

Larry Landry
Phoenix

William C. Scalzo
Phoenix

Mark Winkleman
State Land Commissioner

Kenneth E. Travous
Executive Director

Arizona State Parks
1300 W. Washington
Phoenix, AZ 85007

Tel & TTY: 602.542.4174
AZStateParks.com

800.285.3703 from
(520 & 928) area codes

General Fax:
602.542.4180

Director's Office Fax:
602.542.4188

Maricopa County
Public Works

2901 W. Durango St
Phoenix, AZ 85009
Phone: 602-506-2055
Fax: 602-506-4161
www.maricopa.gov

The Brothers Four
3635 S. 43rd Avenue
Phoenix, AZ 85009

August 4, 2008

Subject: Project Control No. 126.05.20 – Gila River Sediment project

Dear Sirs:

The Flood Control District of Maricopa County [District] is in the process of collecting sediment samples from various locations along the Gila River bed from SR 85 on the west to approximately Avondale Blvd. on the east. The purpose of the sample collections is to characterize the bed material size gradations along this reach of the Gila River. A backhoe will be used to collect the samples and the sites are located so that the backhoe can reach them.

Our records indicate that one of the proposed locations is located on property owned by The Brothers Four. I have enclosed for your records a map and a table detailing the location.

This* Letter Form Right-of-Entry *grants the District and its agents a temporary right of ingress & egress and temporary right to conduct sediment sample collections on your property.

The District is offering a payment of **Five Hundred and no/100 Dollars** [$500.00] to each property owner within the Project. We consider this payment to be "just compensation" for the minimal right requested.

To be valid, this **Letter Form Right-of-Entry** must have the Owner's, or legal representative's written acceptance granting the District and its agents the herein described right. If the Letter is satisfactory to you, please sign and date at the bottom right of this letter and return in the enclosed self addressed stamped envelope. Please retain the copy of this letter marked "Owner's Copy" for your records.

The District herein agrees to be liable for damages caused by itself or its agents upon your property.

Should you have any questions regarding this matter, please feel free to contact me at 602.506.4650, or e-mail me at patmertz@mail.maricopa.gov.

Respectfully,

J. Patrick Mertz

J. Patrick Mertz, SR/WA
Right of Way Agent
Public Works Real Estate Division
Enclosure

The Brothers Four
3635 S. 43rd Avenue
Phoenix, AZ 85009

Approved:

By: _____
The Brothers Four

Its: GEN. MGR

8-11-08
Date

Maricopa County
Public Works

2901 W. Durango St
Phoenix, AZ 85009
Phone: 602-506-2055
Fax: 602-506-4161
www.maricopa.gov

RECEIVED
AUG 27 2008
BY:

OWNER'S COPY

HE Capital KR LLC
2850 E. Camelback Road, Suite 110
Phoenix, AZ 85016

August 26, 2008

Subject: Project Control No. 126.05.20 – Gila River Sediment project

Dear Sirs:

The Flood Control District of Maricopa County [District] is in the process of collecting sediment samples from various locations along the Gila River bed from SR 85 on the west to approximately Avondale Blvd. on the east. The purpose of the sample collections is to characterize the bed material size gradations along this reach of the Gila River. A backhoe will be used to collect the samples and the sites are located so that the backhoe can reach them.

Our records indicate that one of the proposed locations is located on property owned by HE Capital KR LLC. I have enclosed for your records a map and a table detailing the location.

This* Letter Form Right-of-Entry *grants the District and its agents a temporary right of ingress & egress and temporary right to conduct sediment sample collections on your property.

The District is offering a payment of **Five Hundred and no/100 Dollars** [$500.00] to each property owner within the Project. We consider this payment to be "just compensation" for the minimal right requested.

To be valid, this **Letter Form Right-of-Entry** must have the Owner's, or legal representative's written acceptance granting the District and its agents the herein described right. If the Letter is satisfactory to you, please sign and date at the bottom right of this letter and return in the enclosed self addressed stamped envelope. Please retain the copy of this letter marked "Owner's Copy" for your records.

The District herein agrees to be liable for damages caused by itself or its agents upon your property.

Should you have any questions regarding this matter, please feel free to contact me at 602.506.4650, or e-mail me at patmertz@mail.maricopa.gov.

Respectfully,

J Patrick Mertz

J. Patrick Mertz, SR/WA
Right of Way Agent
Public Works Real Estate Division
Enclosure

HE Capital KR LLC
2850 E. Camelback Road, Suite 100
Phoenix, AZ 85016

Approved:

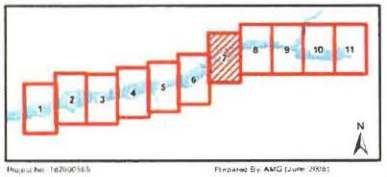
By: _____
HE Capital KR LLC

Its: Officer

9.19.08
Date

Table 6
Sample Sites on Private Properties

Sample Site	Owner	Sample Location Township Range Section	Q1 Q2	Lat	Long	Parcel No.
5d	Brothers Four The	T1S R3W 12	SW SE	33° 20' 57" N	112° 30' 53" W	400-02-004-A
9c	Buckeye Water CONS & DRN DIST	T1N R1W 33	SE NE	33° 23' 0" N	112° 21' 29" W	500-79-012-B
9d	Buckeye Water CONS & DRN DIST	T1N R1W 33	SE SE	33° 22' 41" N	112° 21' 32" W	500-79-004-B
7e	HE CAPITAL KR LLC	T1N R2W 35	SE SE	33° 22' 44" N	112° 25' 51" W	502-59-007-A



Project No. 1628001613

Prepared By: AMG (June 2008)

Legend:

- WEST Consultants
- Construction & Inspection CO
- Proposed Location
- El Rio
- Terracon
- H Gate
- Access Route
- Sand & Gravel Site
- 1,000 ft Corridor
- BLM
- Indian Res.
- Local or State Parks
- Game & Fish
- State Trust
- Parcel

N

1" = 1,000'

0 500 1,000 Feet

Gila River Sediment Program Sampling Sites

Stantec Consulting Inc.
8211 S. 48th Street
Phoenix, AZ U.S.A. 85044

Stantec

Maricopa County

Parks & Recreation Department

234 N. Central Avenue
Suite 6400
Phoenix, AZ 85004-2208
Phone: (602) 506-2930
Fax: (602) 506-4692

September 16, 2008

Maricopa County Public Works
C/O J. Patrick Mertz, Right-Of-Way Agent
Public Works Real Estate Division
2901 W. Durango Street
Phoenix, AZ 85009

Subject: Project Control No. 126.05.20 – Gila River Sediment program

Dear Mr. Mertz :

We are in receipt of your letter dated August 1, 2008, regarding Maricopa County Flood Control's request to collect sediment samples along the section of the Gila River. We also recognize your request to remove a sample from Maricopa County Park and Recreation's park proper at the Estrella Mountain Regional Park.

We authorize the excavation to the maximum of 10 feet and the maximum removal of ½ to 1 cubic foot of material replacing the remaining material in the approximate vicinity East of the Bullard Bridge at site 9a and 9b respectively from the map provided. The following conditions will apply:

1) Must have letter during sampling;
2) Cannot disturb any vegetation in the area;
3) Allowed to use small back hoe;
4) Must contact park supervisor at (623) 932-3811 prior to sampling to insure proper notification to park staff;
5) Must be no evidence that a sample was removed or that there was equipment on site;
6) If conditions are unsafe such as but not limited to ground too soft to travel on, sampling is not allowed to occur and must be rescheduled;
7) The process of gathering is at your own risk and Parks is not responsible for injury or equipment;
8) No dust is allowed during removal of sample or during the driving to and from site area; and
9) Flood Control must have permission to travel on properties by proper authorities needed to get to sampling location.

If you have any questions, please feel free to contact me at 480.888.5353

Sincerely,

Teresa Retterbush

Teresa Retterbush
Regional Superintendent

/jw

CC: Carolyn Mayberry, Park Supervisor
Ken Mouw, Engineering Manager
Chrono and Central Files

Maricopa County
Public Works

2901 W. Durango St
Phoenix, AZ 85009
Phone: 602-506-2055
Fax: 602-506-4161
www.maricopa.gov

Buckeye Water Conservation and Drainage District
PO Box 726
Buckeye, AZ 85326

August 4, 2008

Subject: Project Control No. 126.05.20 – Gila River Sediment program

Dear Sirs:

The Flood Control District of Maricopa County [District] is in the process of collecting sediment samples from various locations along the Gila River bed from SR 85 on the west to approximately Avondale Blvd. on the east. The purpose of the sample collections is to characterize the bed material size gradations along this reach of the Gila River. A backhoe will be used to collect the samples and the sites are located so that the backhoe can reach them.

Our records indicate that two of these proposed locations are located on lands owned by the Buckeye Water Conservation and Drainage District. I have enclosed for your records a map and a table detailing these locations.

This* Letter Form Right-of-Entry *grants the District and its agents a temporary right of ingress & egress and temporary right to conduct sediment sample collections on your property.

The District is offering a payment of **Five Hundred and no/100 Dollars** [$500.00] to each property owner within the Project. We consider this payment to be "just compensation" for the minimal right requested.

To be valid, this **Letter Form Right-of-Entry** must have the Owner's, or legal representative's written acceptance granting the District and its agents the herein described right. If the Letter is satisfactory to you, please sign and date at the bottom right of this letter and return in the enclosed self addressed stamped envelope. Please retain the copy of this letter marked "Owner's Copy" for your records.

The District herein agrees to be liable for damages caused by itself or its agents upon your property.

Should you have any questions regarding this matter, please feel free to contact me at 602.506.4650, or e-mail me at patmertz@mail.maricopa.gov.

Respectfully,

J. Patrick Mertz, SR/WA
Right of Way Agent
Public Works Real Estate Division
Enclosure

Buckeye Water Conservation and Drainage District
PO Box 726
Buckeye, AZ 85326

Approved:

By: Ed Zerak
Buckeye Water Conservation and Drainage District

Its: General Manager

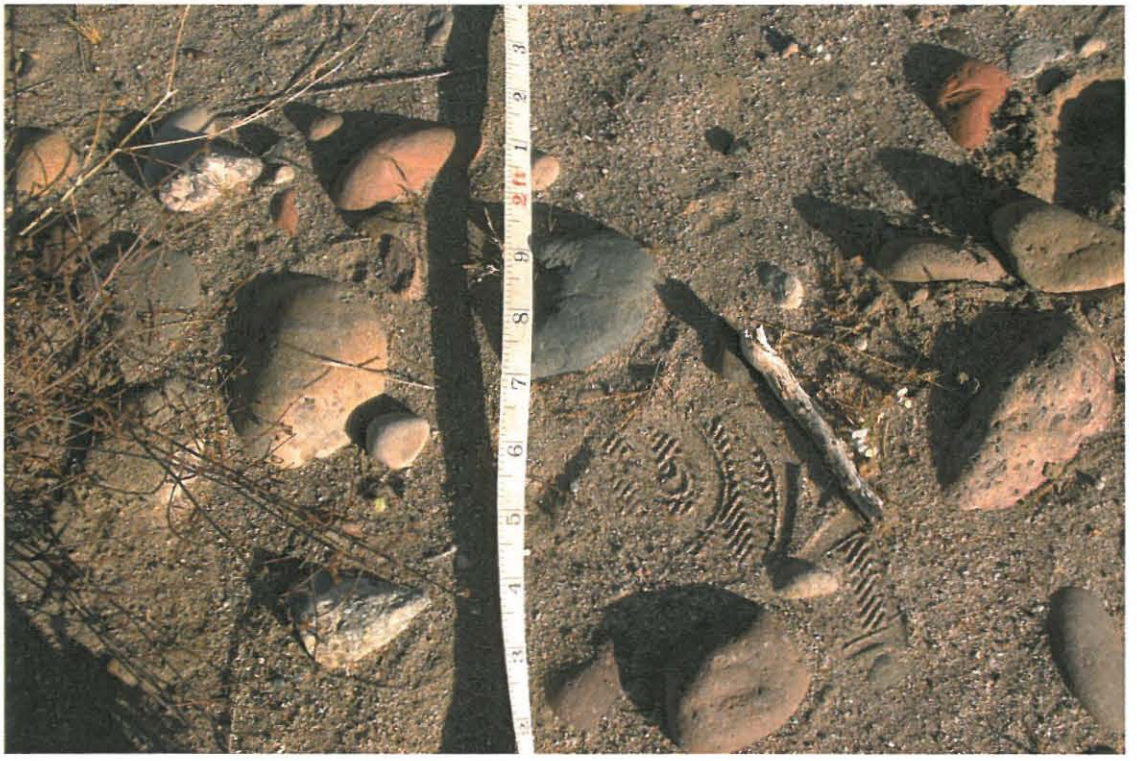
8/8/08
Date

Attachment C

Photographs of Sample Sites

Site 1 - Looking Upstream

Site 1 - Looking Downstream



Site 1 - Ground

Site 1 - Ground

Site 1 - Ground

Site 1 - Ground

Site 1 - Ground

Site 1 - Ground

Site 1 - Test Pit

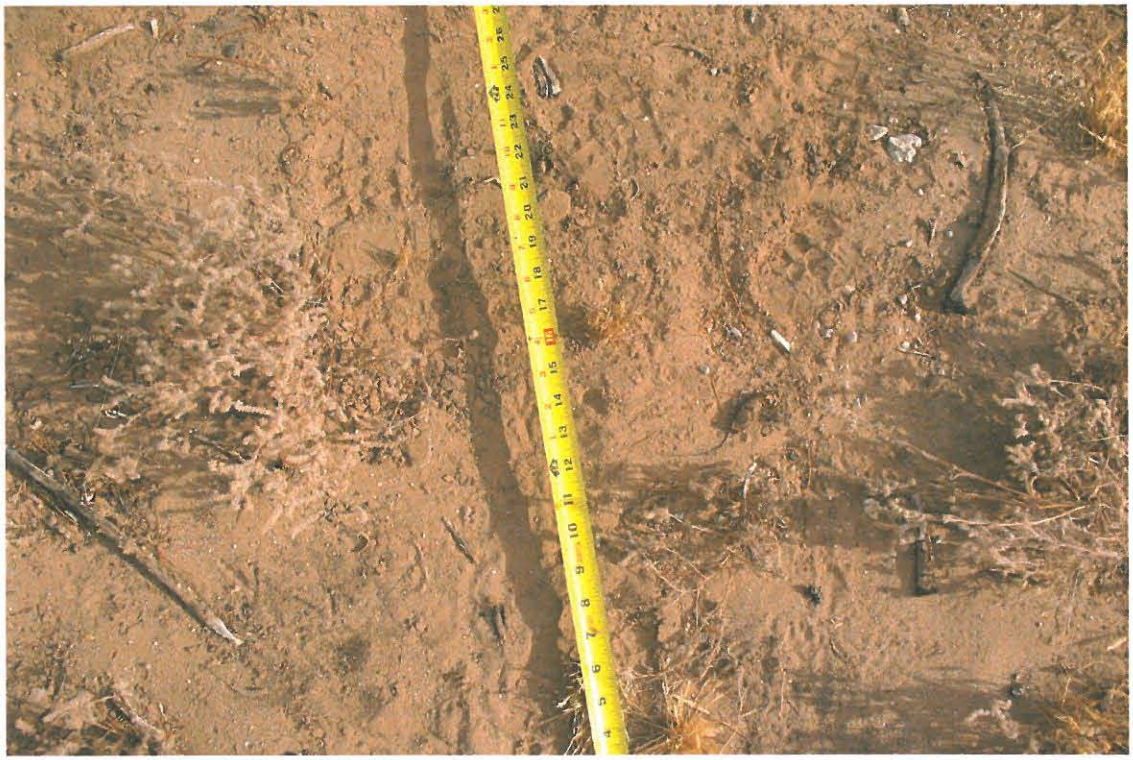
Site 1 - Bottom of Test Pit

Site 1 - Middle of Test Pit

Site 1 - Top of Test Pit

Site 2A - Looking Upstream

Site 2A - Looking Downstream



Site 2A - Ground

Site 2A - Test Pit

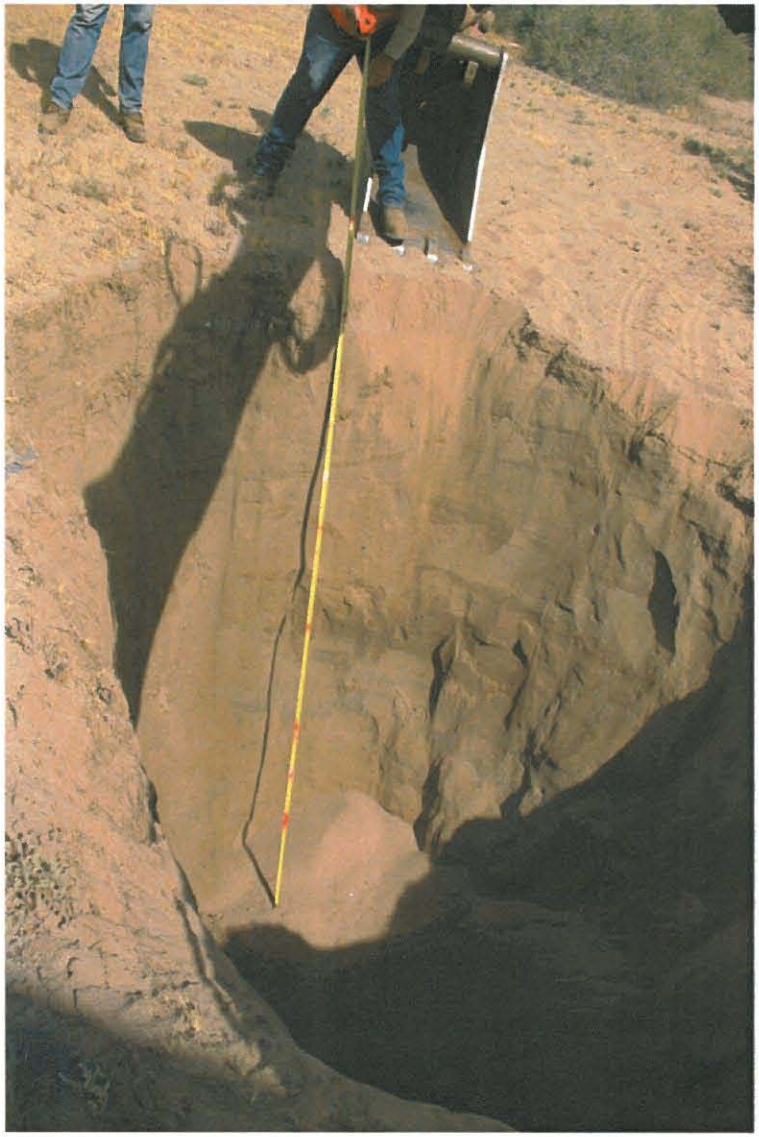
Site 2A - Bottom of Test Pit

Site 2A - Top of Test Pit

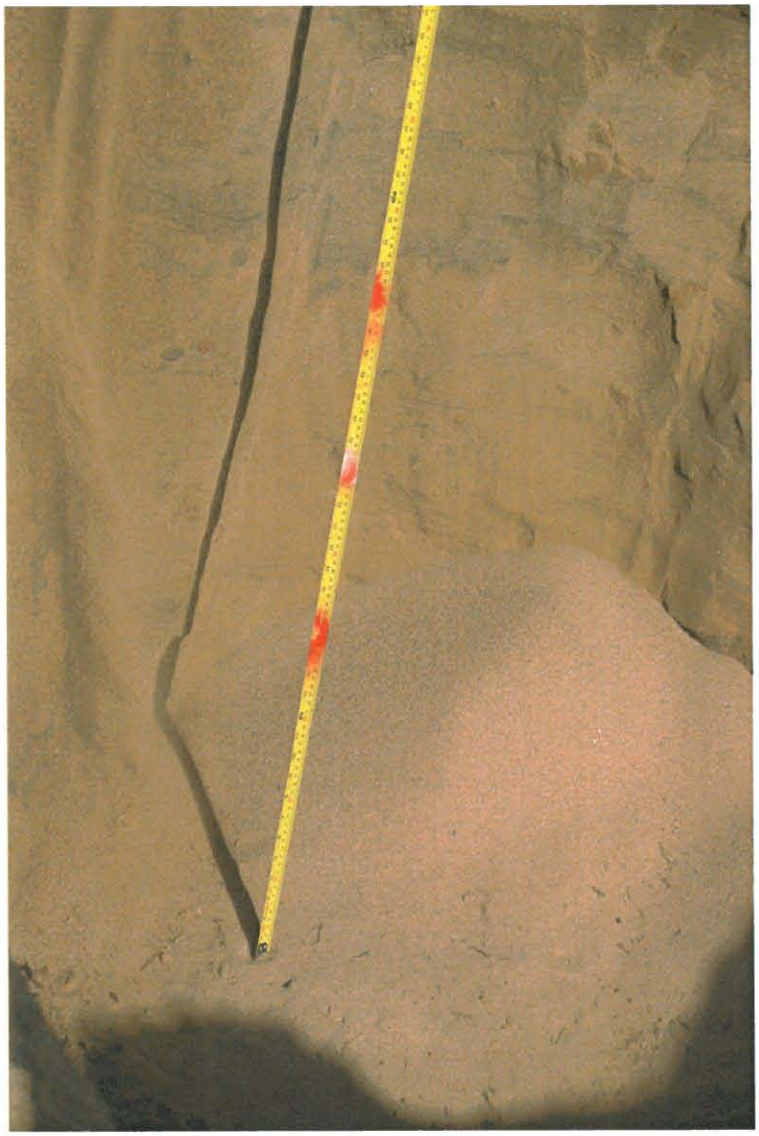
Site 2B - Looking Upstream

Site 2B - Looking Downstream

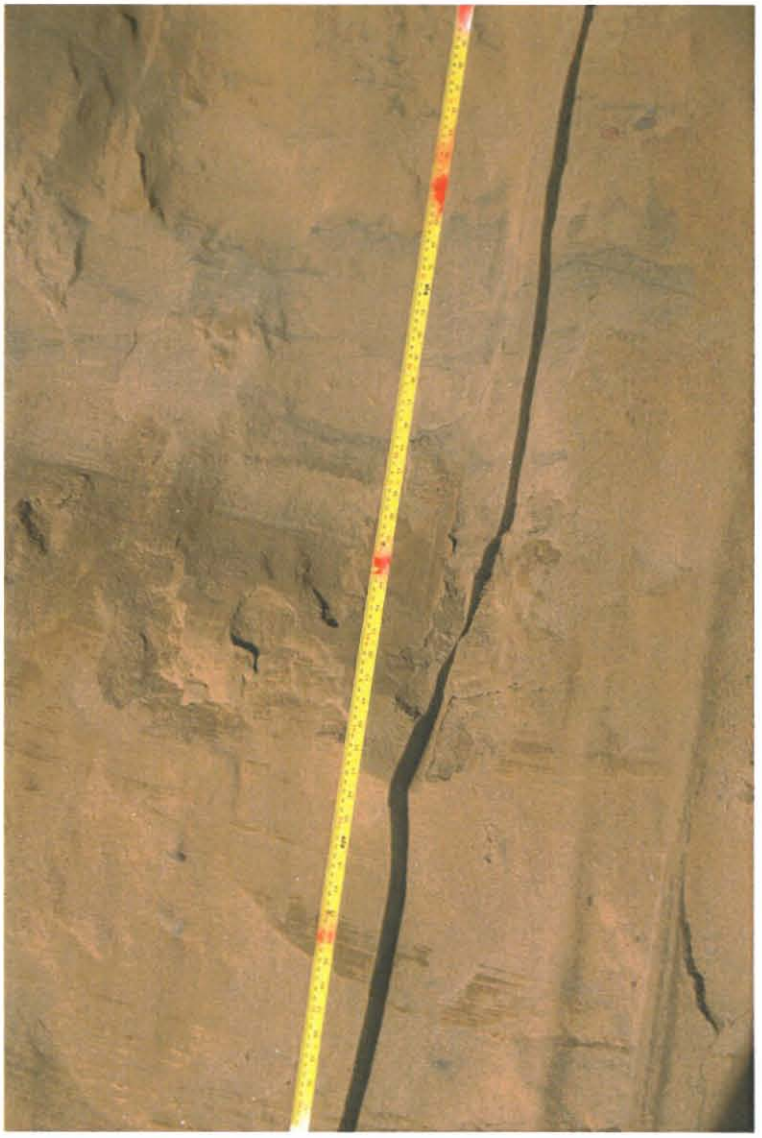
Site 2B - Ground



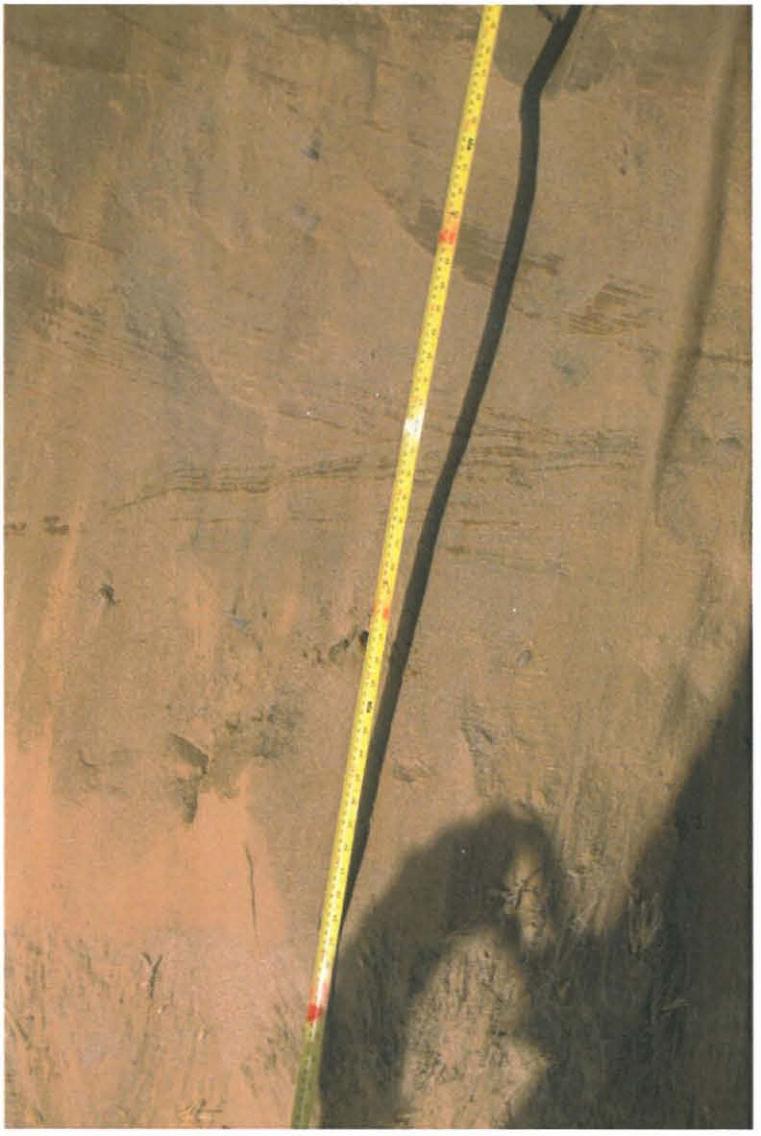
Site 2B - Test Pit



Site 2B - Bottom of Test Pit



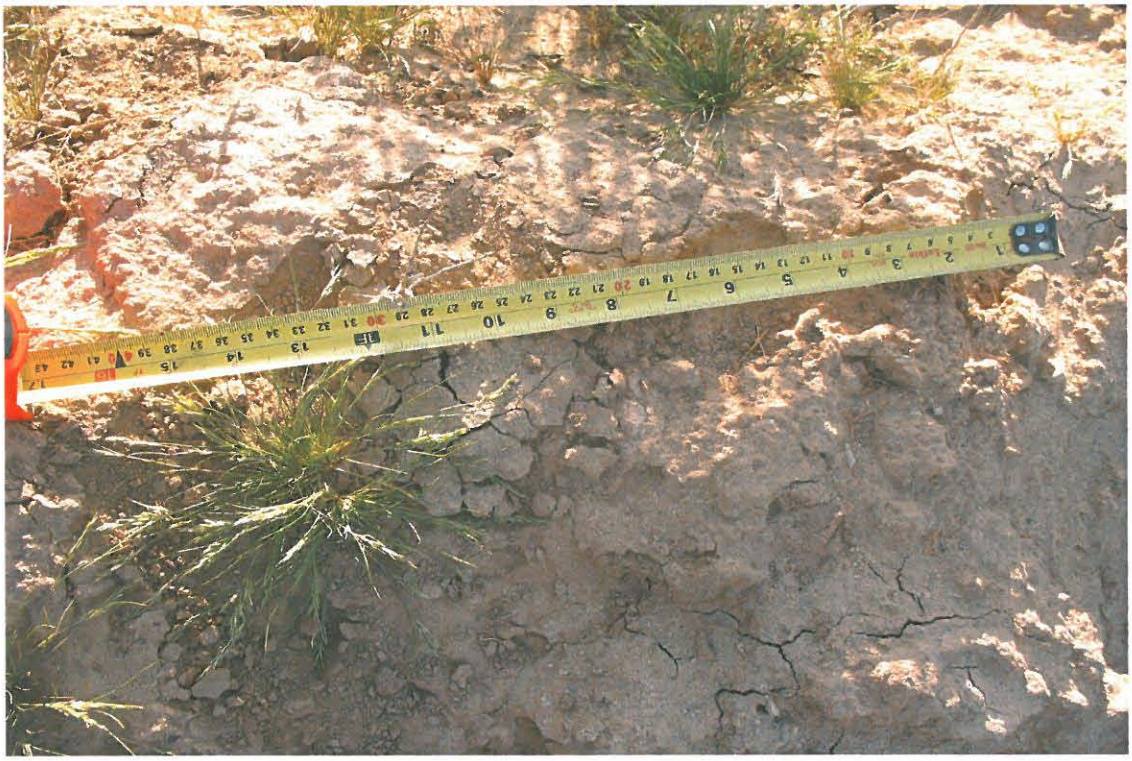
Site 2B - Middle of Test Pit



Site 2B - Top of Test Pit

Site 2C1 - Looking Upstream

Site 2C1 - Looking Downstream



Site 2C1 - Ground

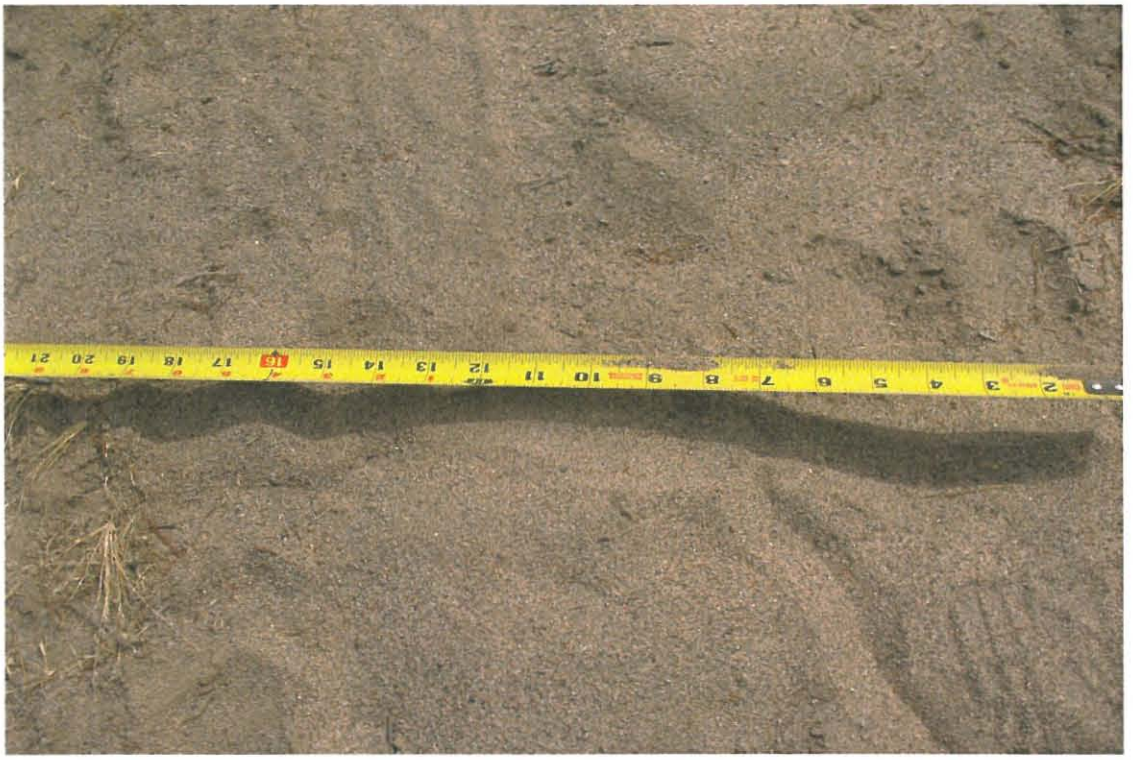
Site 2C1 - Test Pit

Site 2C1 - Bottom of Test Pit

Site 2C1 - Top of Test Pit

Site 2C - Looking Upstream

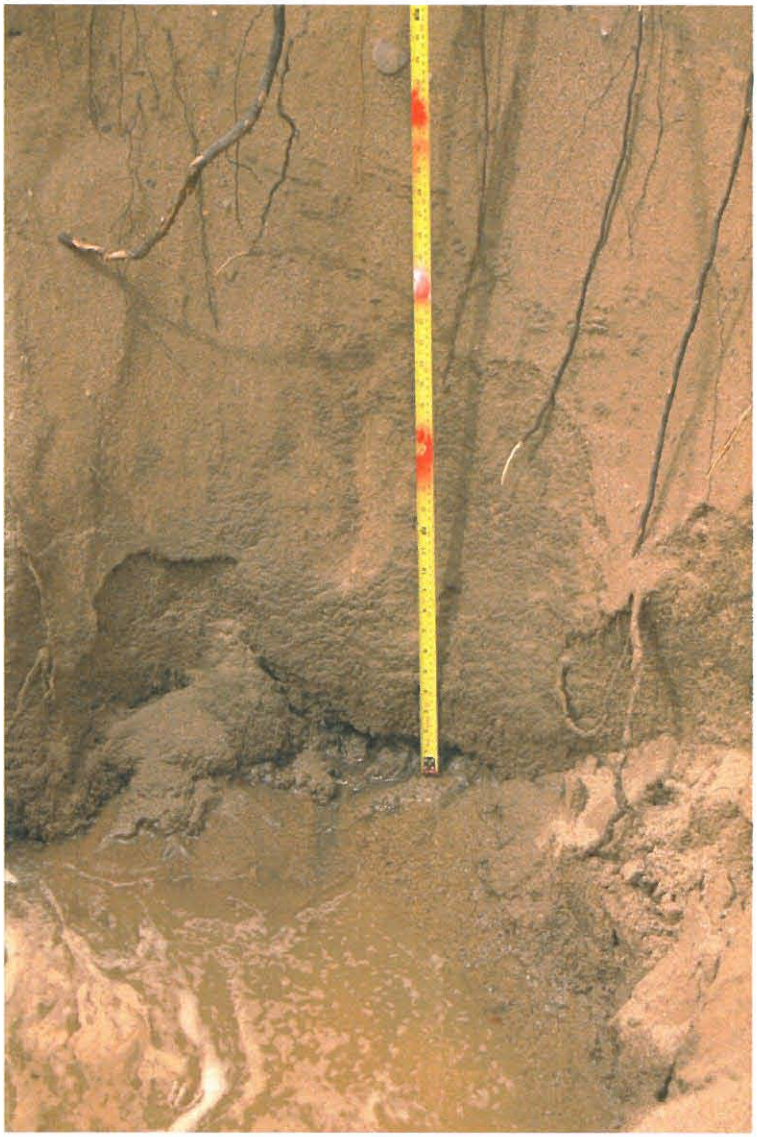
Site 2C - Looking Downstream



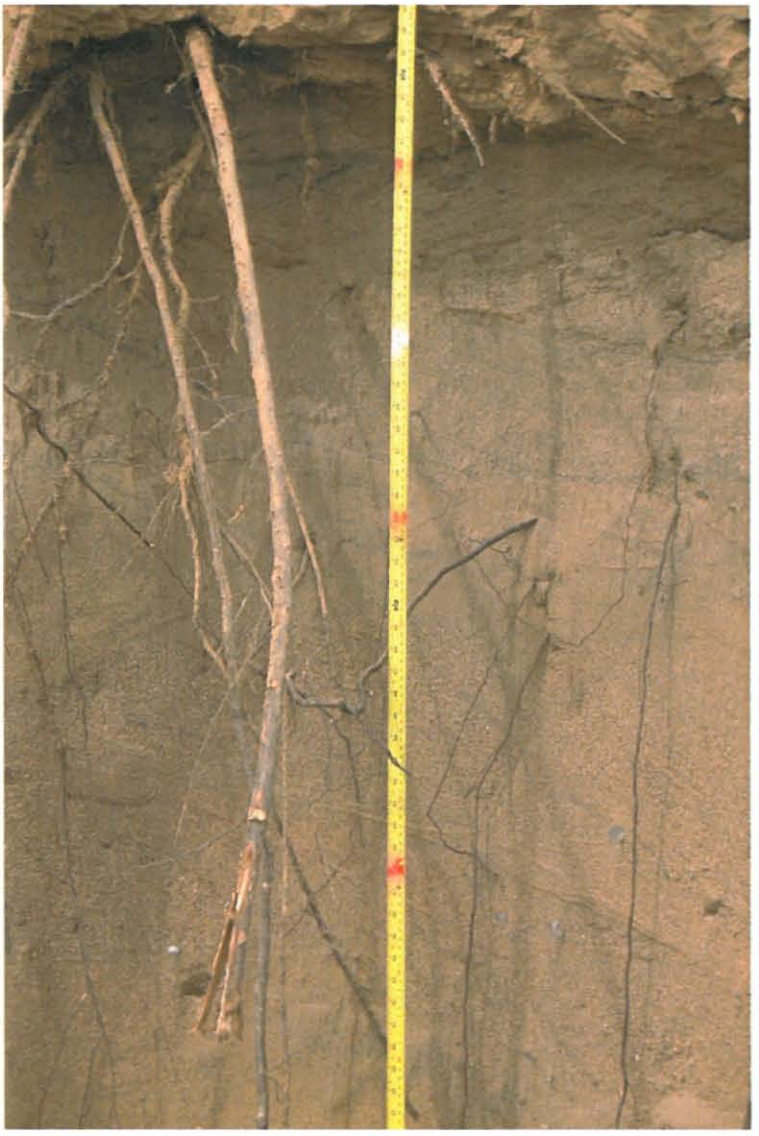
Site 2C - Ground

Site 2C - Site

Site 2C - Test Pit



Site 2C - Bottom of Test Pit



Site 2C - Top of Test Pit

Site 2D - Looking Upstream

Site 2D - Looking Downstream

Site 2D - Ground

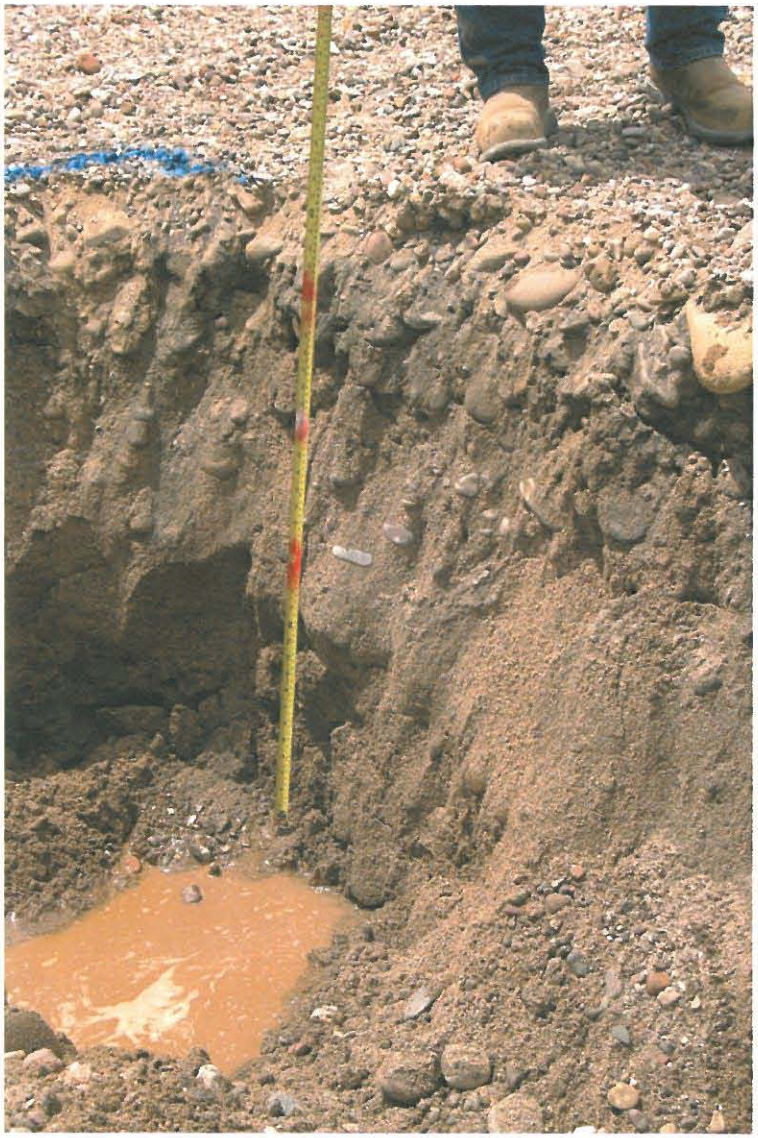
Site 2D - Ground

Site 2D - Ground

Site 2D - Ground

Site 2D - Ground

Site 2D - Ground



Site 2D - Test Pit

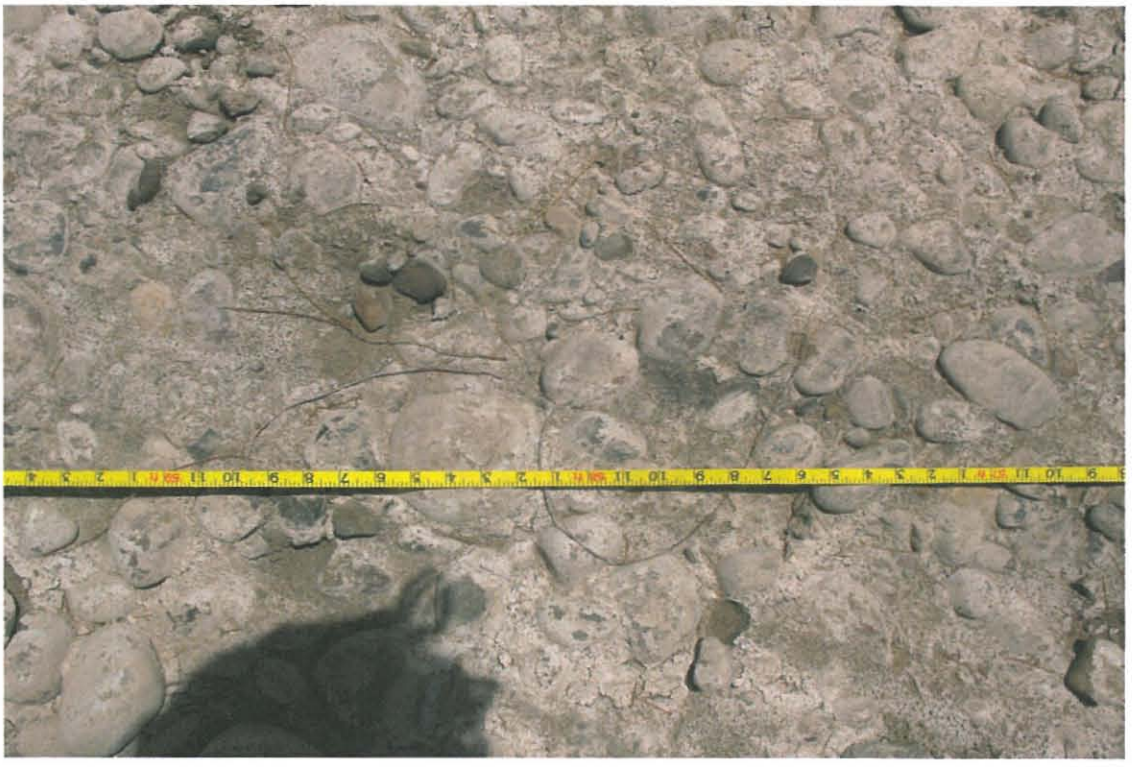
Site 2E - Looking Upstream

Site 2E - Looking Downstream

Site 2E - Ground

Site 2E - Ground

Site 2E - Ground



Site 2E - Ground

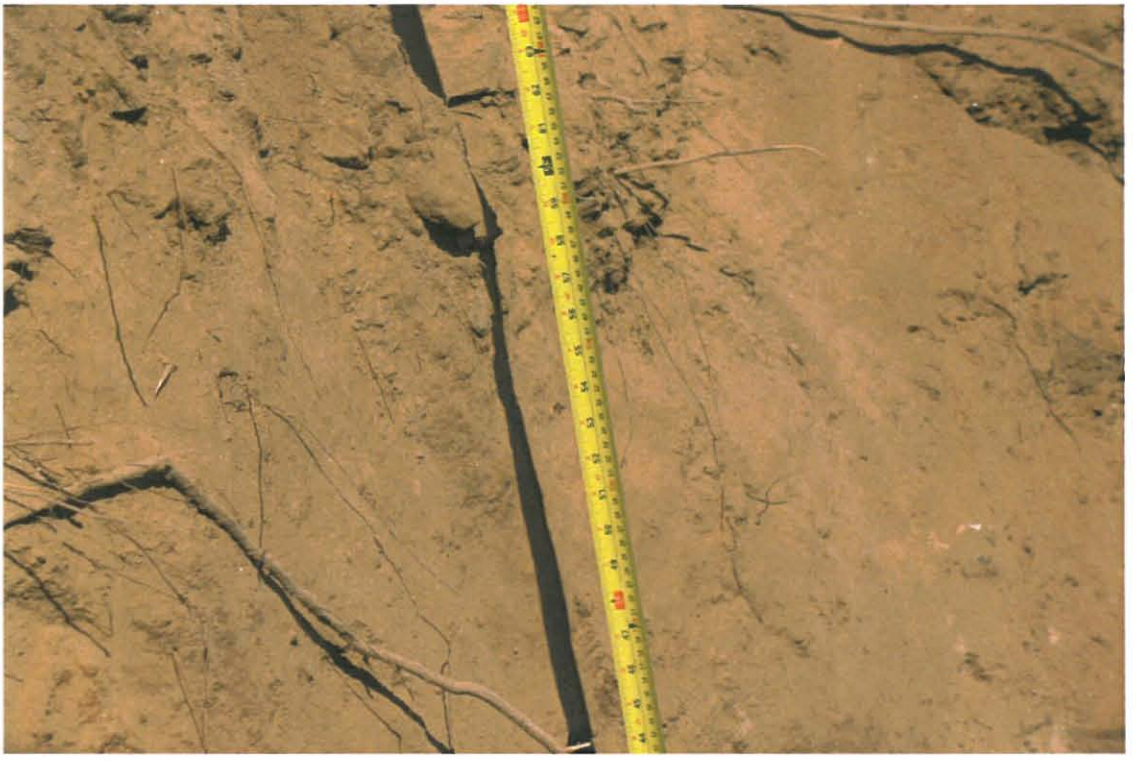
Site 2E - Test Pit

Site 3 - Site

Site 3 - Ground

Site 3 - Looking Upstream

Site 3 - Looking Downstream



Site 3 - Top of Test Pit

Site 3 - Bottom of Test Pit

Site 3 - Test Pit

Site 4 - Site

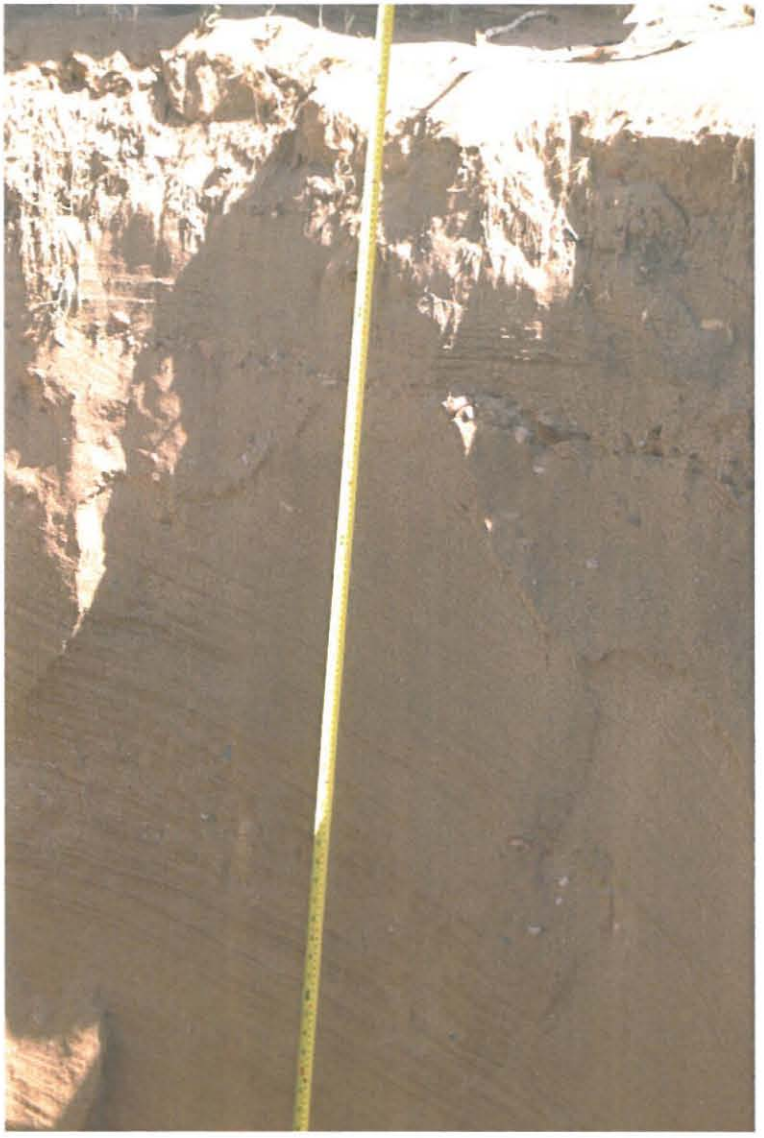
Site 4 - Ground

Site 4 - Looking Upstream

Site 4 - Looking Downstream

Site 4 - Test Pit

Site 4 - Bottom of Test Pit



Site 4 - Top of Test Pit

Site 5A - Looking Upstream

Site 5A - Looking Downstream

Site 5A - Ground

Site 5A -Test Pit

Site 5A - Bottom of Test Pit

Site 5A - Top of Test Pit

Site 5B - Looking Upstream

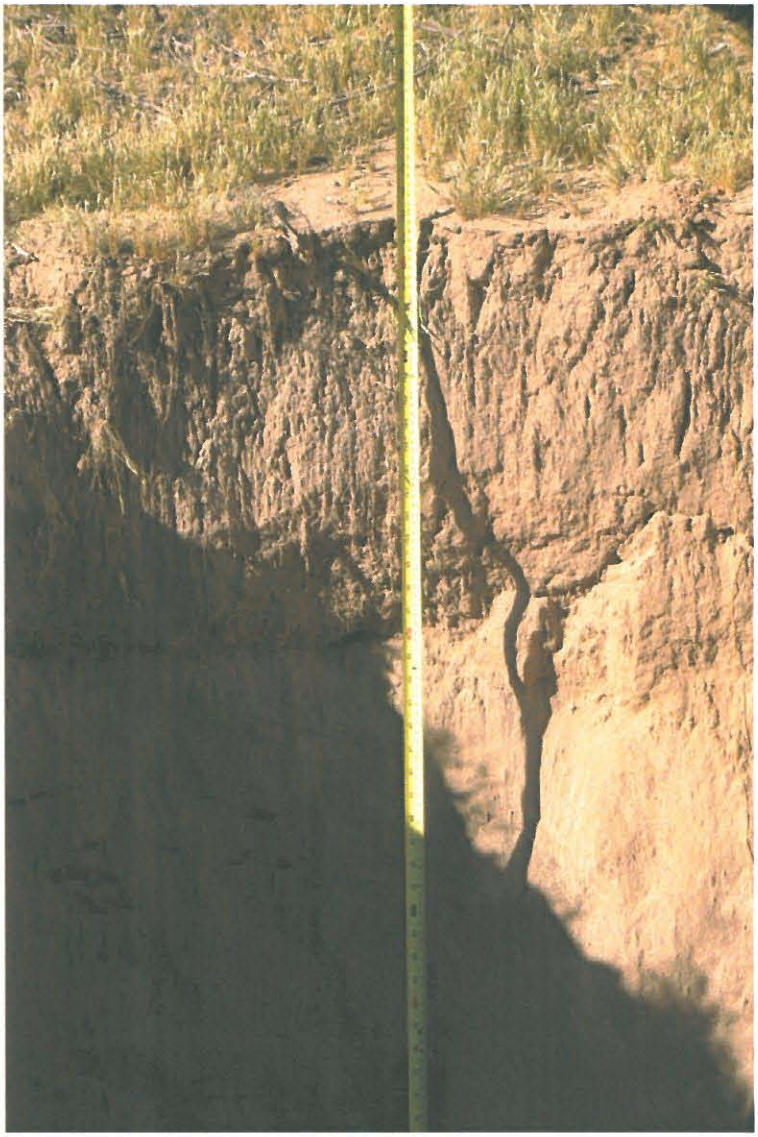
Site 5B - Looking Downstream

Site 5B - Site

Site 5B - Ground

Site 5B - Test Pit

Site 5B - Bottom of Test Pit

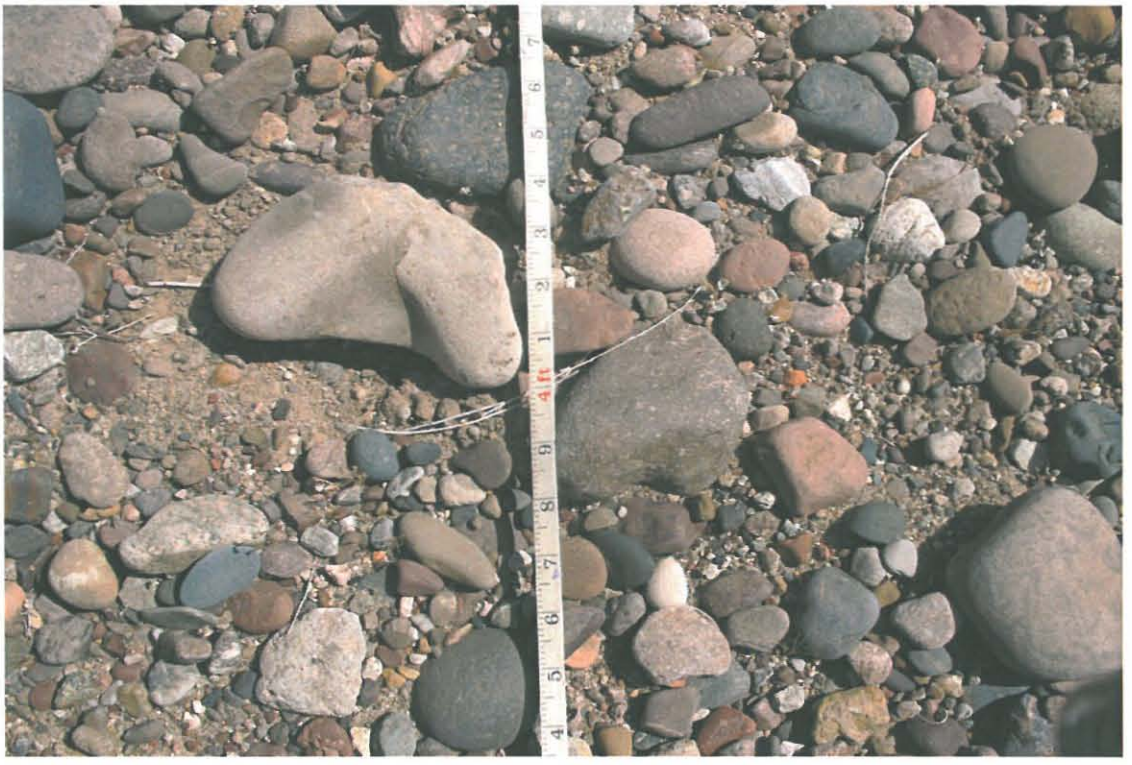


Site 5B - Top of Test Pit

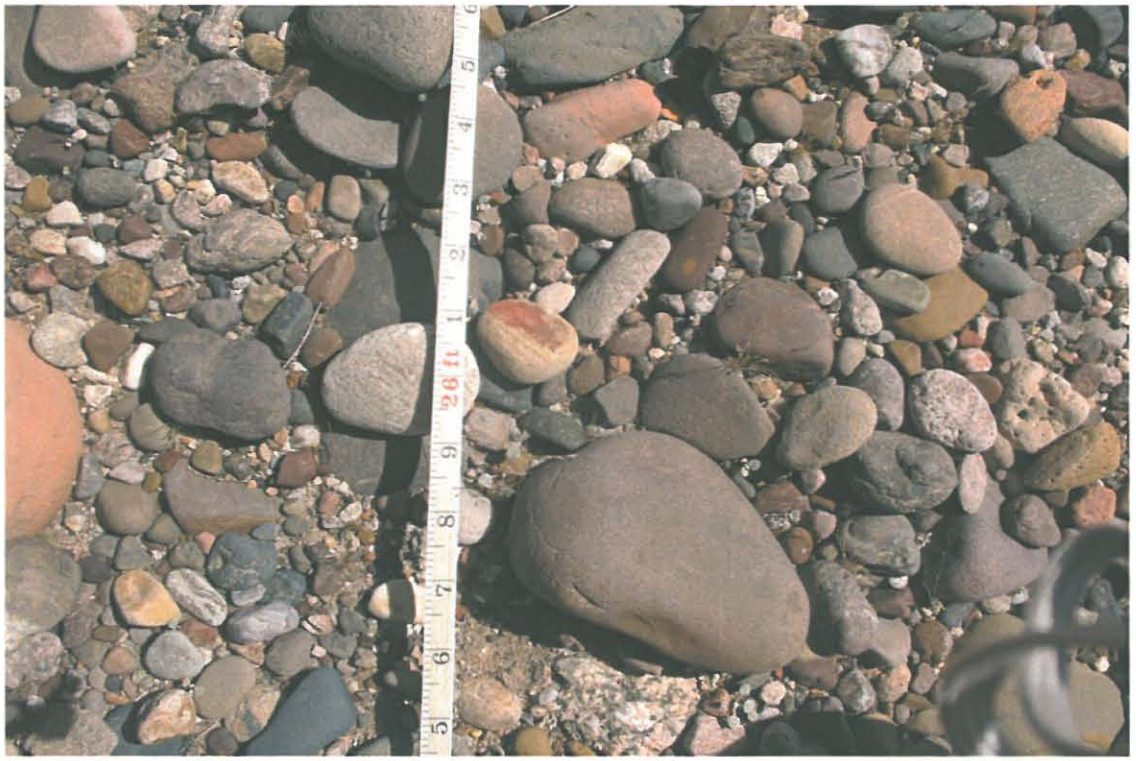
Site 5C - Looking Upstream

Site 5C - Looking Downstream

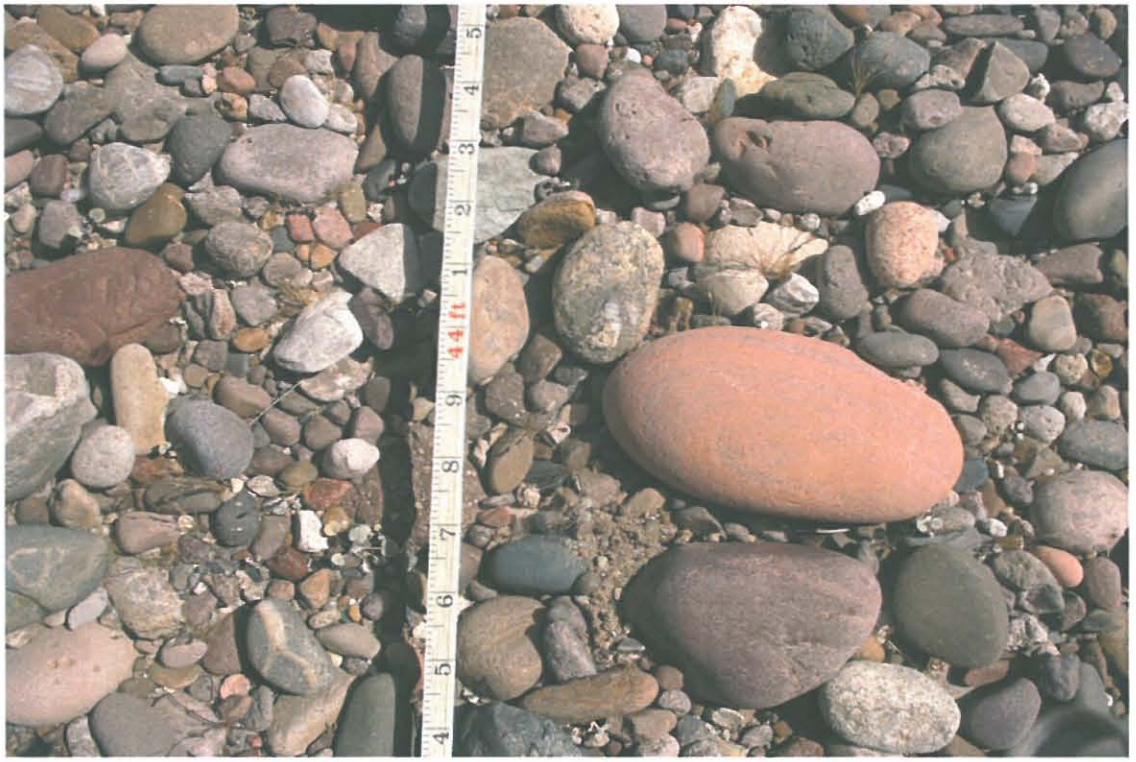
Site 5C - Site



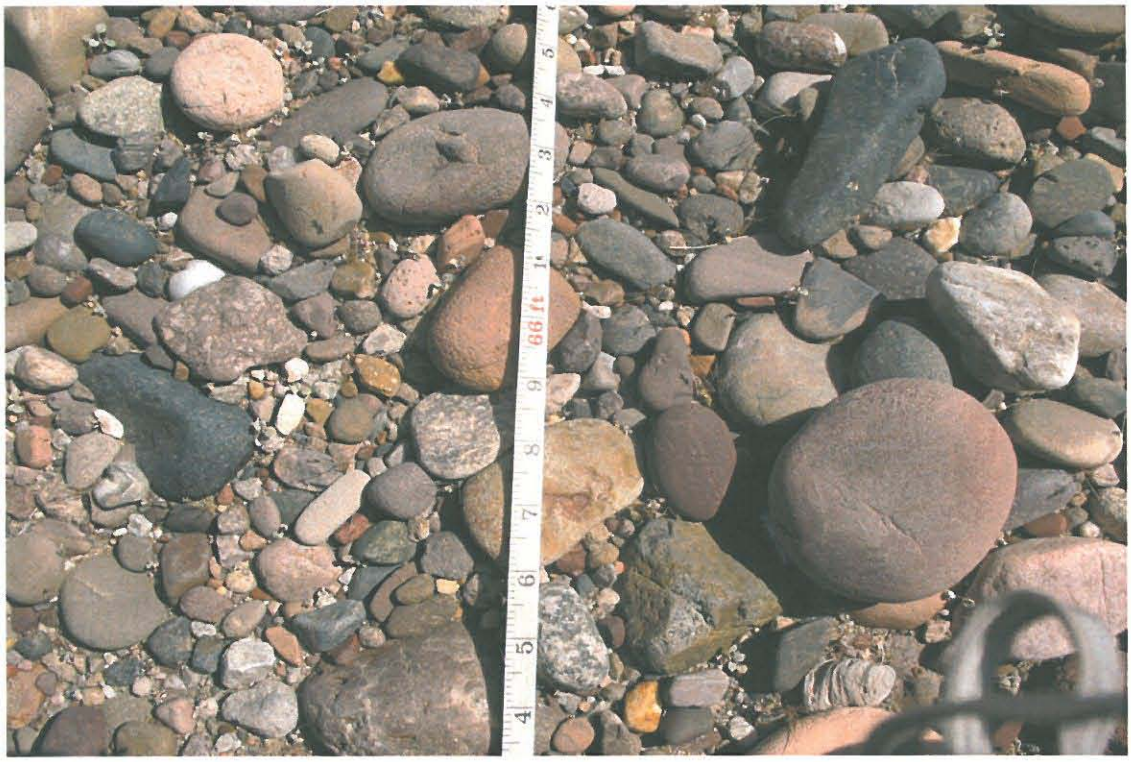
Site 5C - Ground



Site 5C - Ground



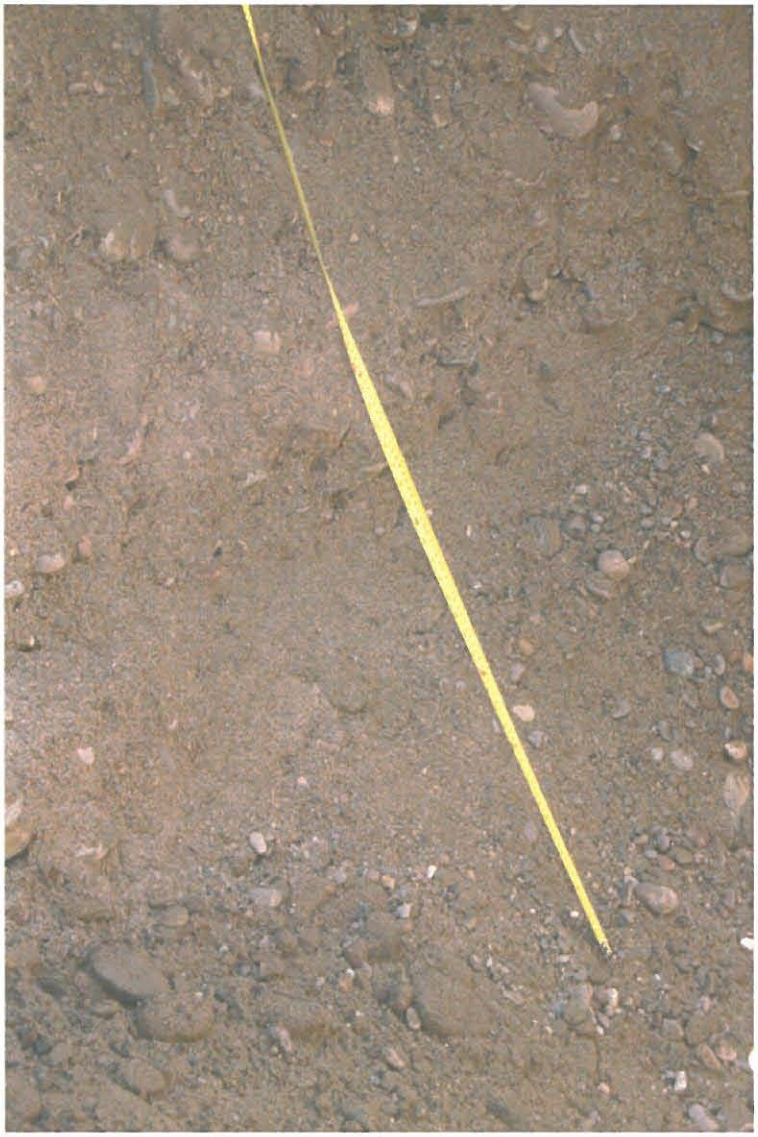
Site 5C - Ground



Site 5C - Ground

Site 5C - Test Pit

Site 5C - Top of Test Pit



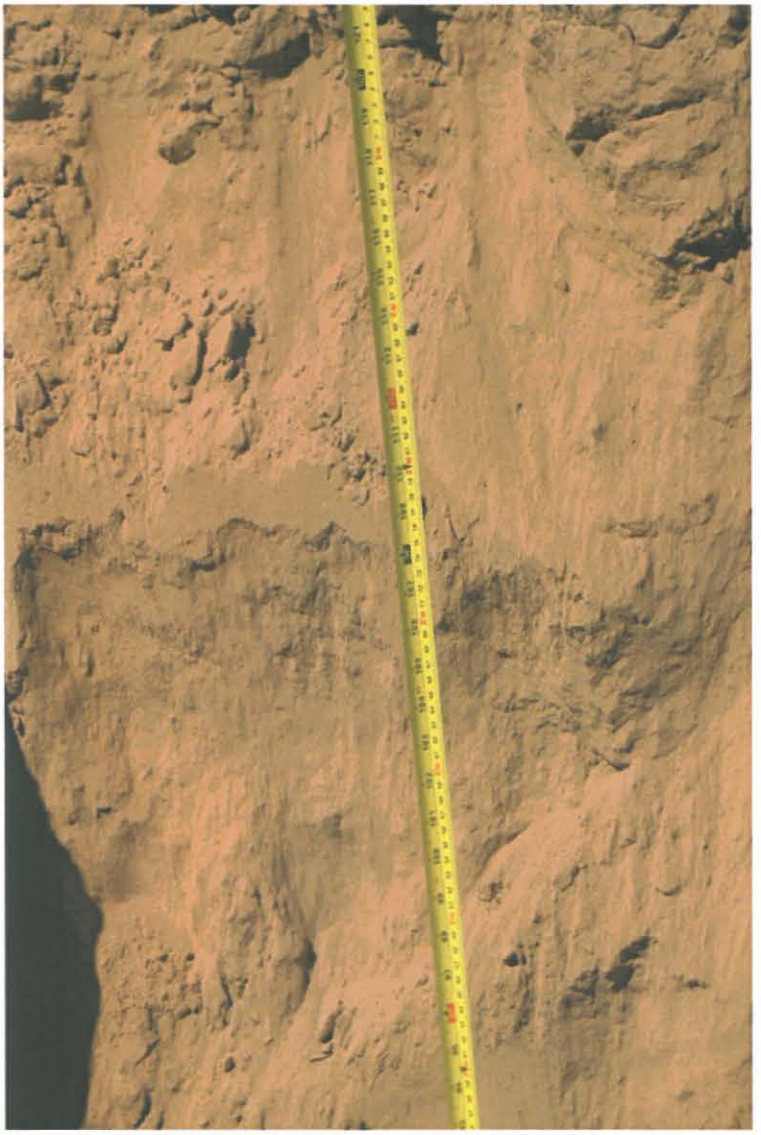
Site 5C - Bottom of Test Pit

Site 5D - Looking Upstream

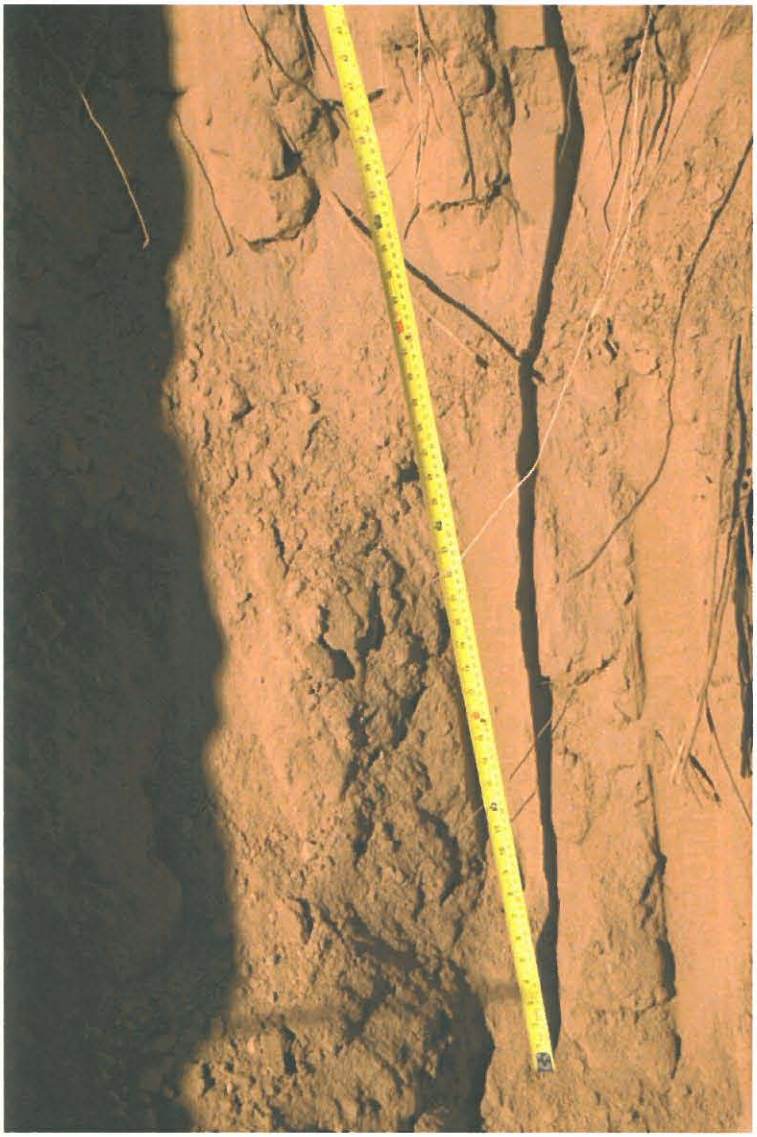
Site 5D - Looking Downstream

Site 5D - Ground

Site 5D - Test Pit



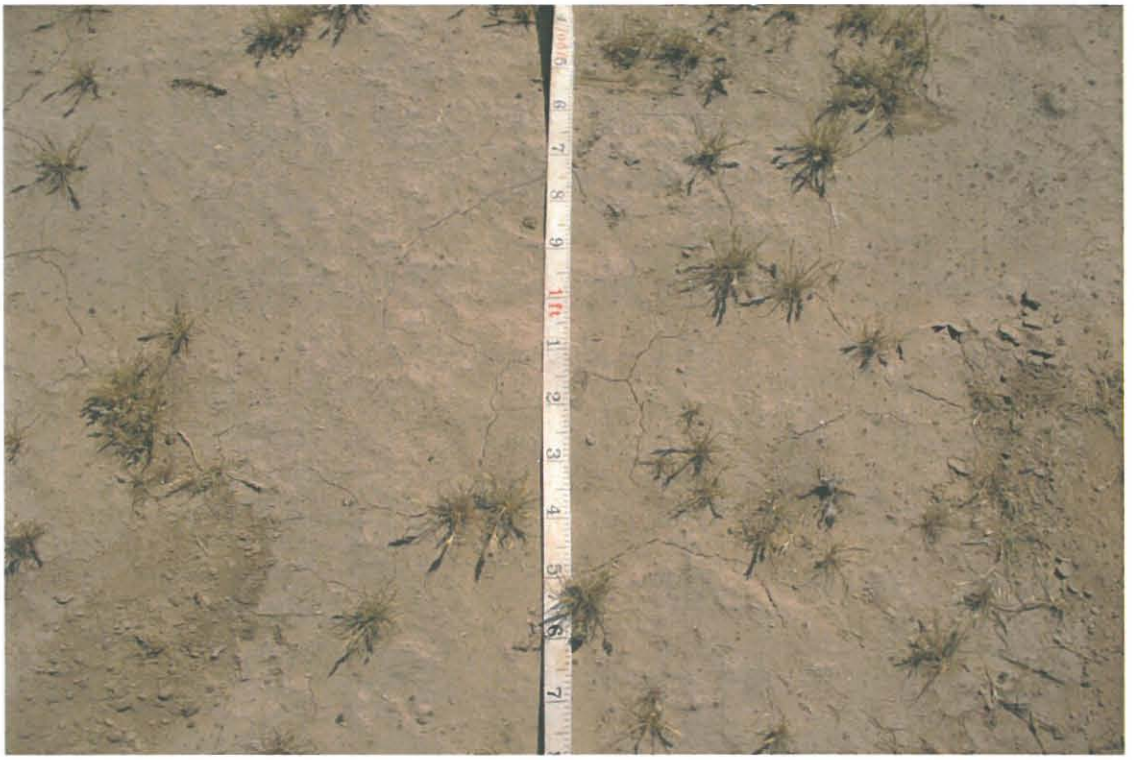
Site 5D - Top of Test Pit



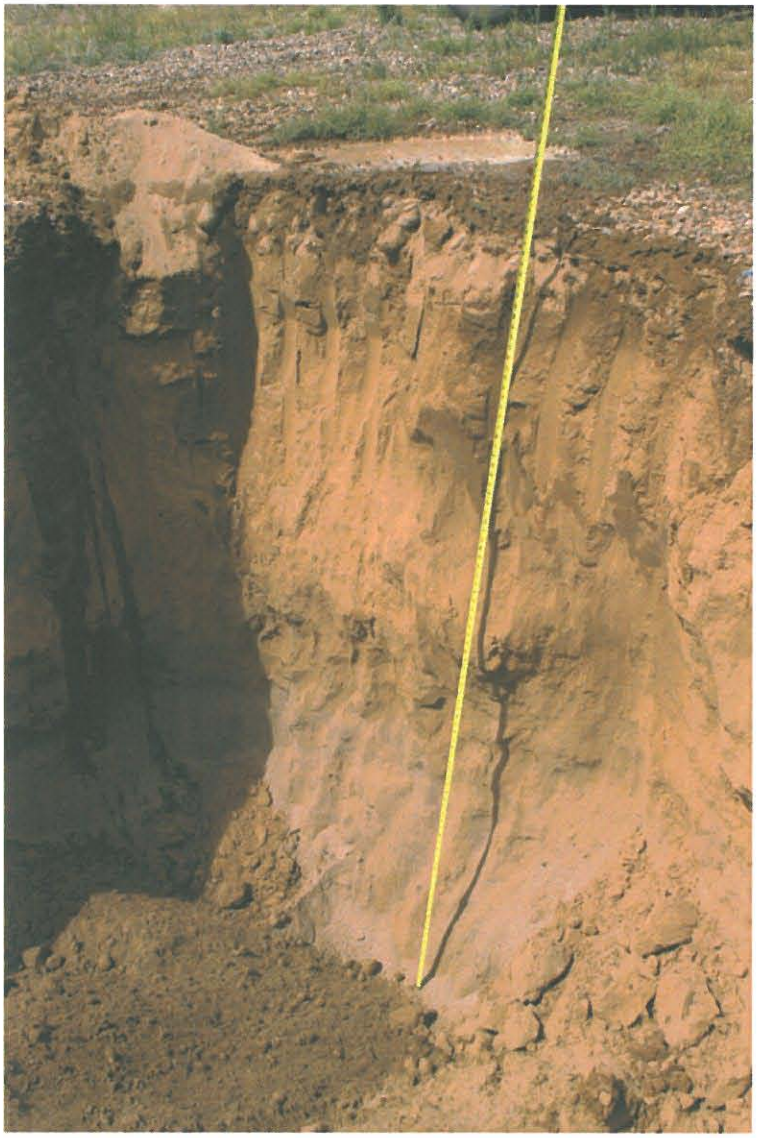
Site 5D - Bottom of Test Pit

Site 6A - Looking Upstream

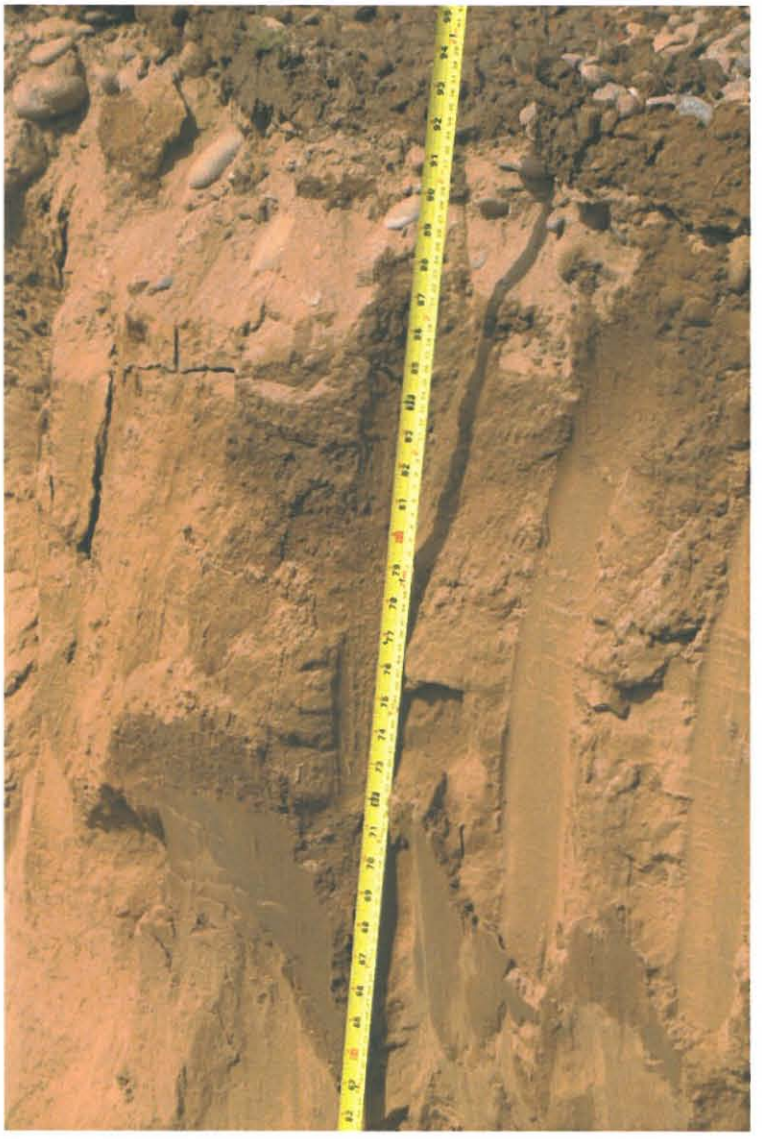
Site 6A - Looking Downstream



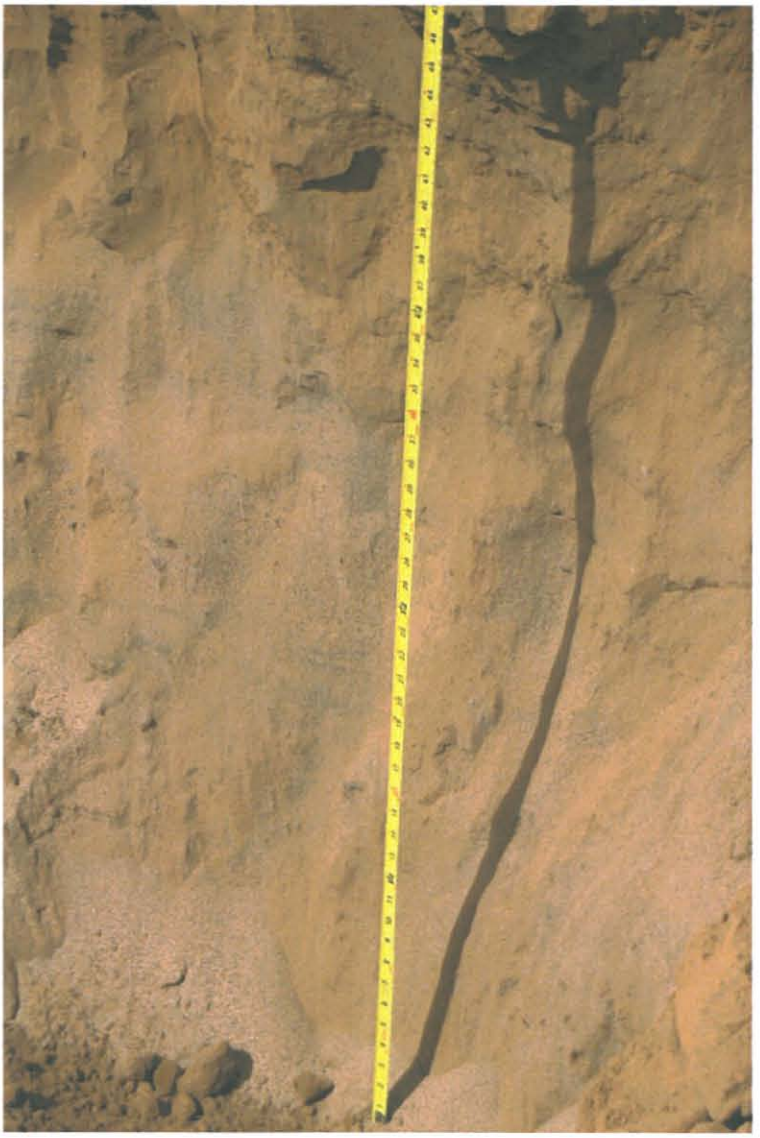
Site 6A - Ground



Site 6A - Test Pit



Site 6A - Top of Test Pit



Site 6A - Bottom of Test Pit

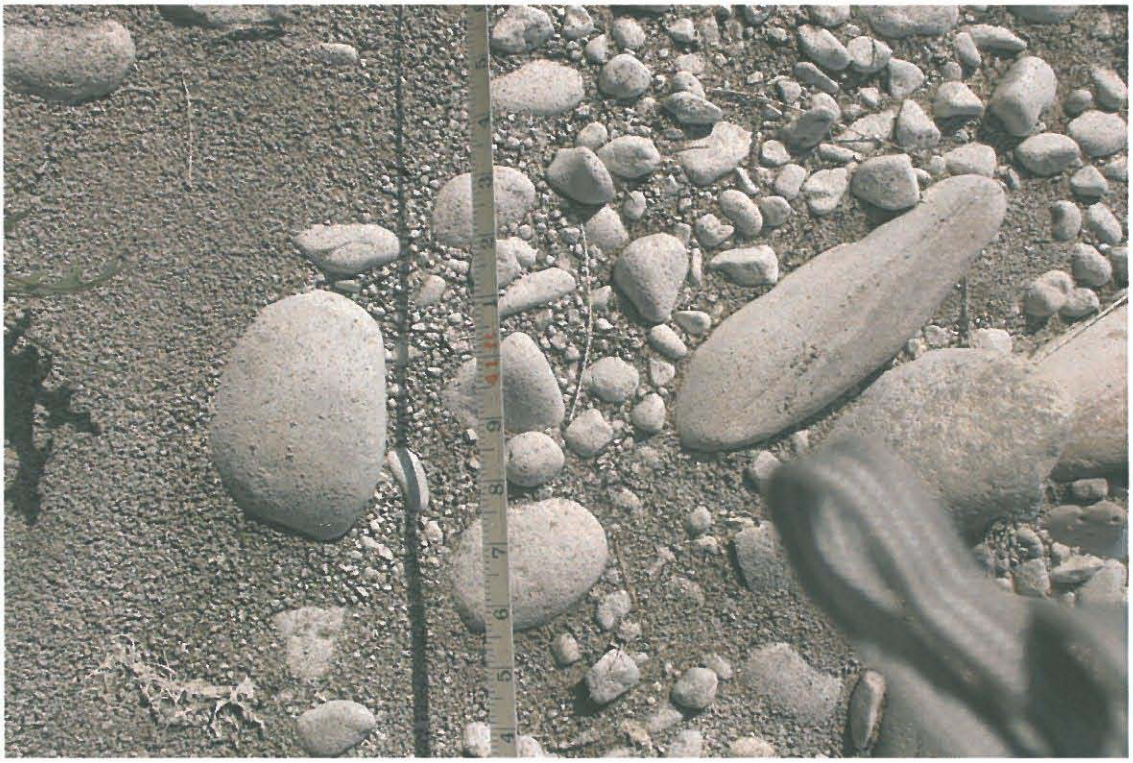
Site 6B - Looking Upstream

Site 6B - Looking Downstream

Site 6B - Site

Site 6B - Ground

Site 6B - Ground



Site 6B - Ground

Site 6B - Ground

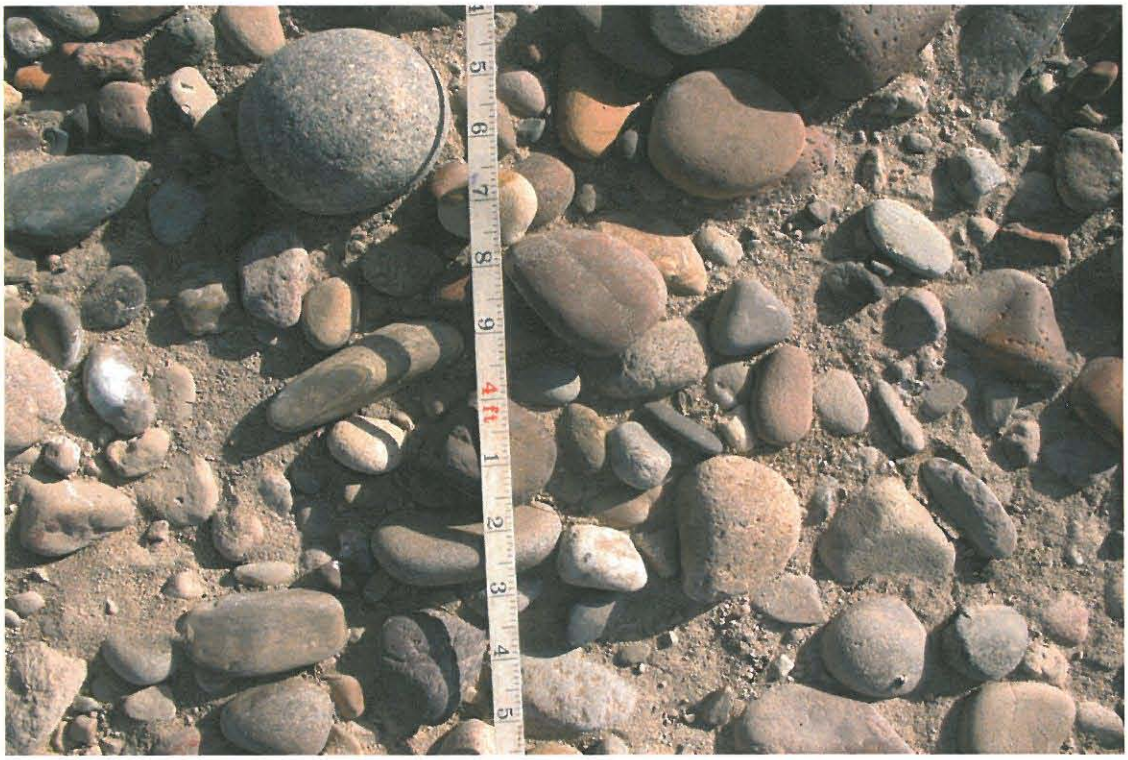
Site 6B - Ground

Site 6B - Test Pit

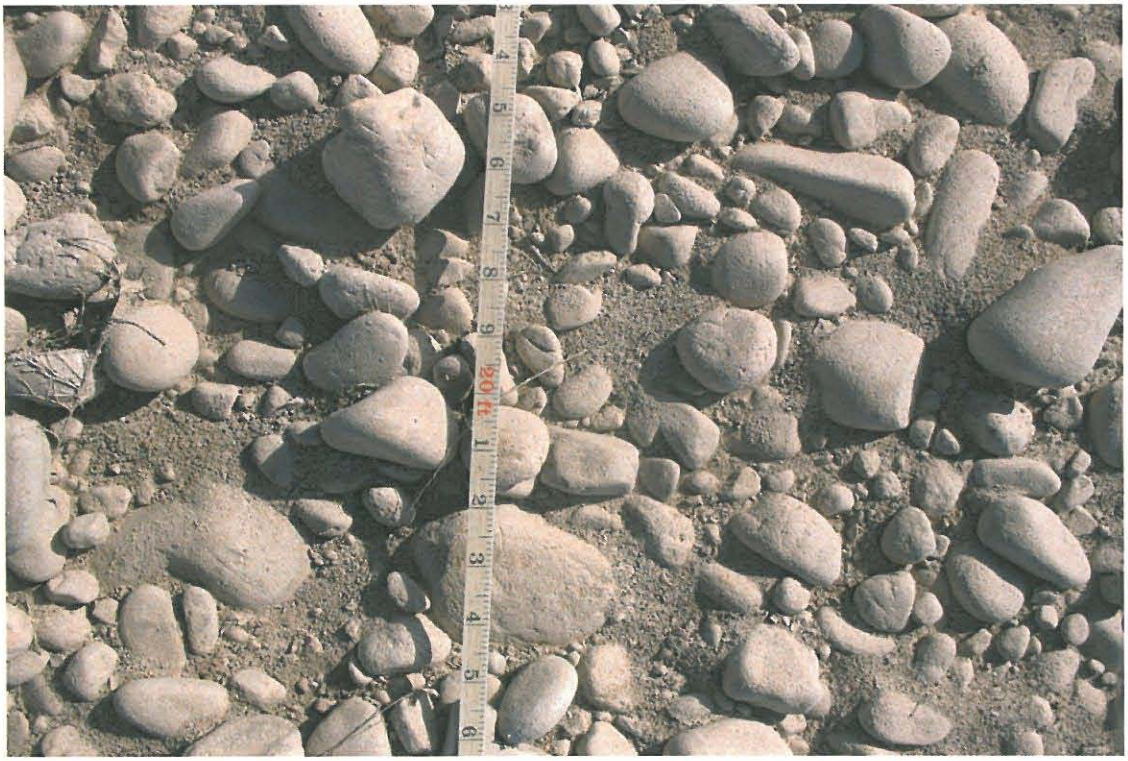
Site 6B - Top of Test Pit

Site 6C - Looking Upstream

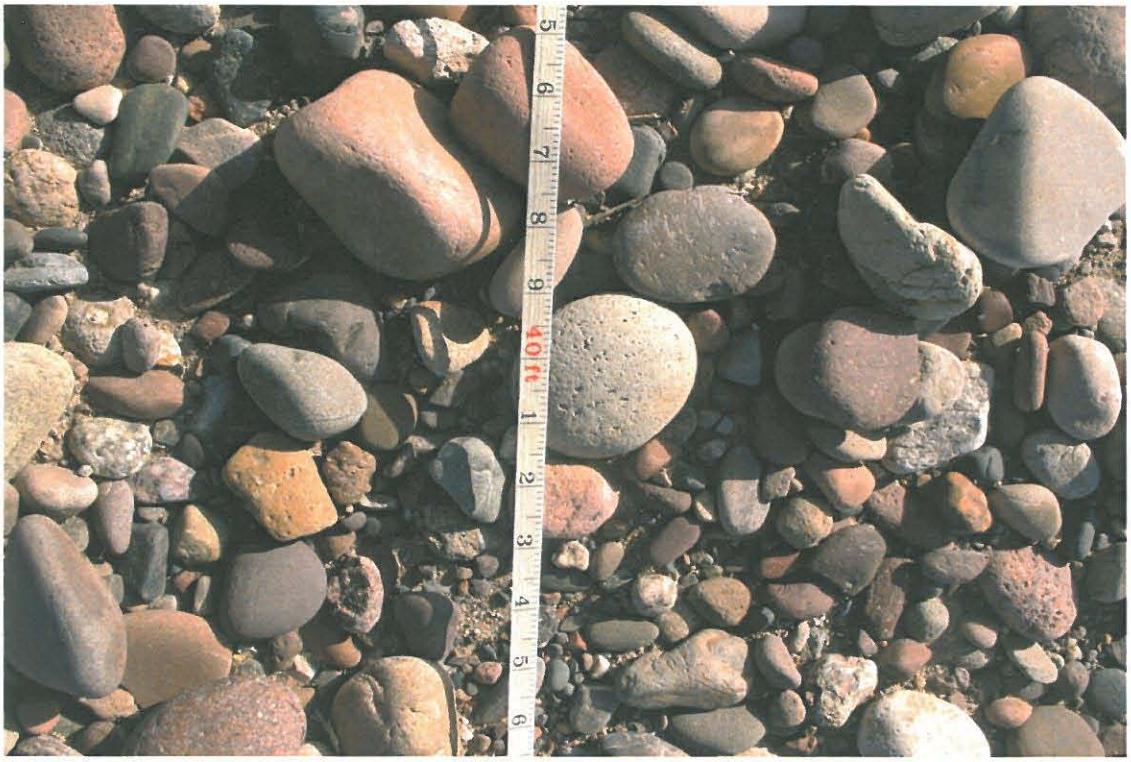
Site 6C - Looking Downstream



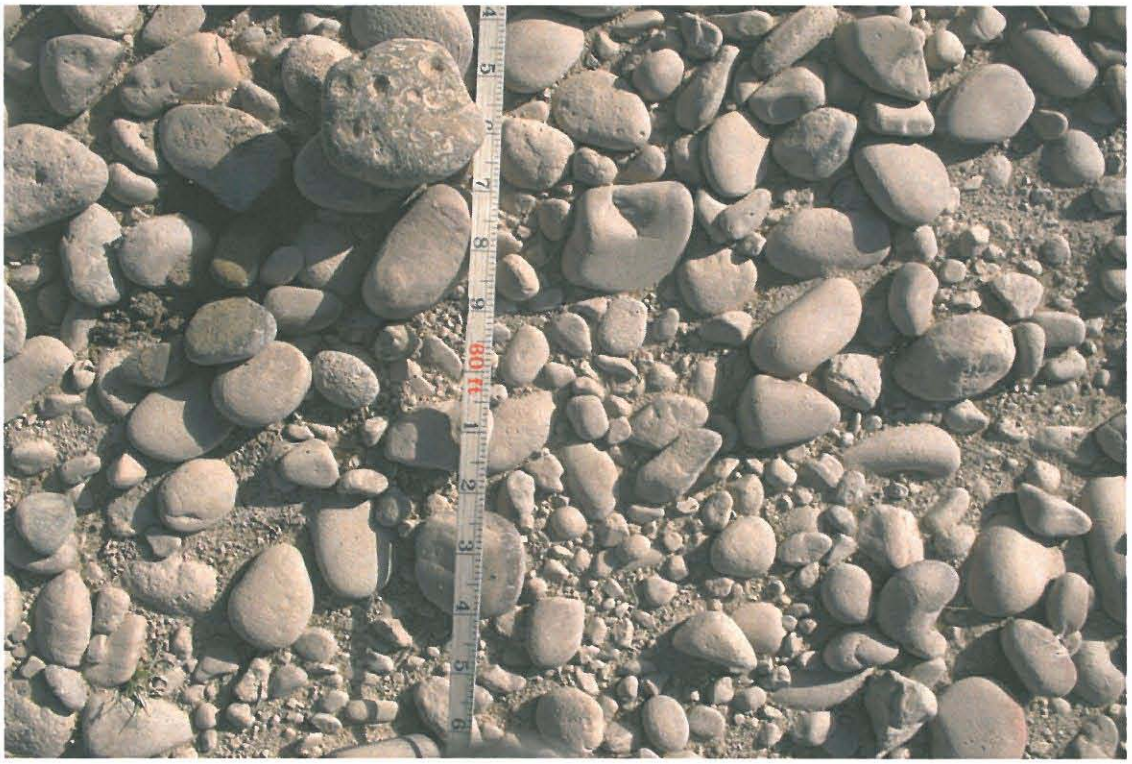
Site 6C - Ground



Site 6C - Ground

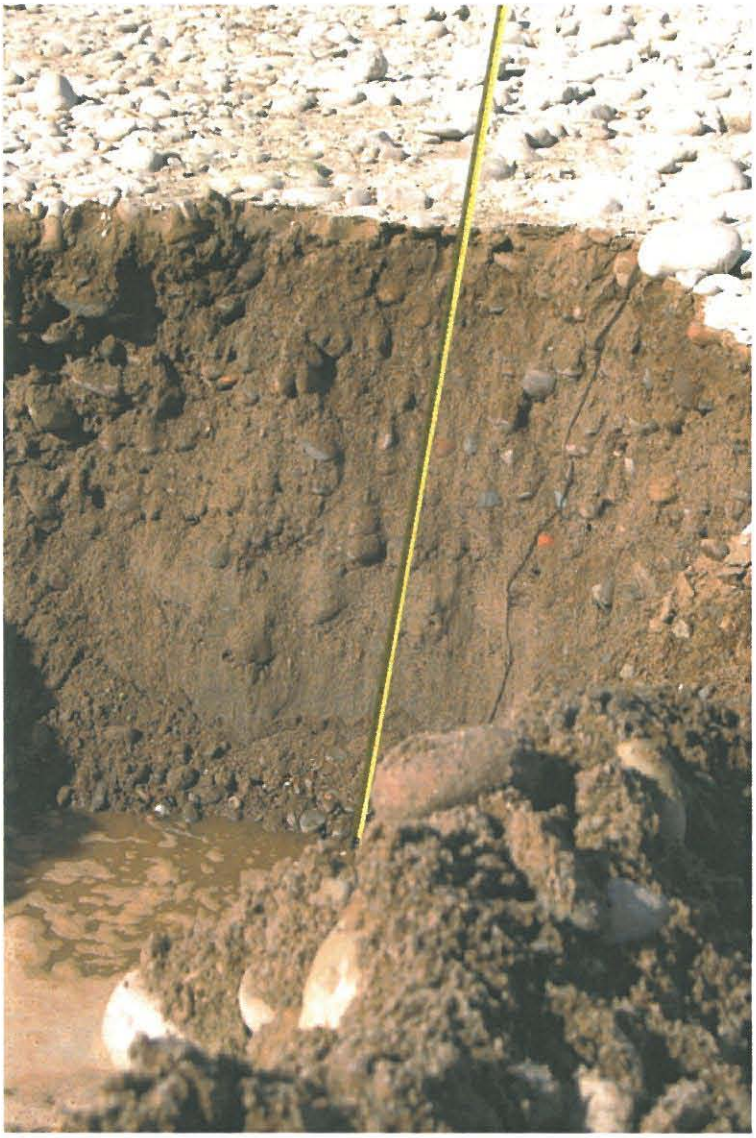


Site 6C - Ground



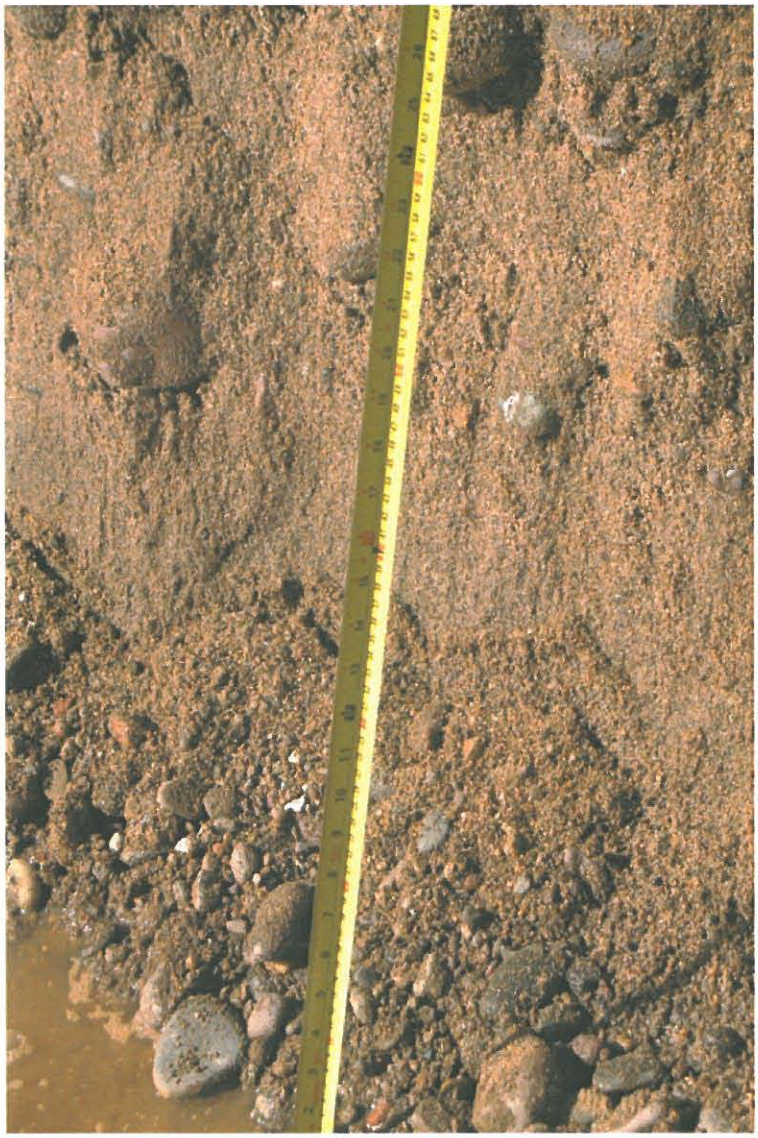
Site 6C - Ground

Site 6C - Ground



Site 6C - Test Pit

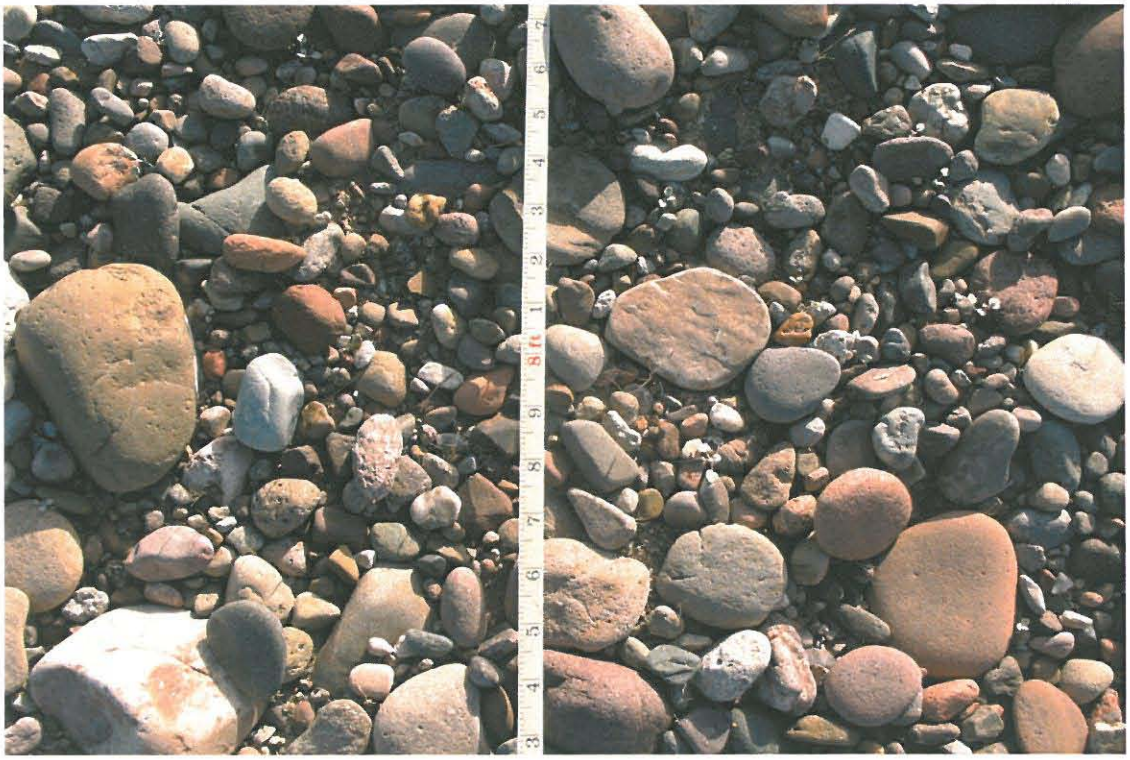
Site 6C - Top of Test Pit



Site 6C - Bottom of Test Pit

Site 6D - Looking Upstream

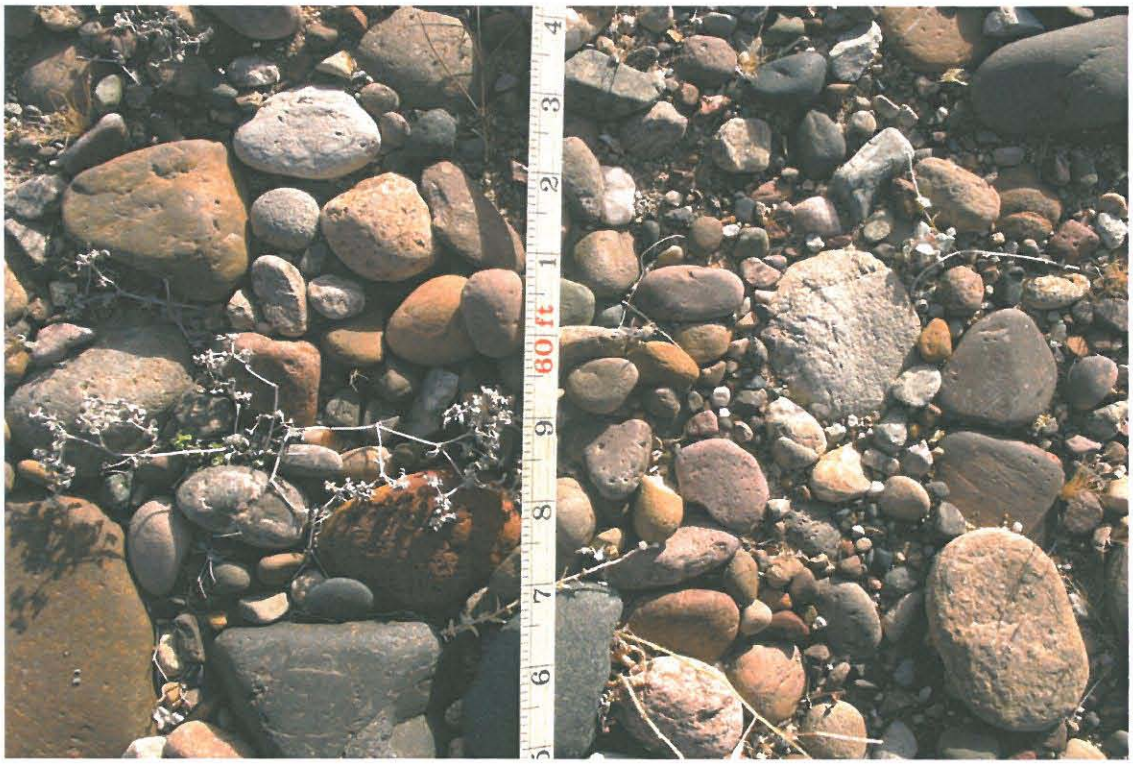
Site 6D - Looking Downstream



Site 6D - Ground

Site 6D - Ground

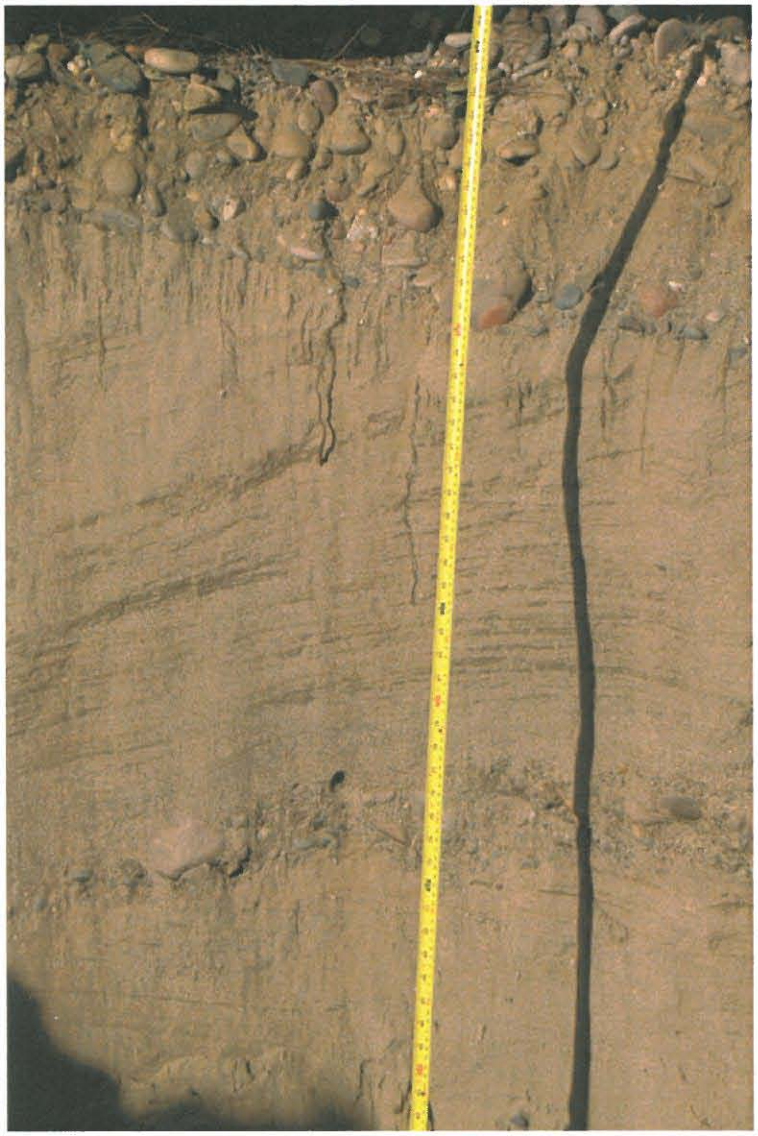
Site 6D - Ground



Site 6D - Ground

Site 6D - Ground

Site 6D - Test Pit



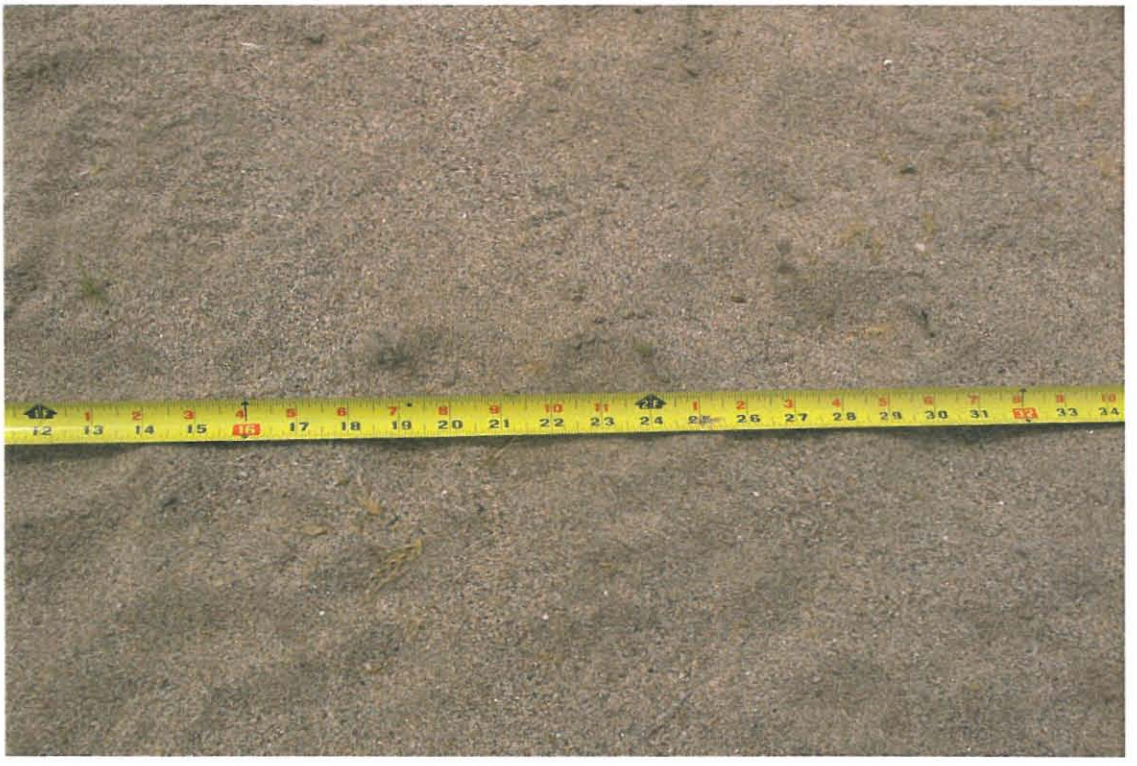
Site 6D - Top of Test Pit

Site 6D - Bottom of Test Pit

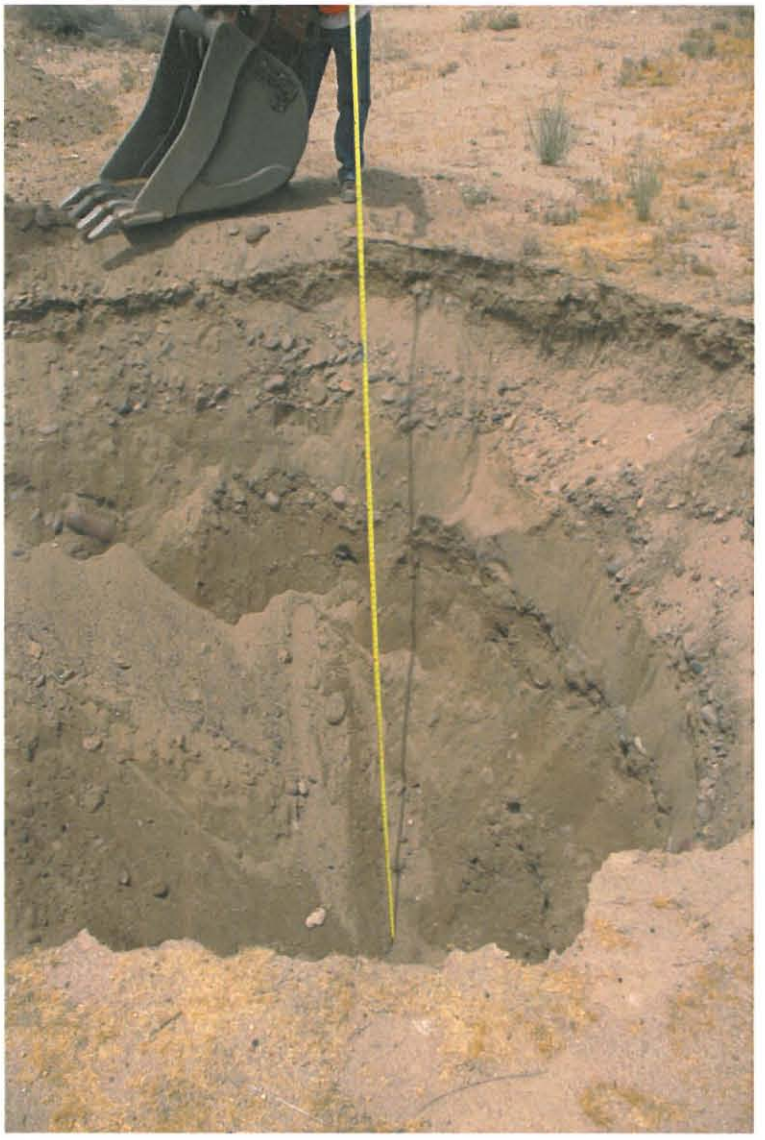
Site 7A - Looking Upstream

Site 7A - Looking Downstream

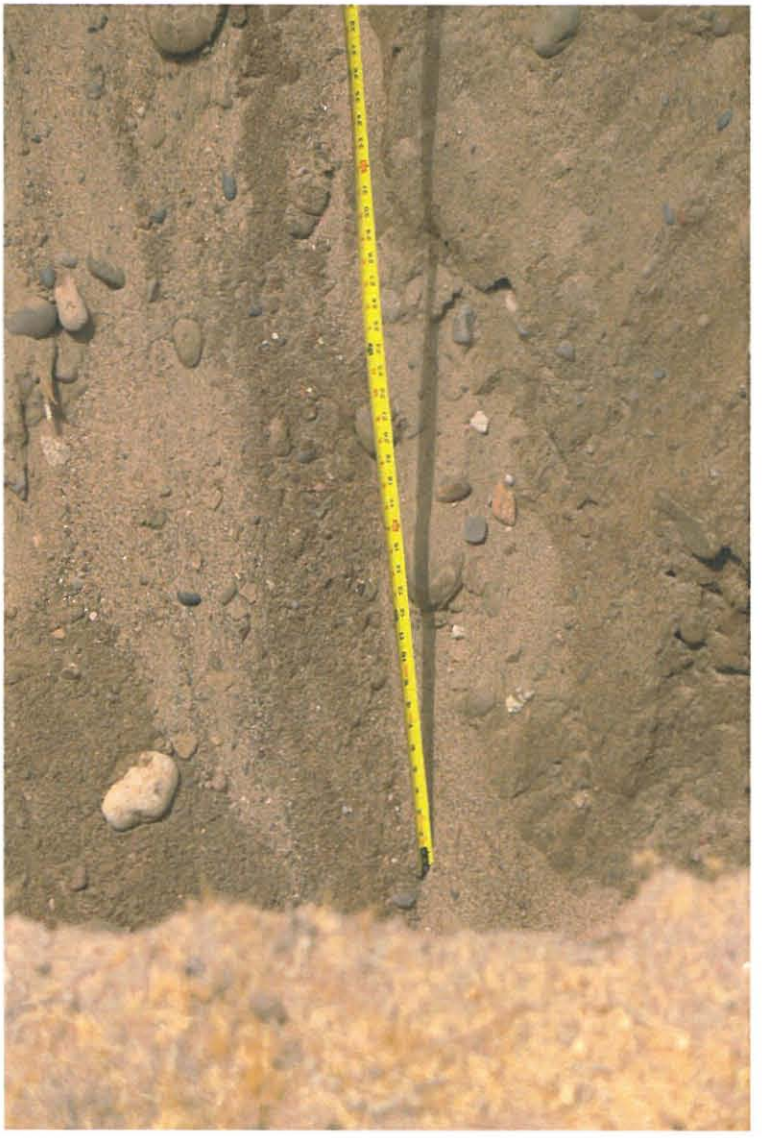
Site 7A - Site



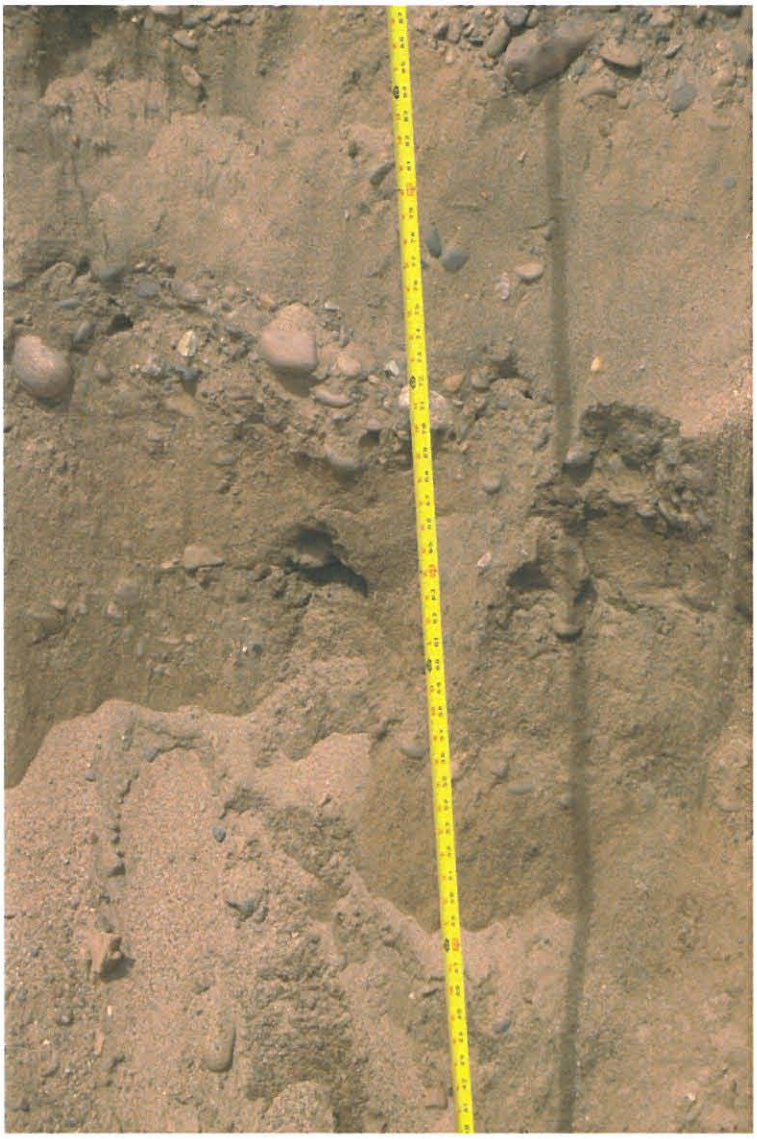
Site 7A - Ground



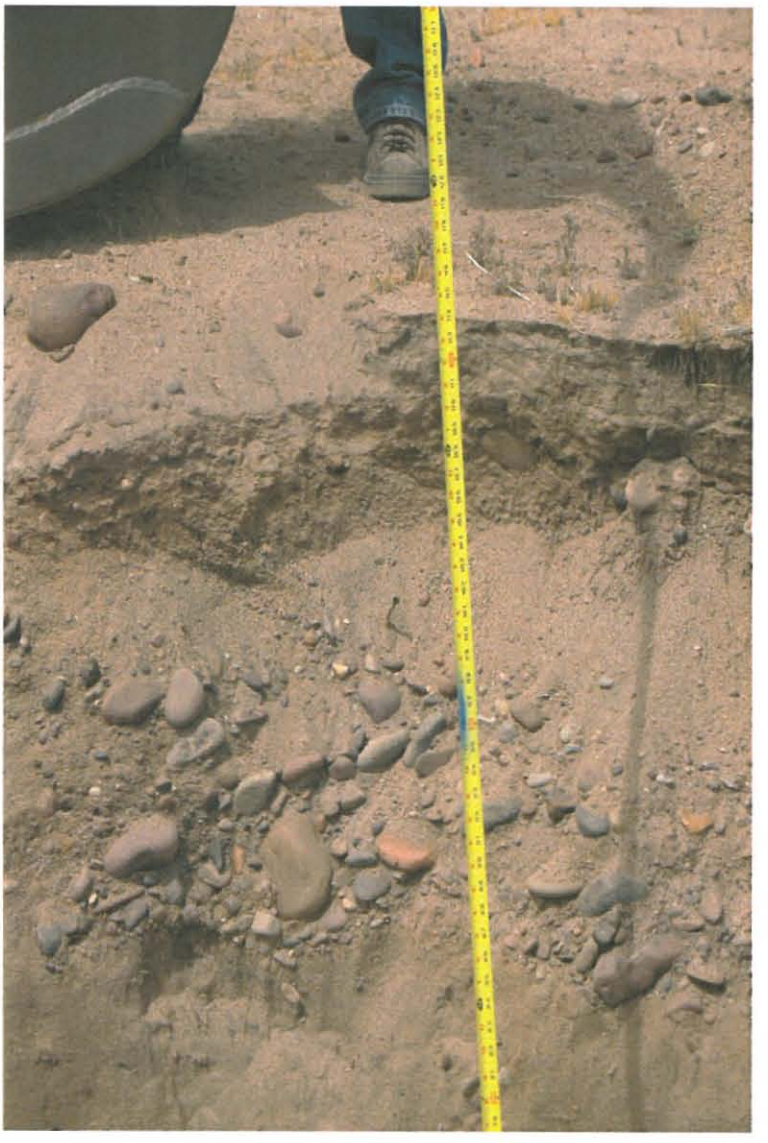
Site 7A - Test Pit



Site 7A - Bottom of Test Pit



Site 7A - Middle of Test Pit



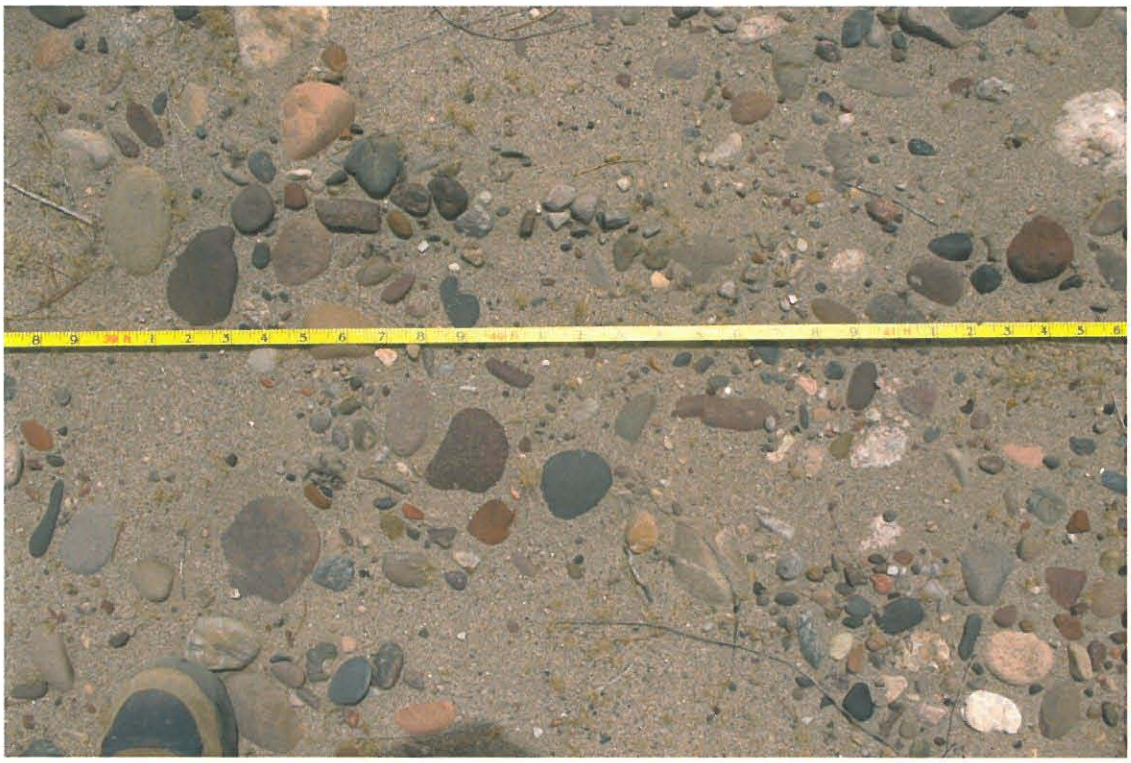
Site 7A - Top of Test Pit

Site 7B - Looking Upstream

Site 7B - Looking Downstream

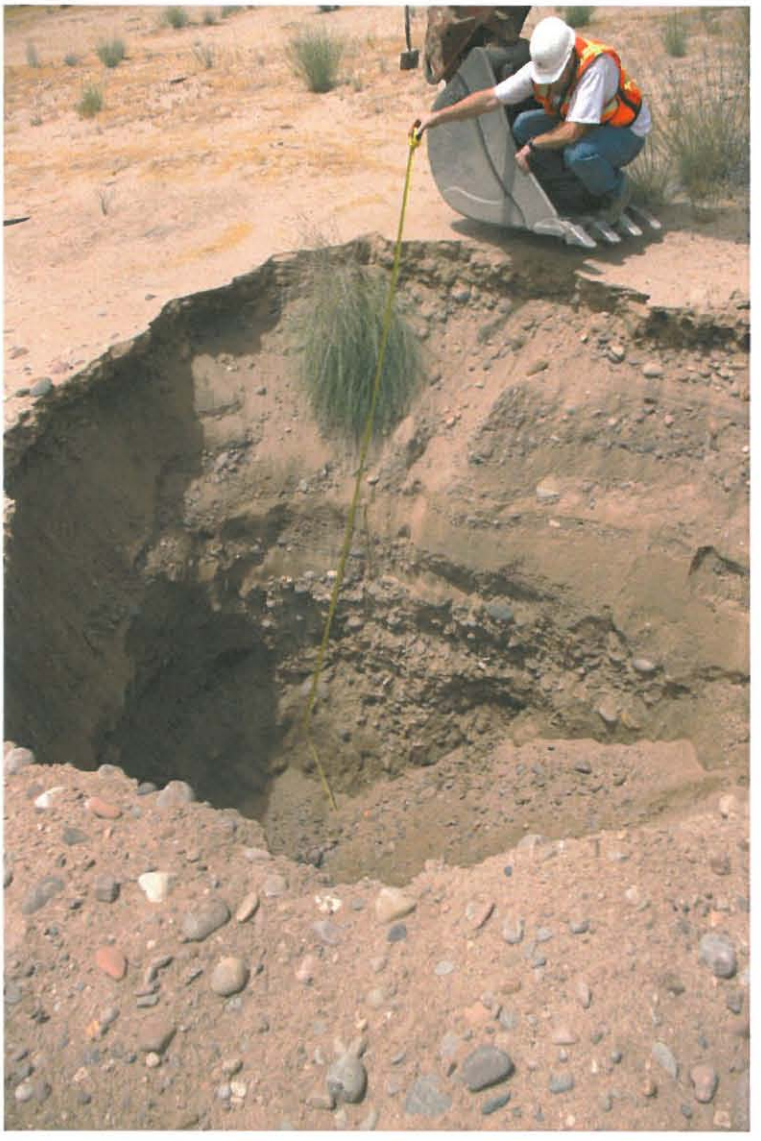
Site 7B - Ground

Site 7B - Ground



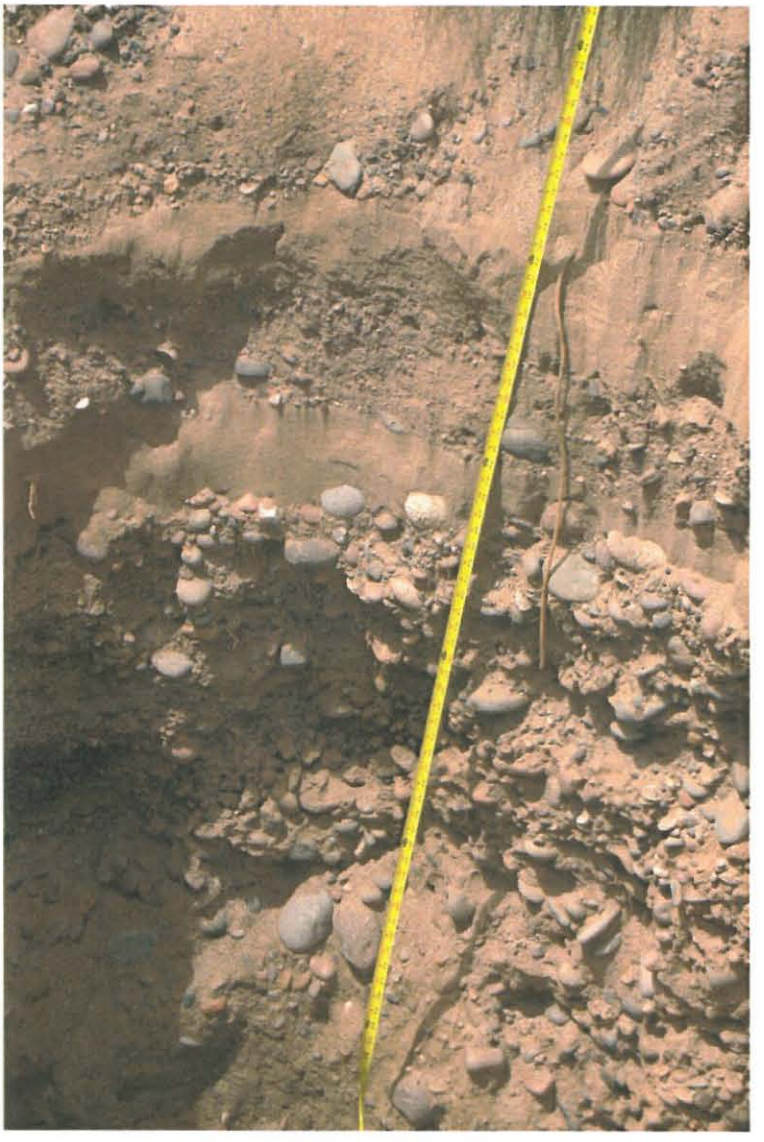
Site 7B - Ground

Site 7B - Ground

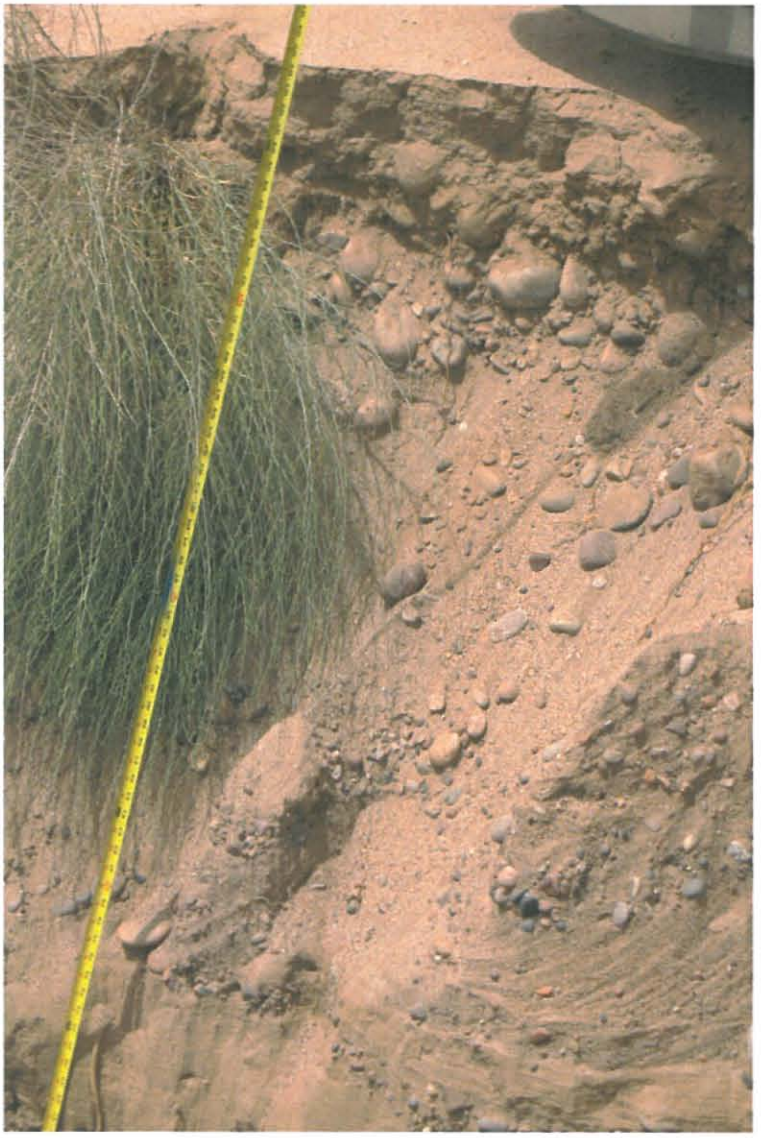


Site 7B - Test Pit

Site 7B - Bottom of Test Pit

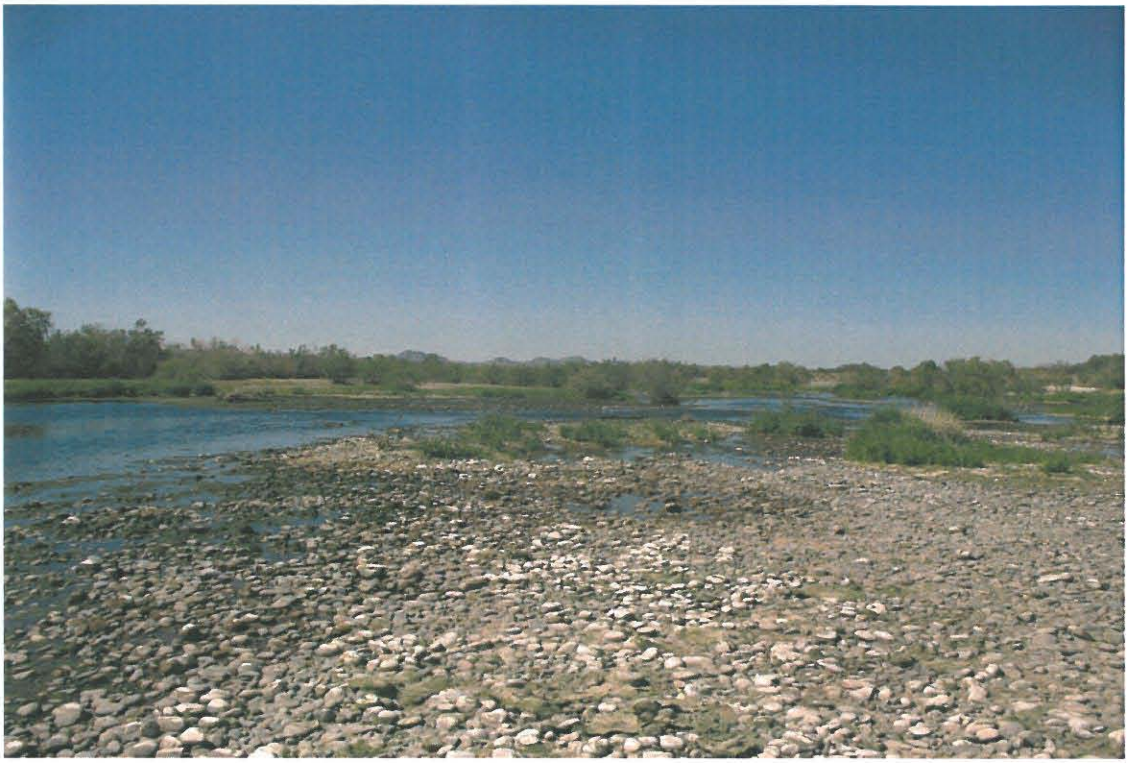


Site 7B - Middle of Test Pit

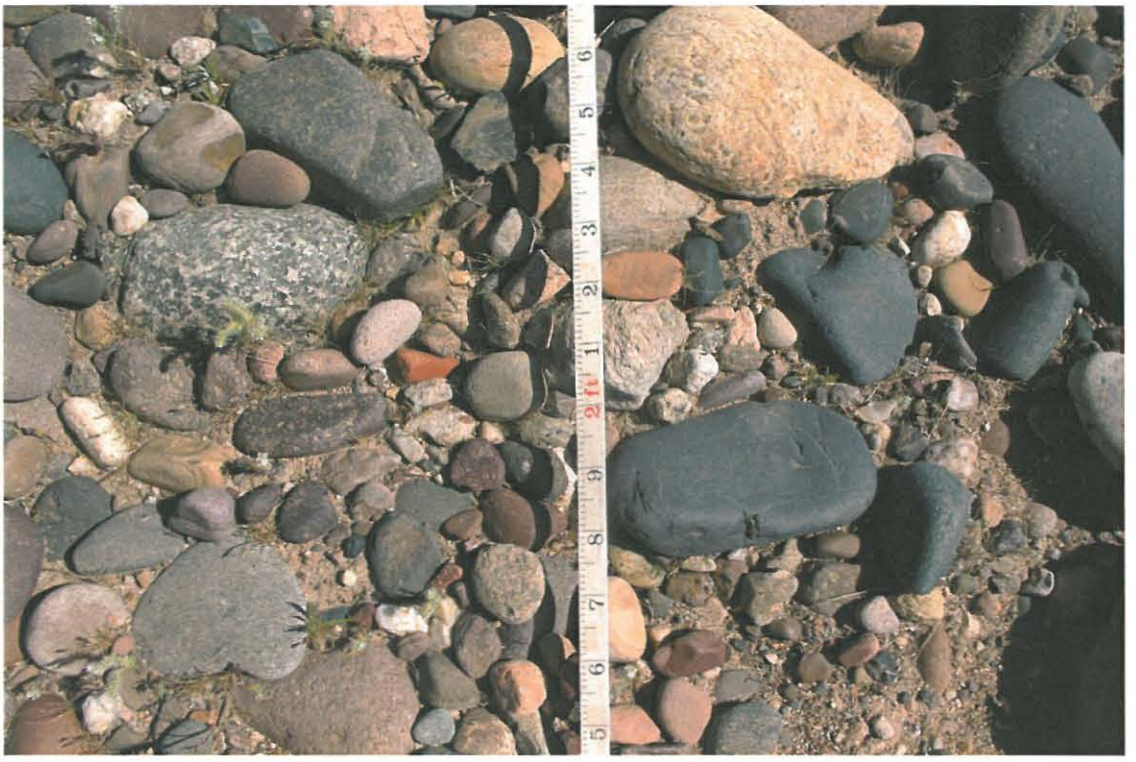


Site 7B - Top of Test Pit

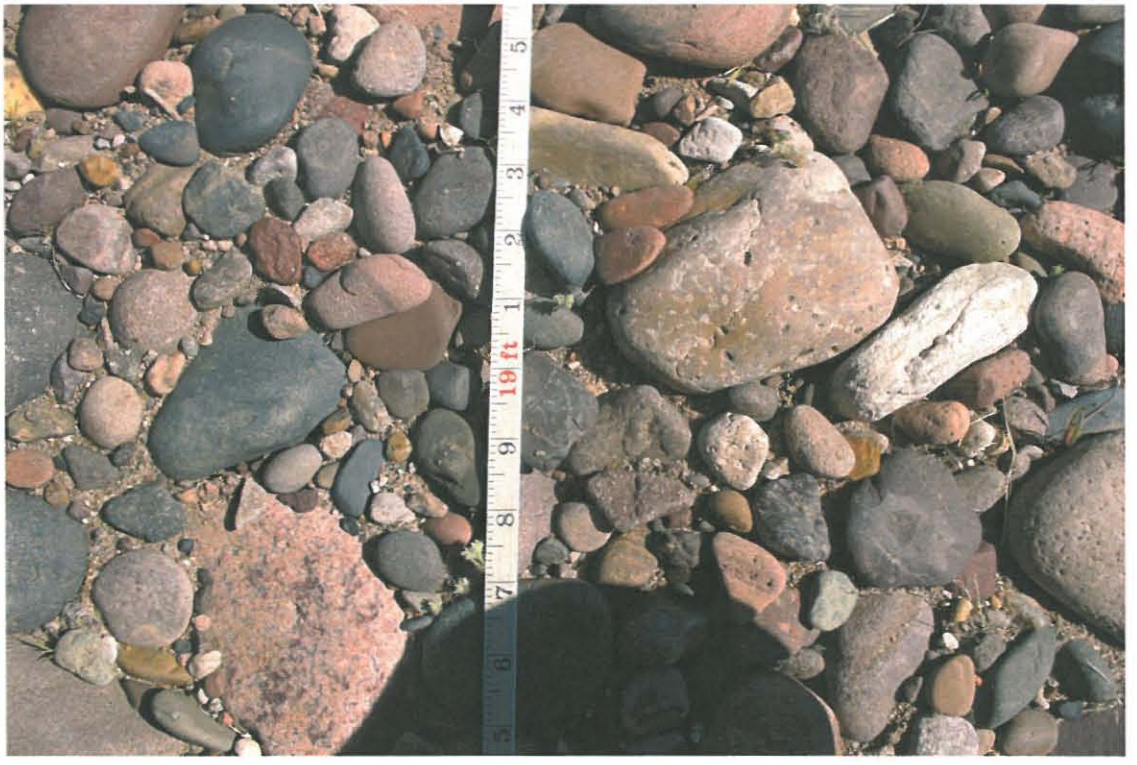
Site 7C - Looking Upstream



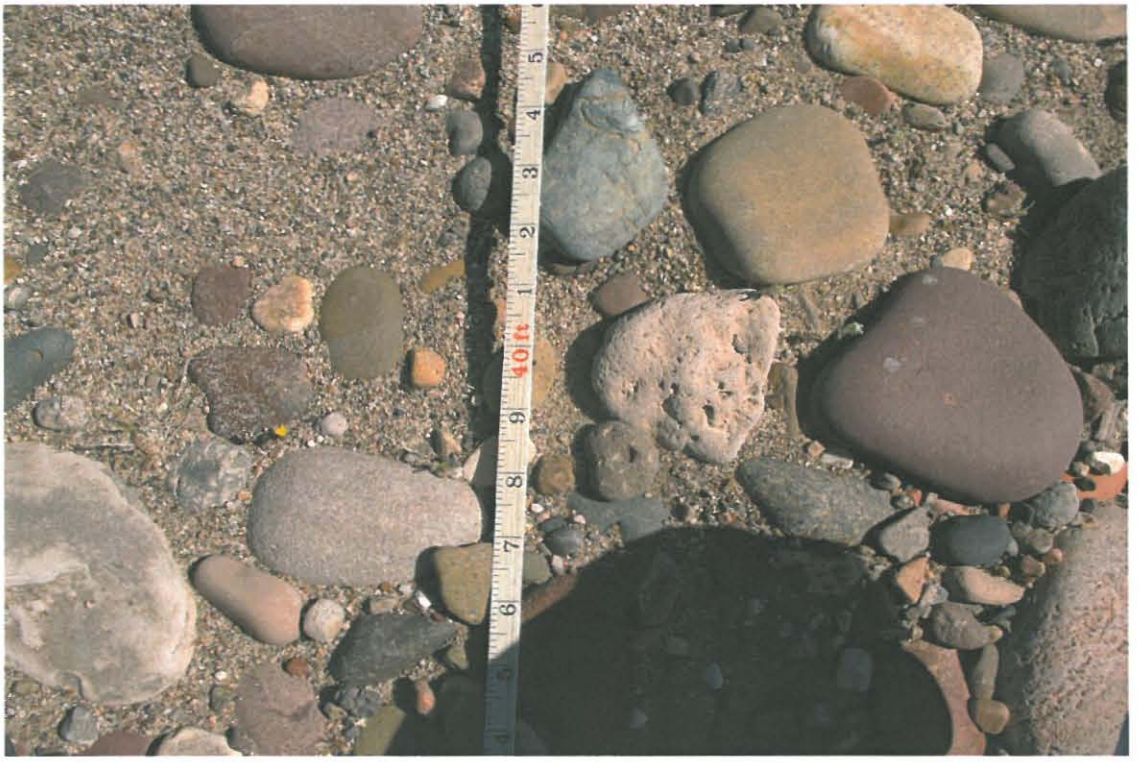
Site 7C - Looking Downstream



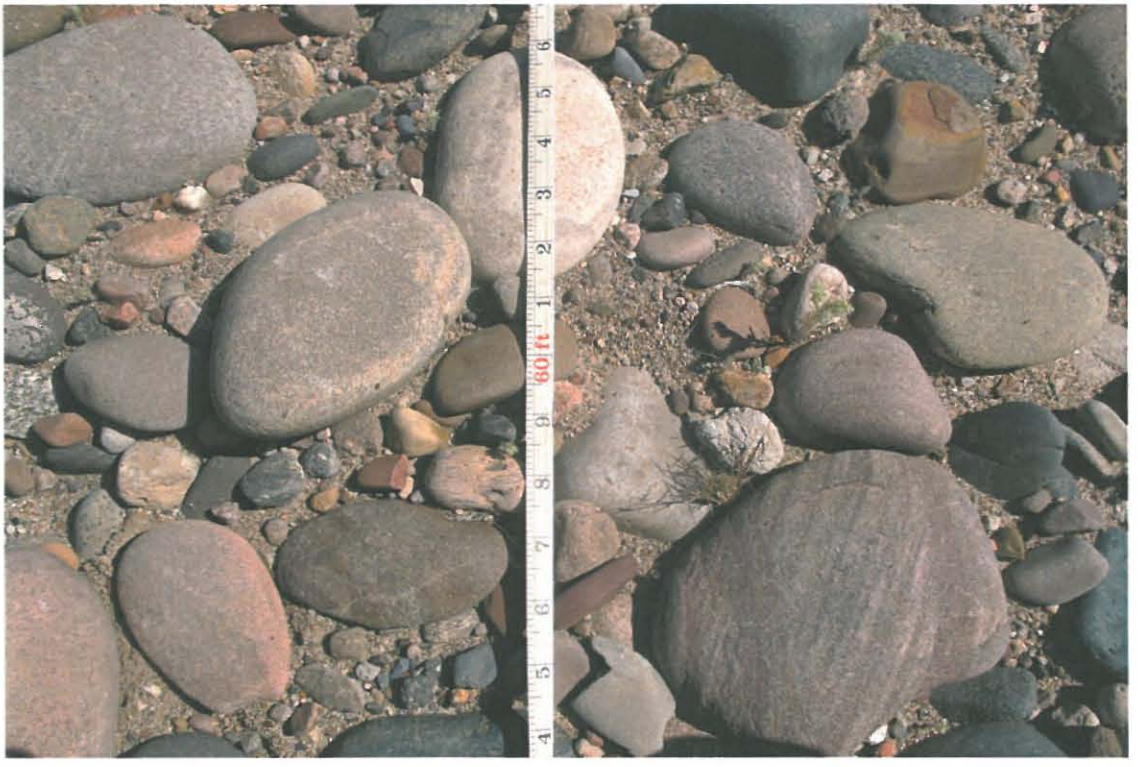
Site 7C - Ground



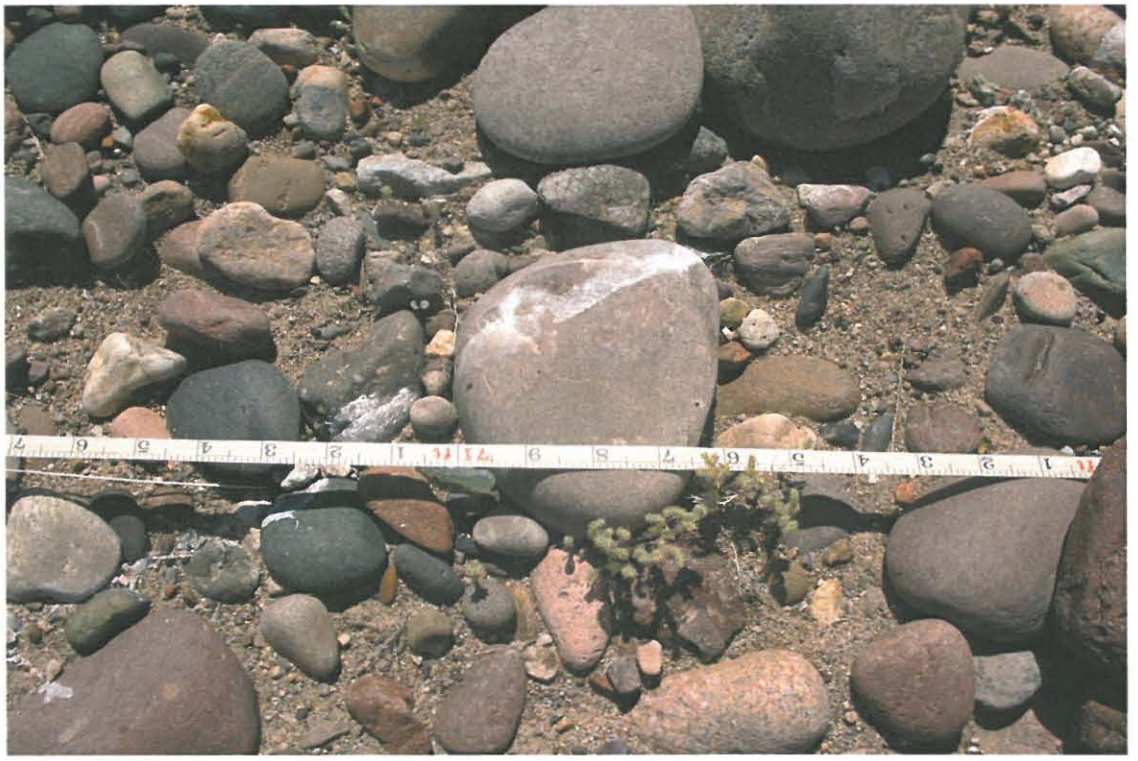
Site 7C - Ground



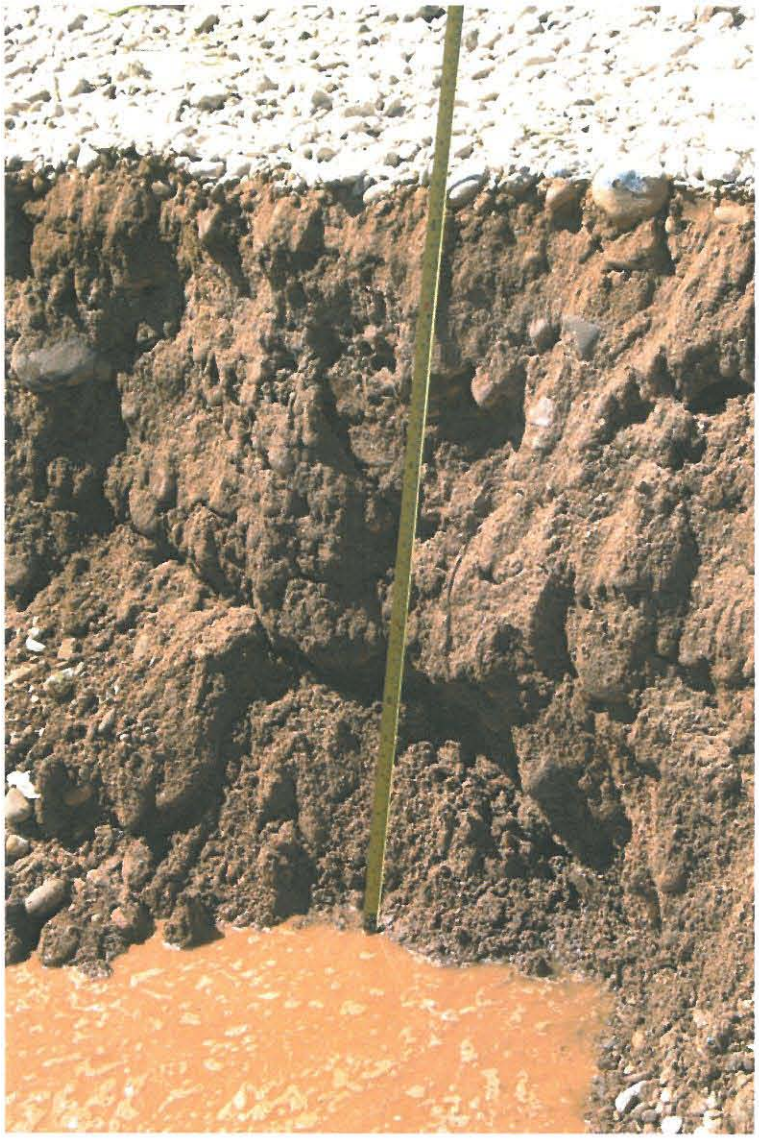
Site 7C - Ground



Site 7C - Ground

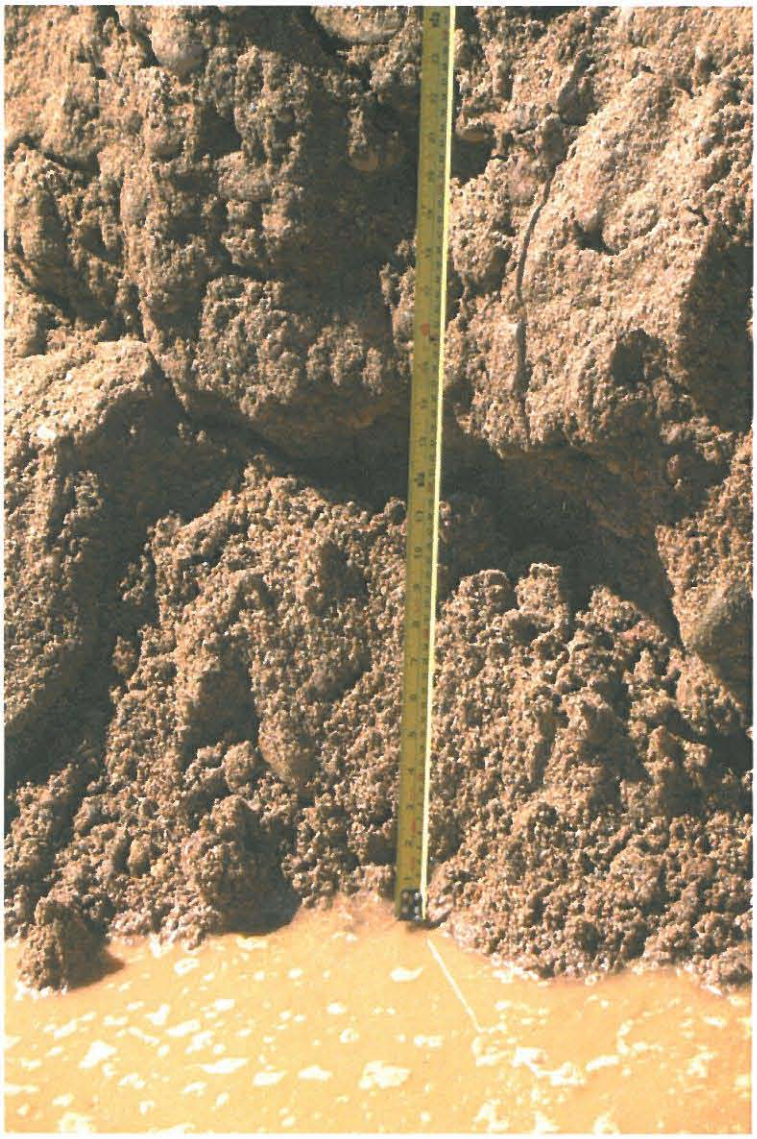


Site 7C - Ground



Site 7C - Test Pit

Site 7C - Top of Test Pit

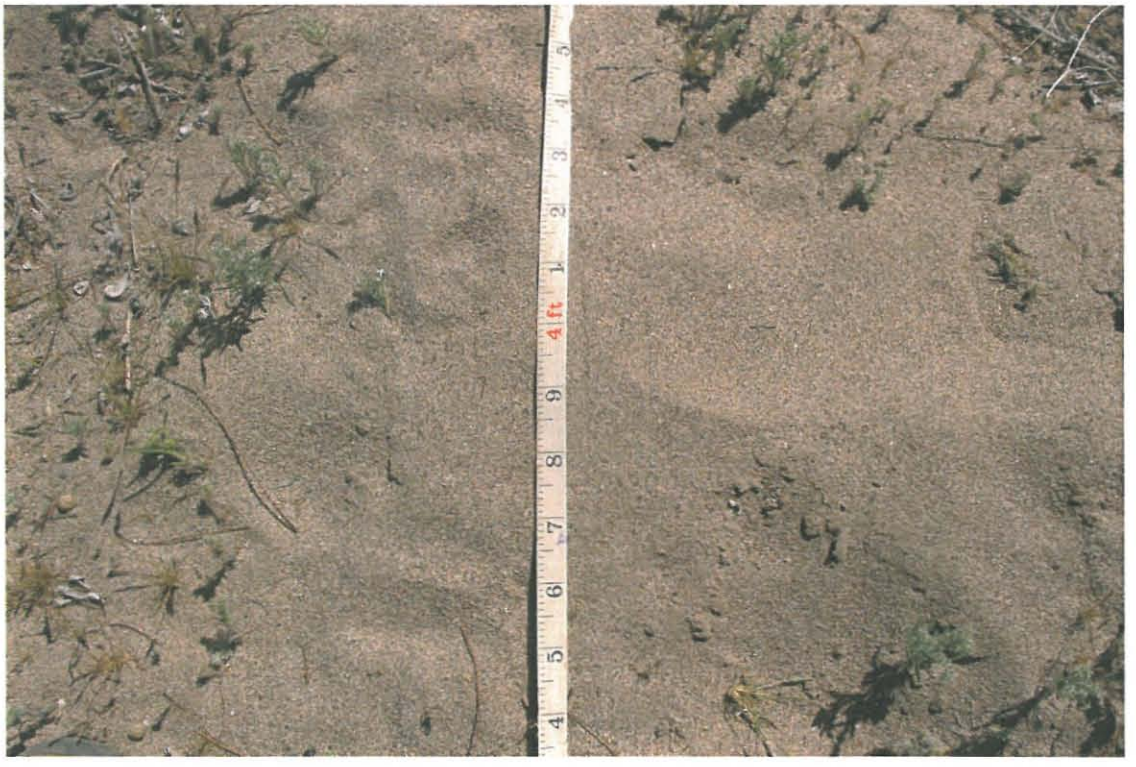


Site 7C - Bottom of Test Pit

Site 7D - Looking Upstream

Site 7D - Looking Downstream

Site 7D - Site



Site 7D - Ground

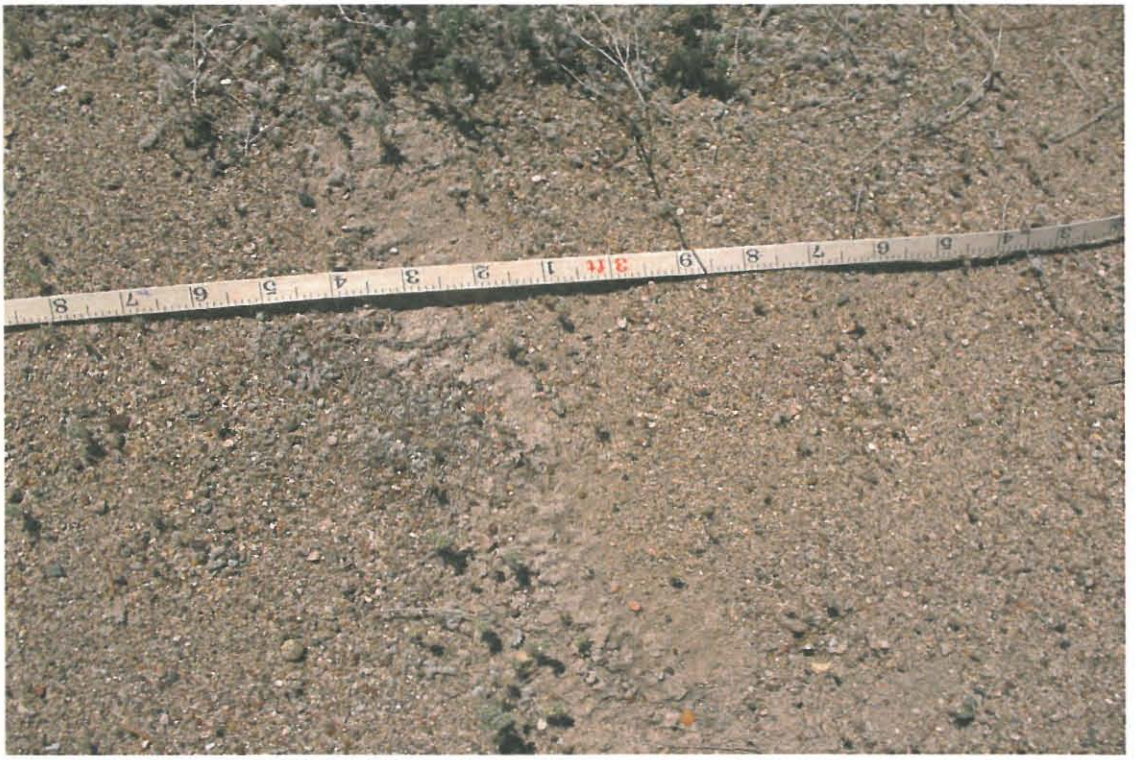
Site 7D - Test Pit

Site 7D - Top of Test Pit

Site 7D - Bottom of Test Pit

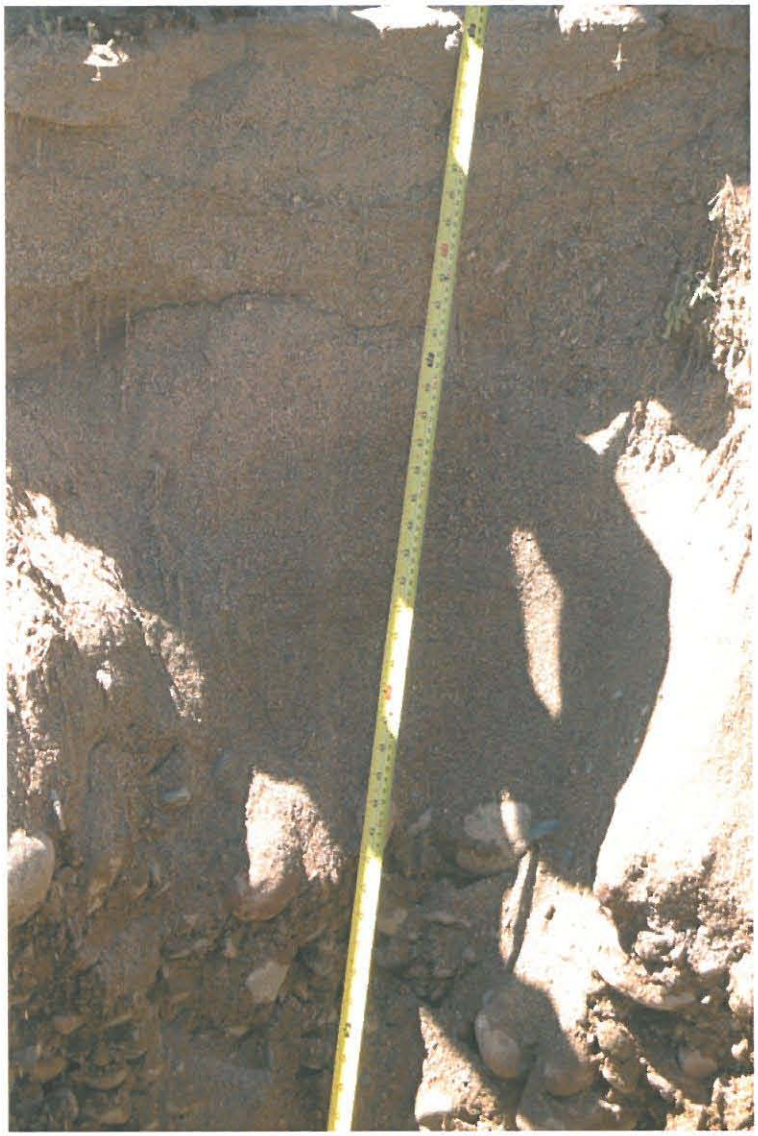
Site 7E - Looking Upstream

Site 7E - Looking Downstream



Site 7E - Ground

Site 7E - Test Pit

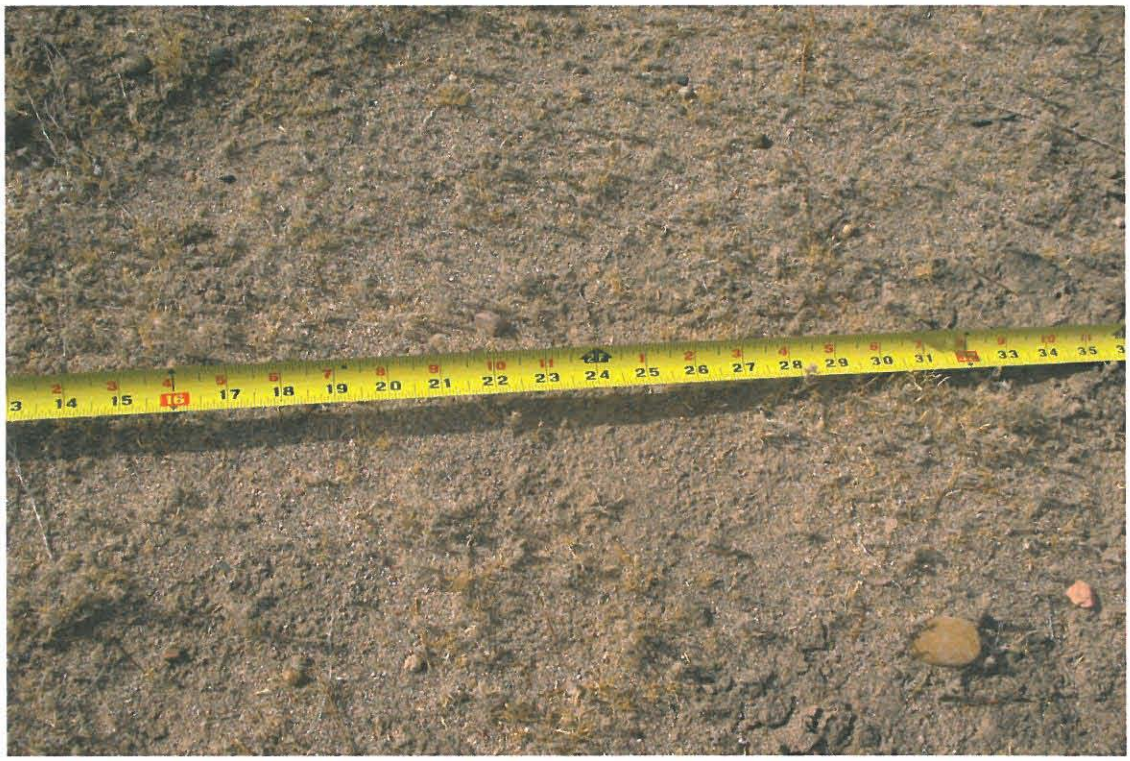


Site 7E - Top of Test Pit

Site 7E - Bottom of Test Pit

Site 7F - Looking Upstream

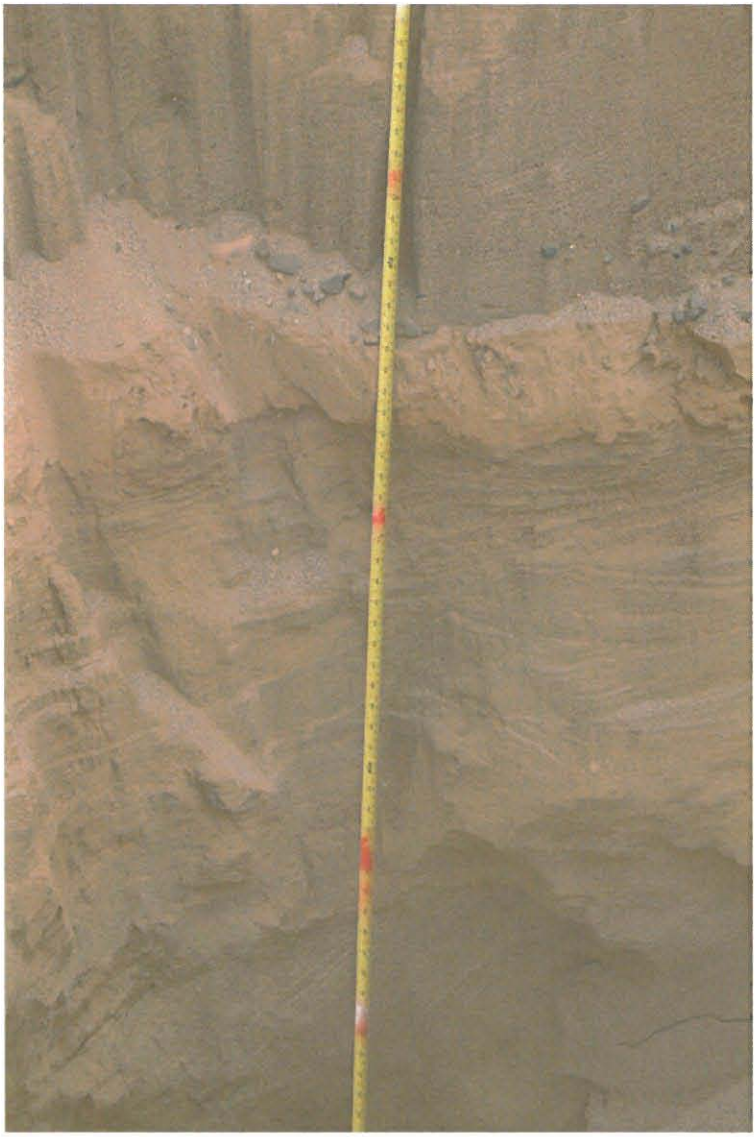
Site 7F - Looking Downstream



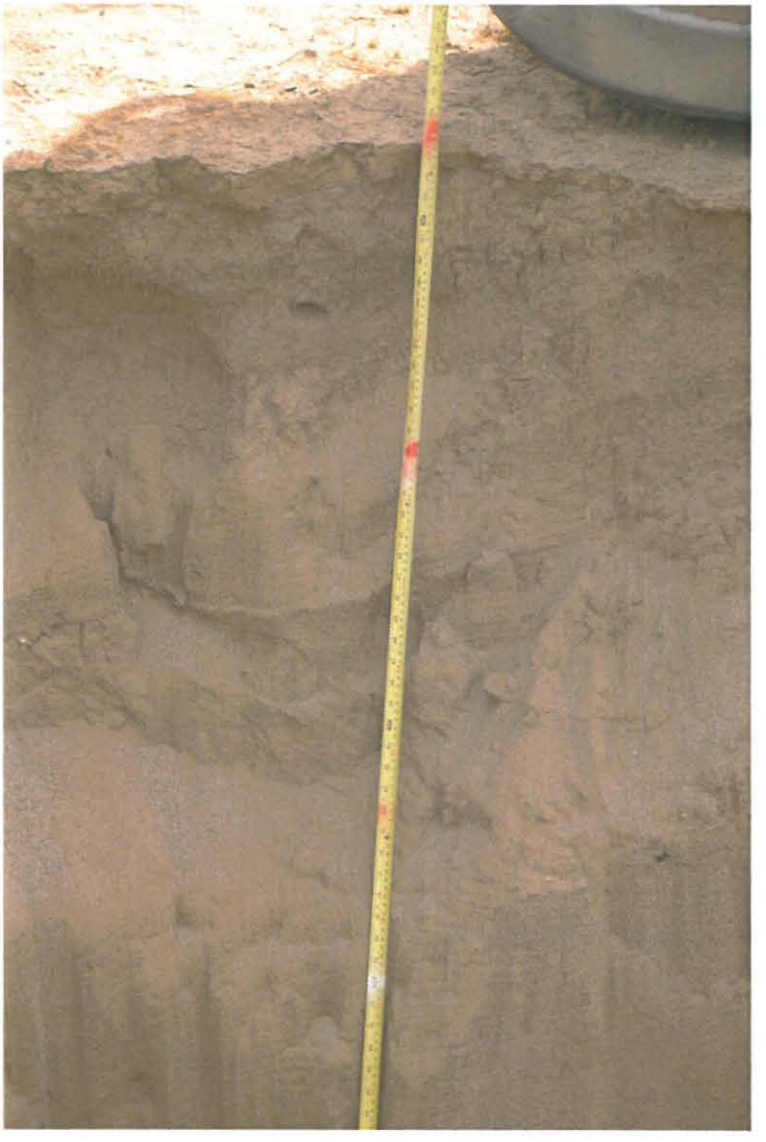
Site 7F - Ground

Site 7F - Test Pit

Site 7F - Bottom of Test Pit



Site 7F - Middle of Test Pit

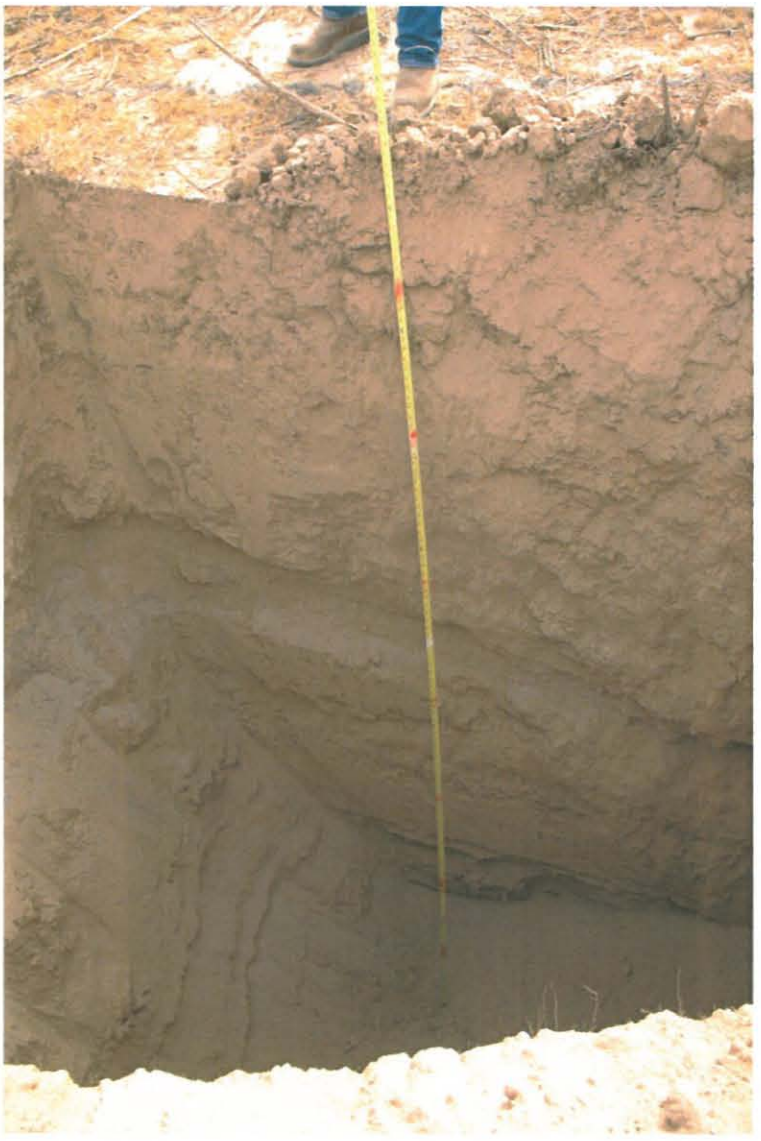


Site 7F - Top of Test Pit

Site 7G - Looking Upstream

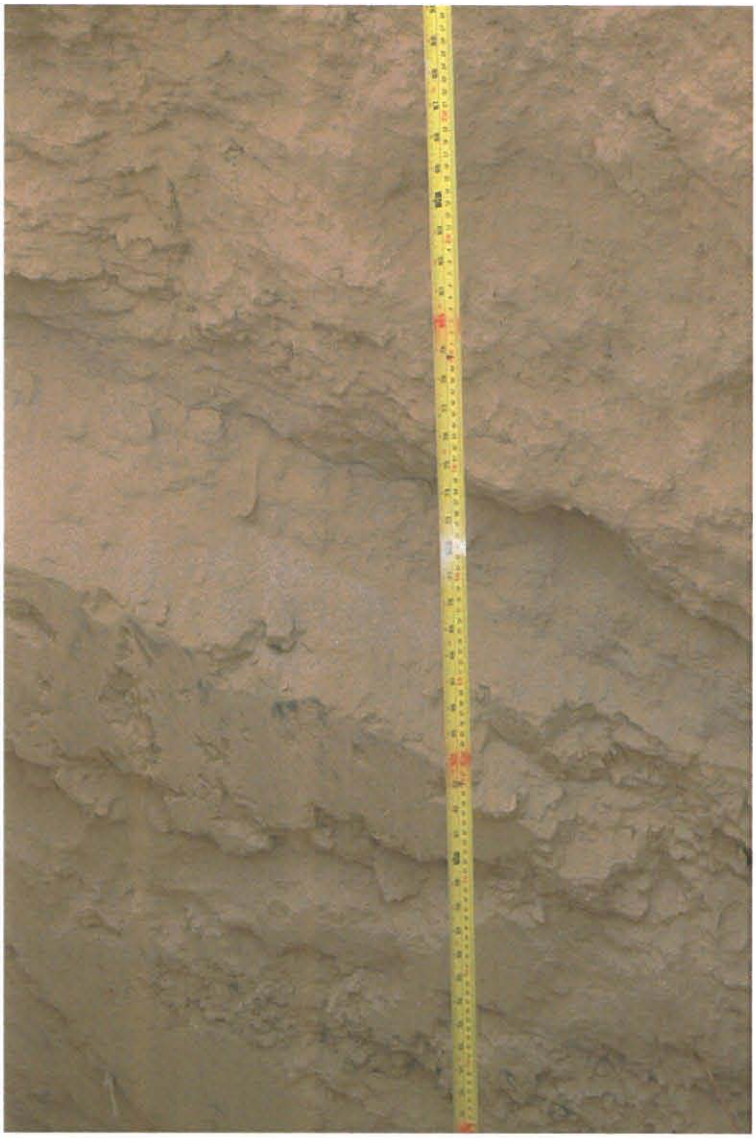
Site 7G - Looking Downstream

Site 7G - Ground

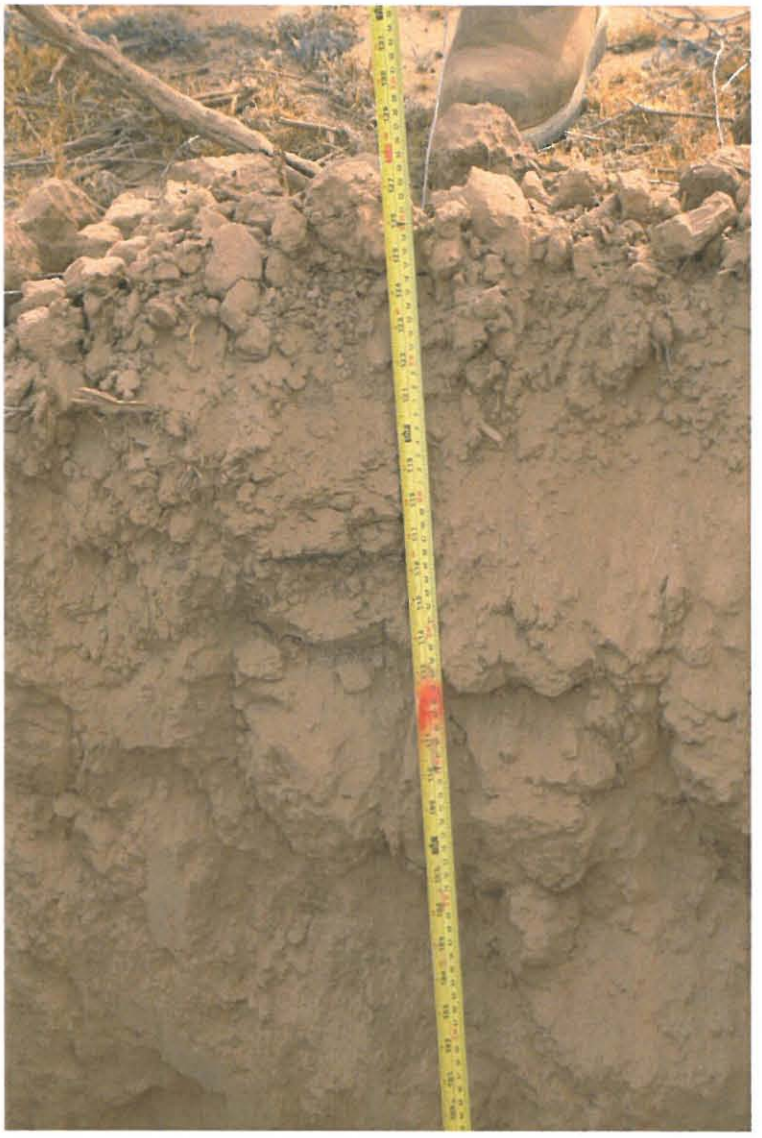


Site 7G - Test Pit

Site 7G - Bottom of Test Pit



Site 7G - Middle of Test Pit

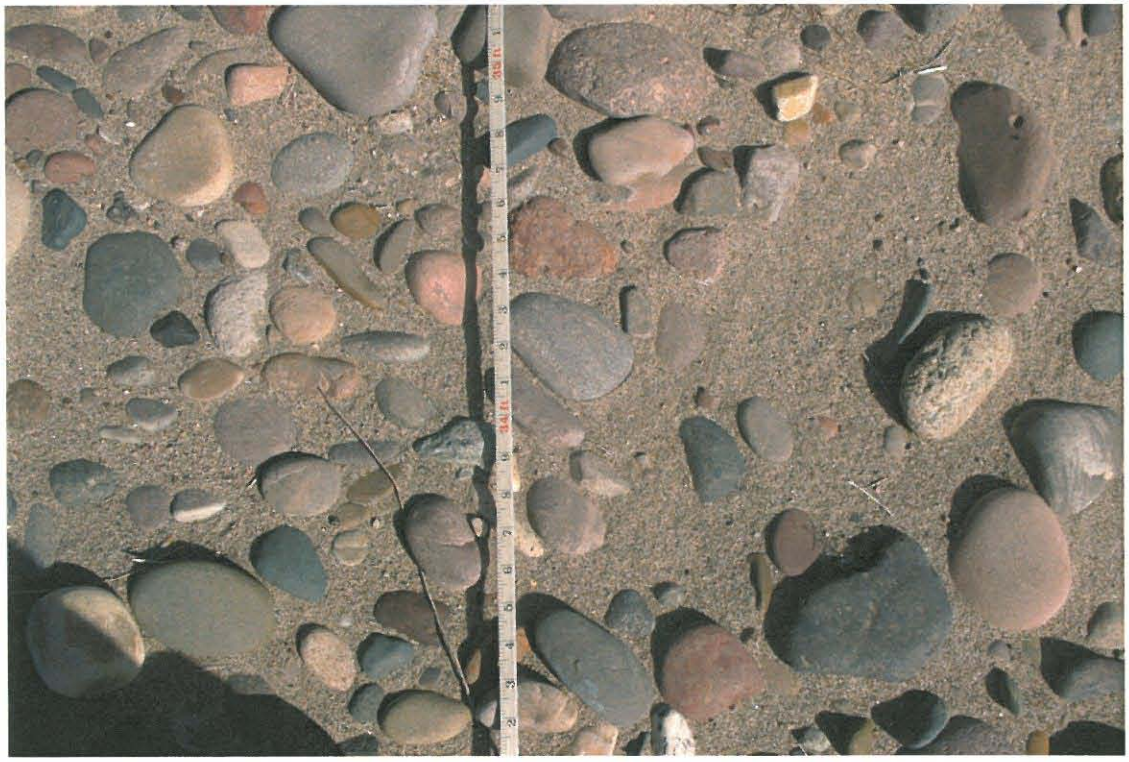


Site 7G - Top of Test Pit

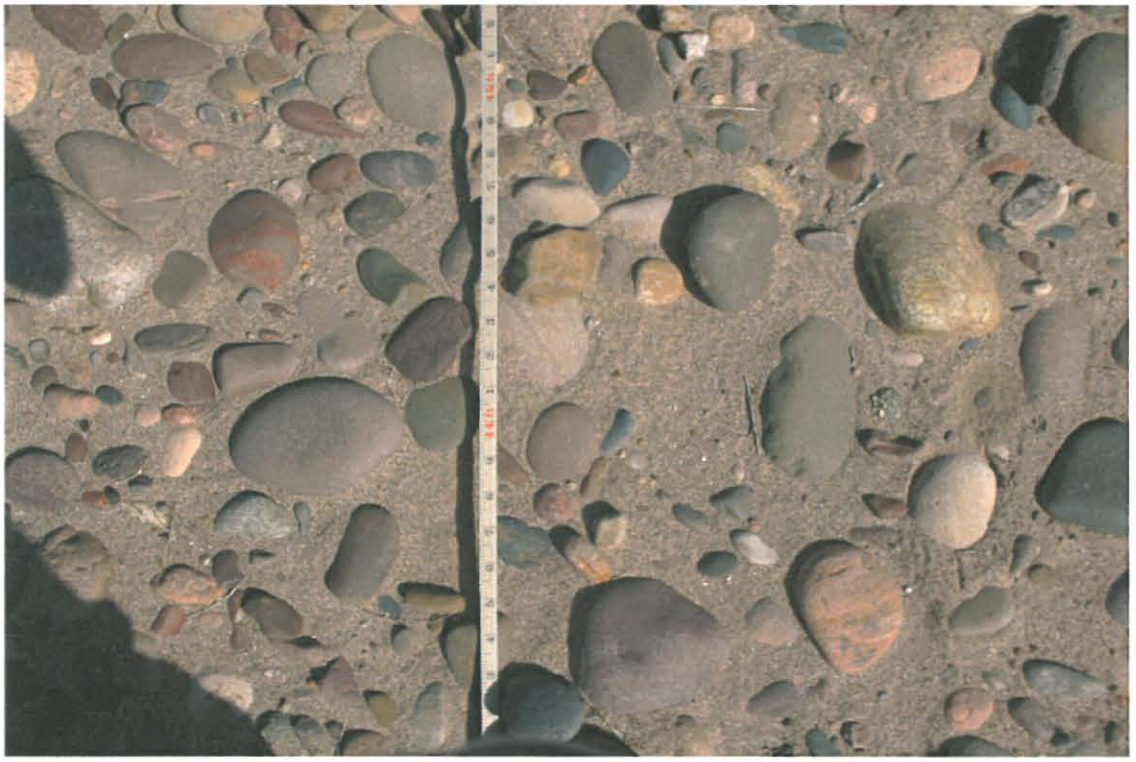
Site 8 - Looking Upstream

Site 8 - Looking Downstream

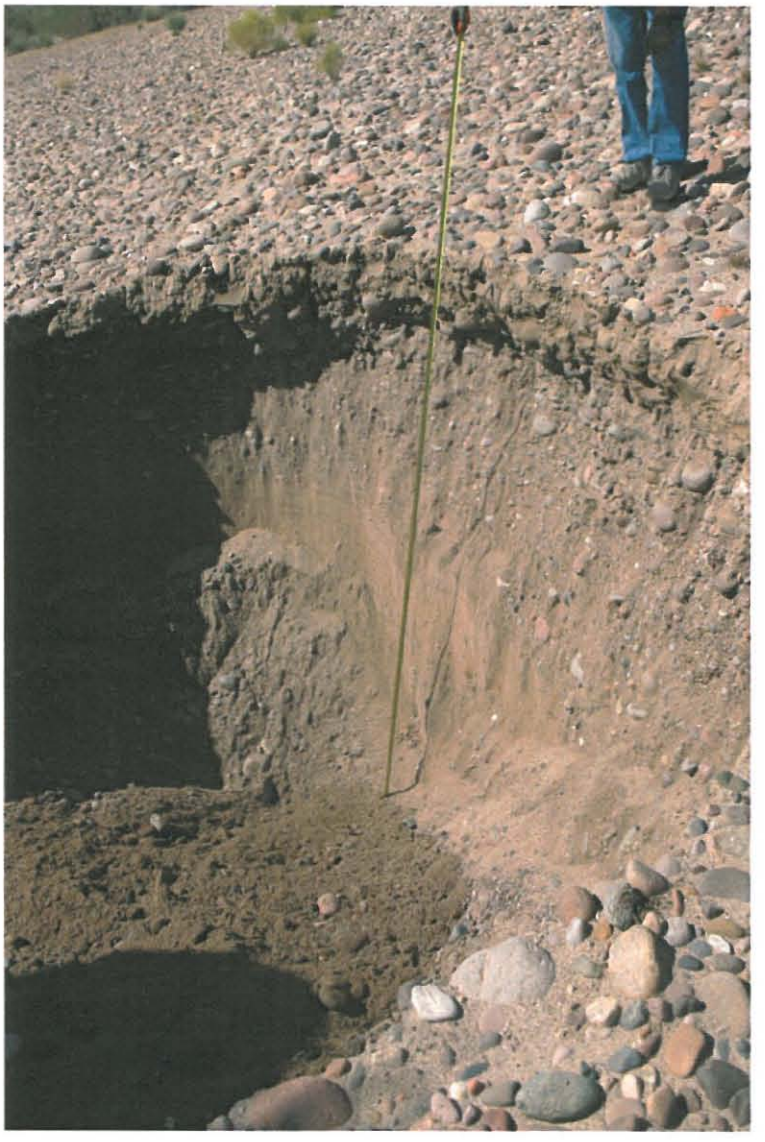
Site 8 - Ground



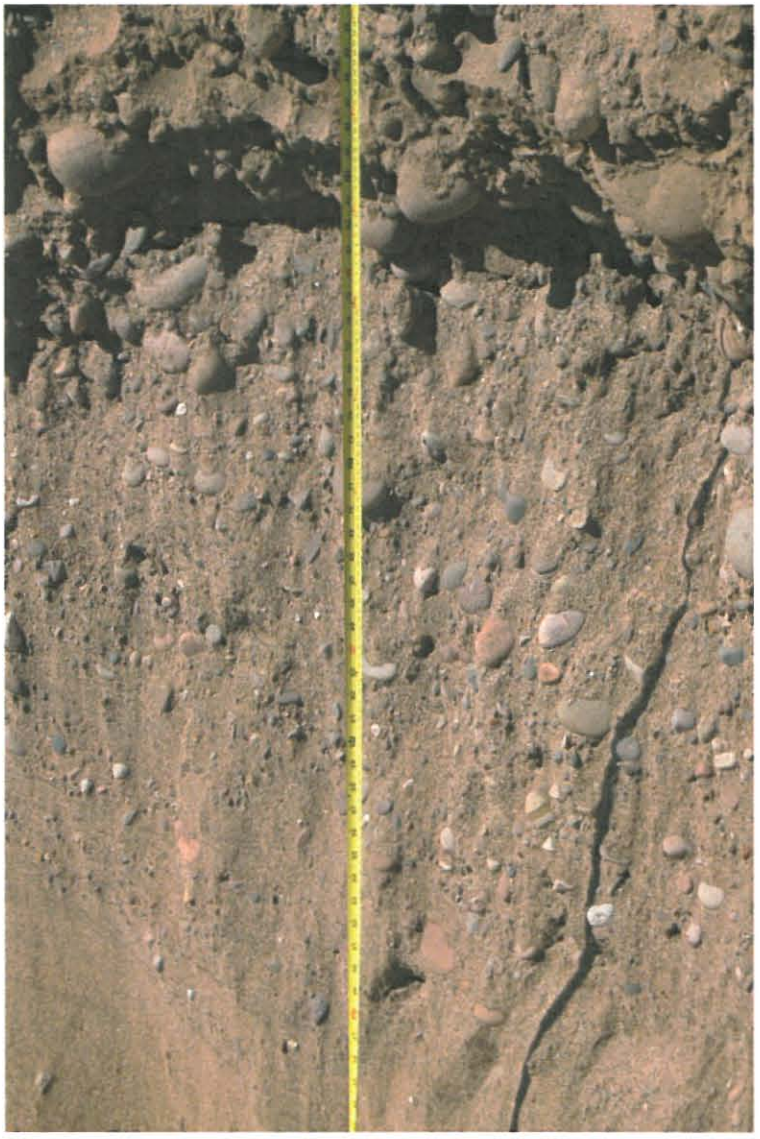
Site 8 - Ground



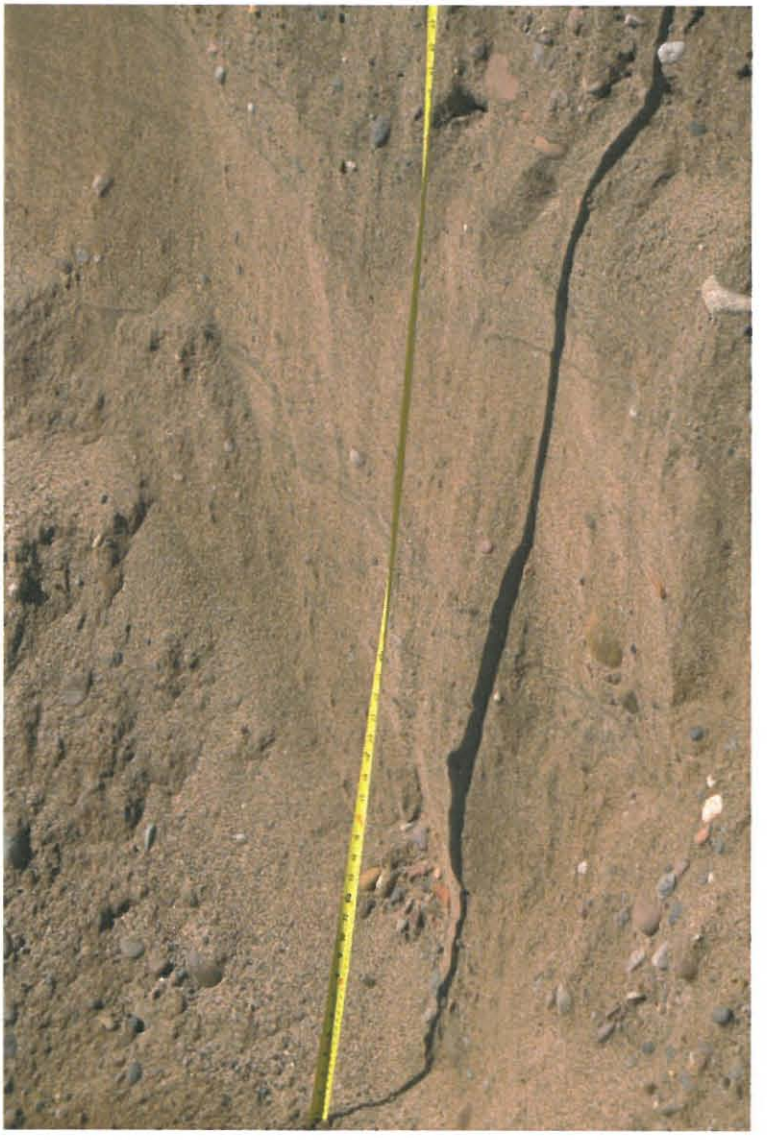
Site 8 - Ground



Site 8 - Test Pit



Site 8 - Top of Test Pit



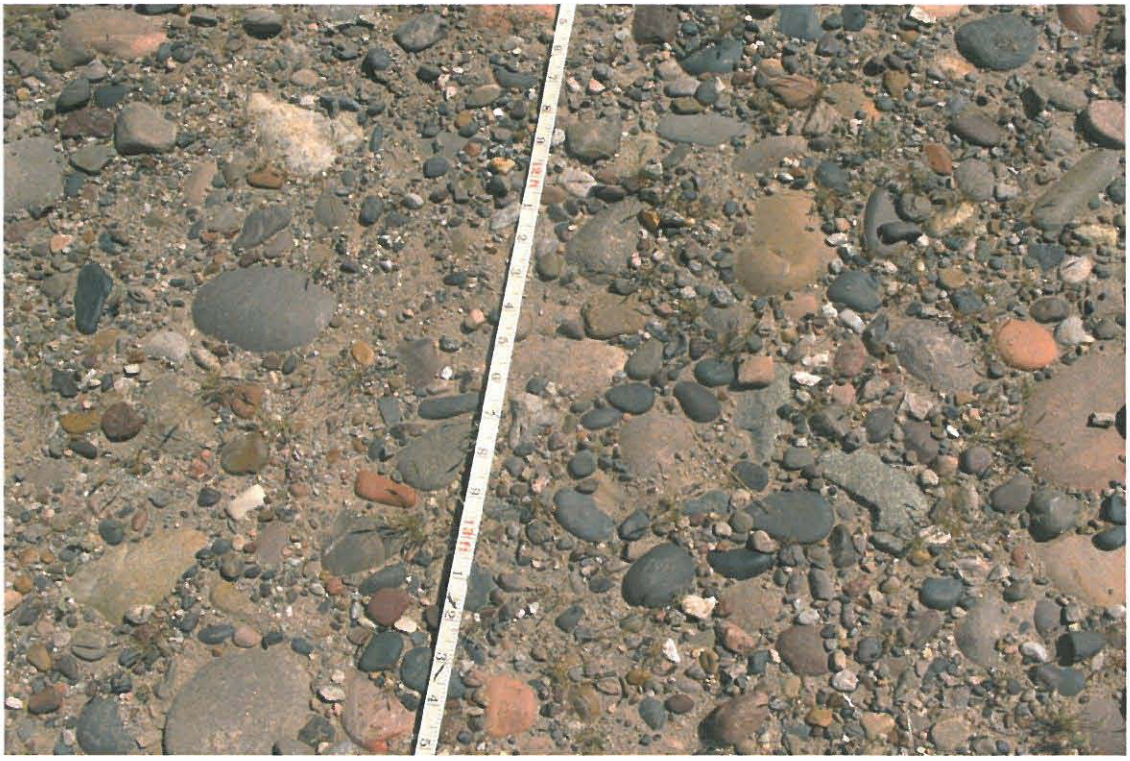
Site 8 - Bottom of Test Pit

Site 9A - Looking Upstream

Site 9A - Looking Downstream

Site 9A - Ground

Site 9A - Ground



Site 9A - Ground

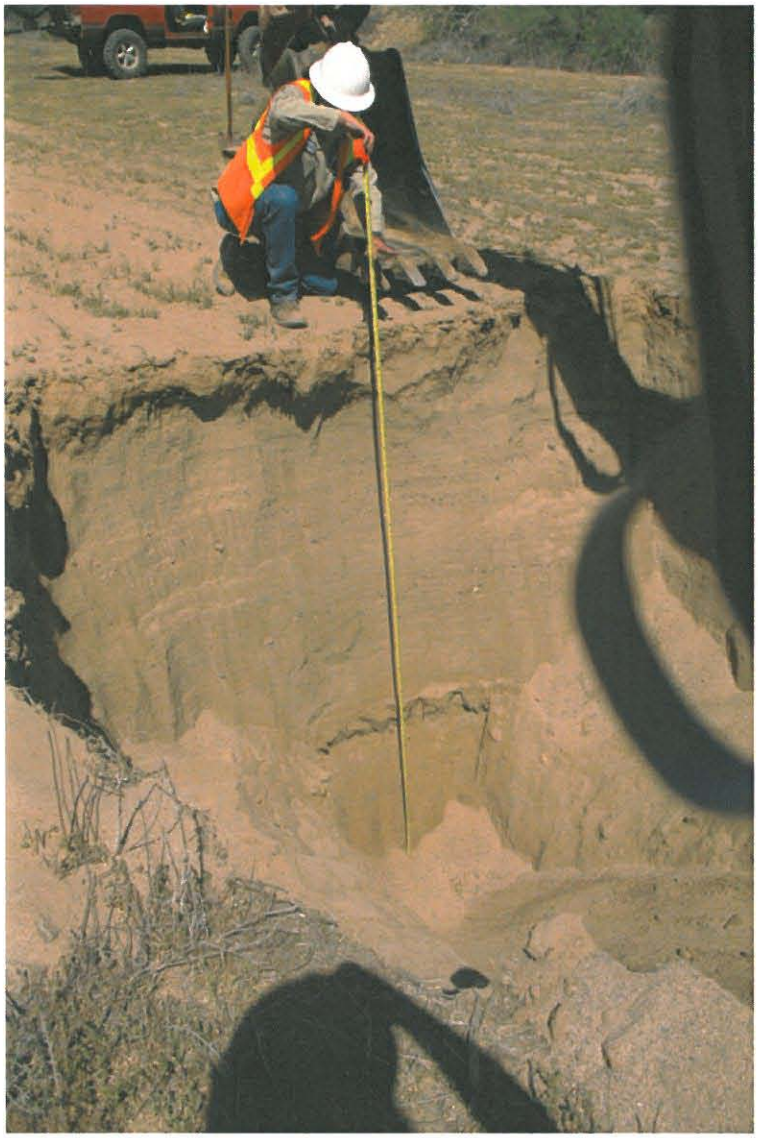
Site 9A - Top of Test Pit

Site 9A - Test Pit

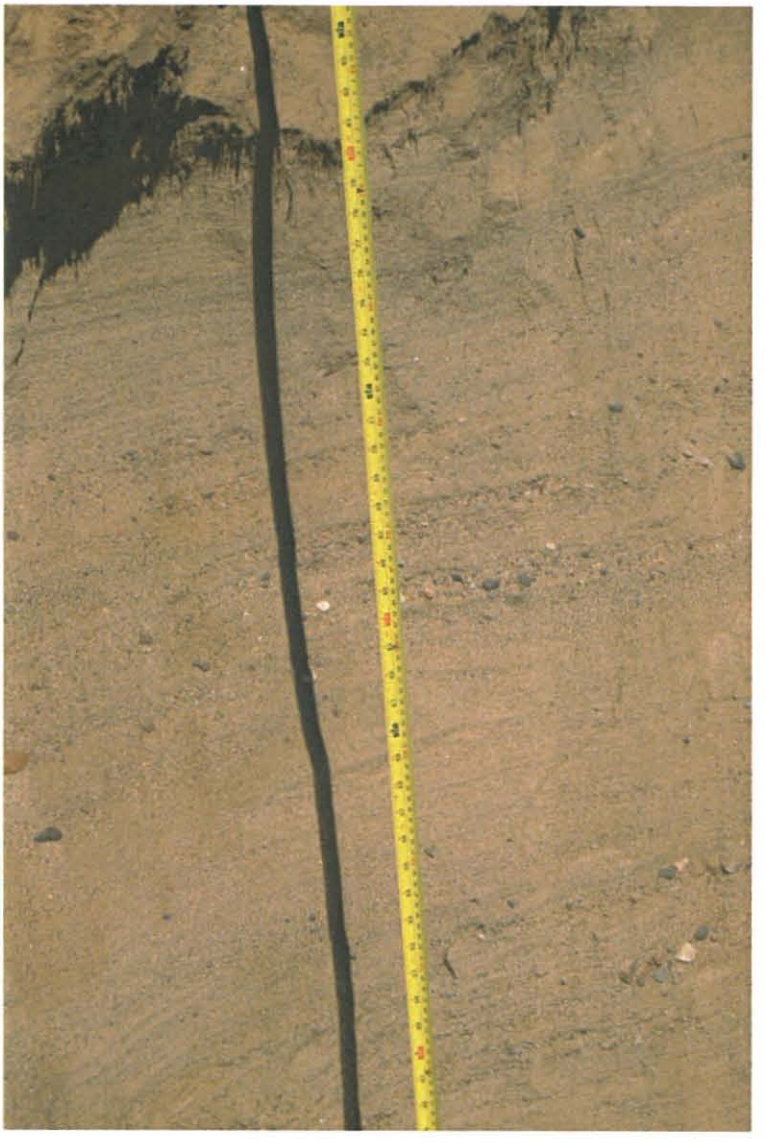
Site 9B - Looking Upstream

Site 9B - Looking Downstream

Site 9B - Ground



Site 9B - Test Pit



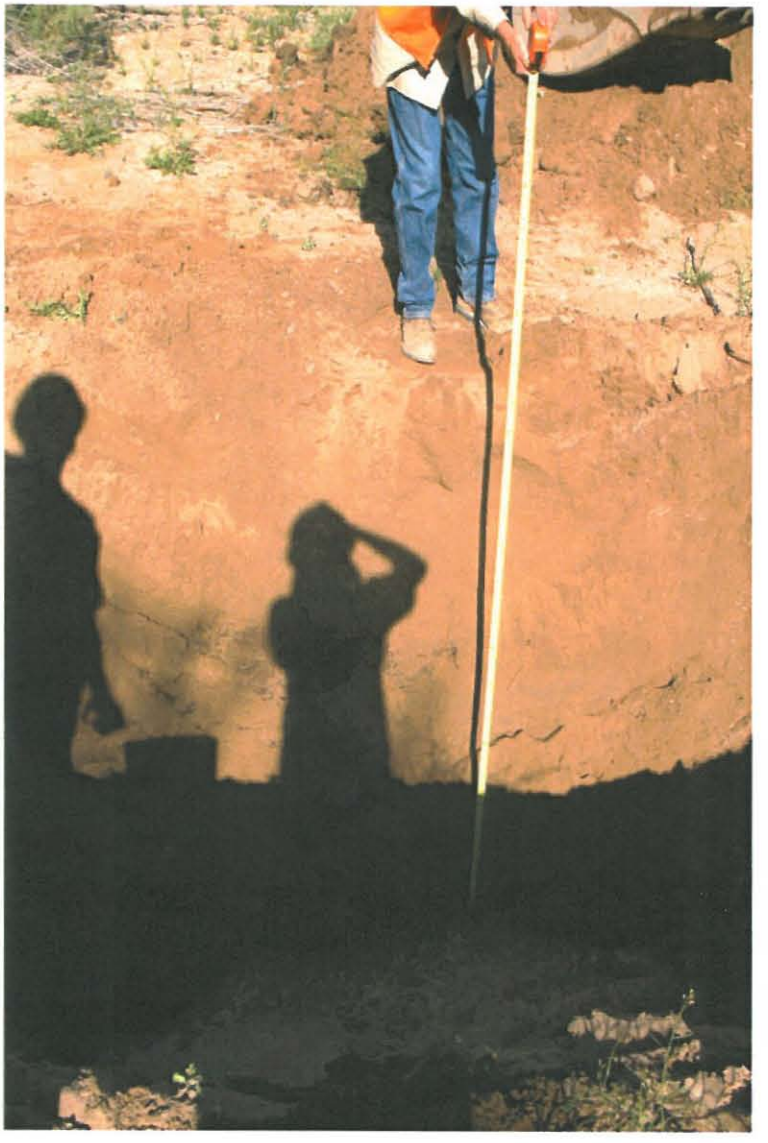
Site 9B - Top of Test Pit

Site 9C - Looking Upstream

Site 9C - Looking Downstream

Site 9C - Ground

Site 9C - Test Pit



Site 9C - Test Pit

Site 9D - Looking Upstream

Site 9D - Looking Downstream

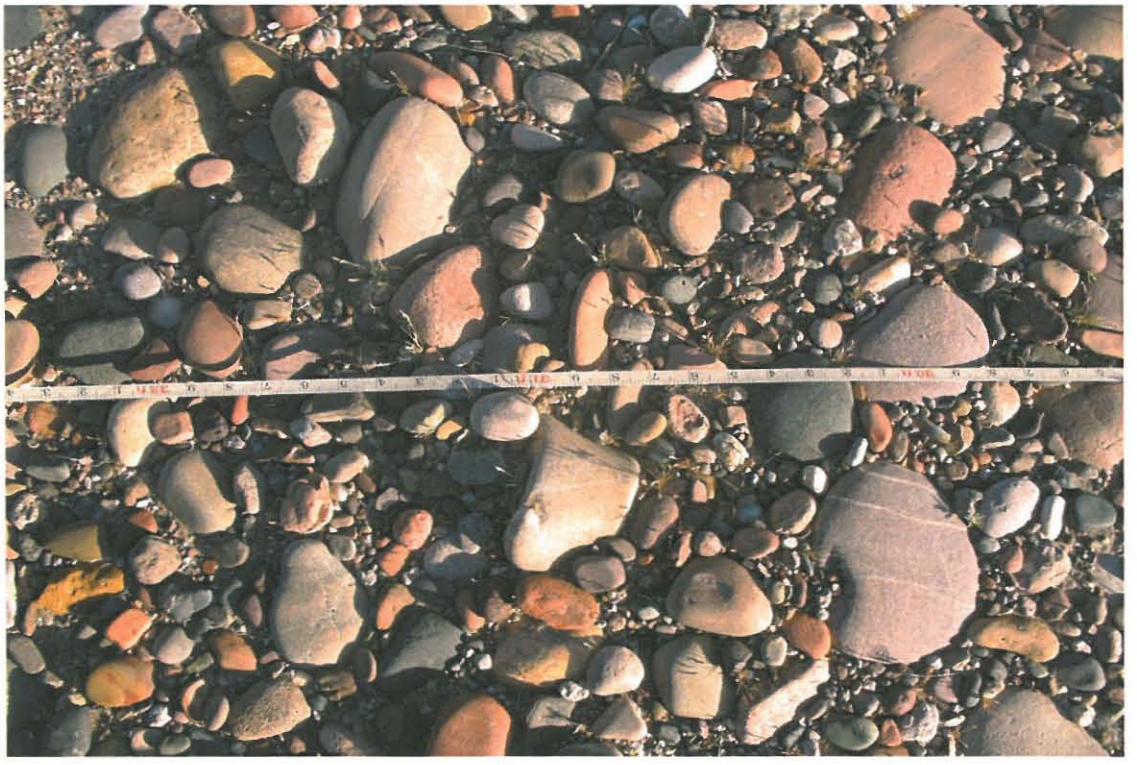
Site 9D - Ground

Site 9D - Test Pit

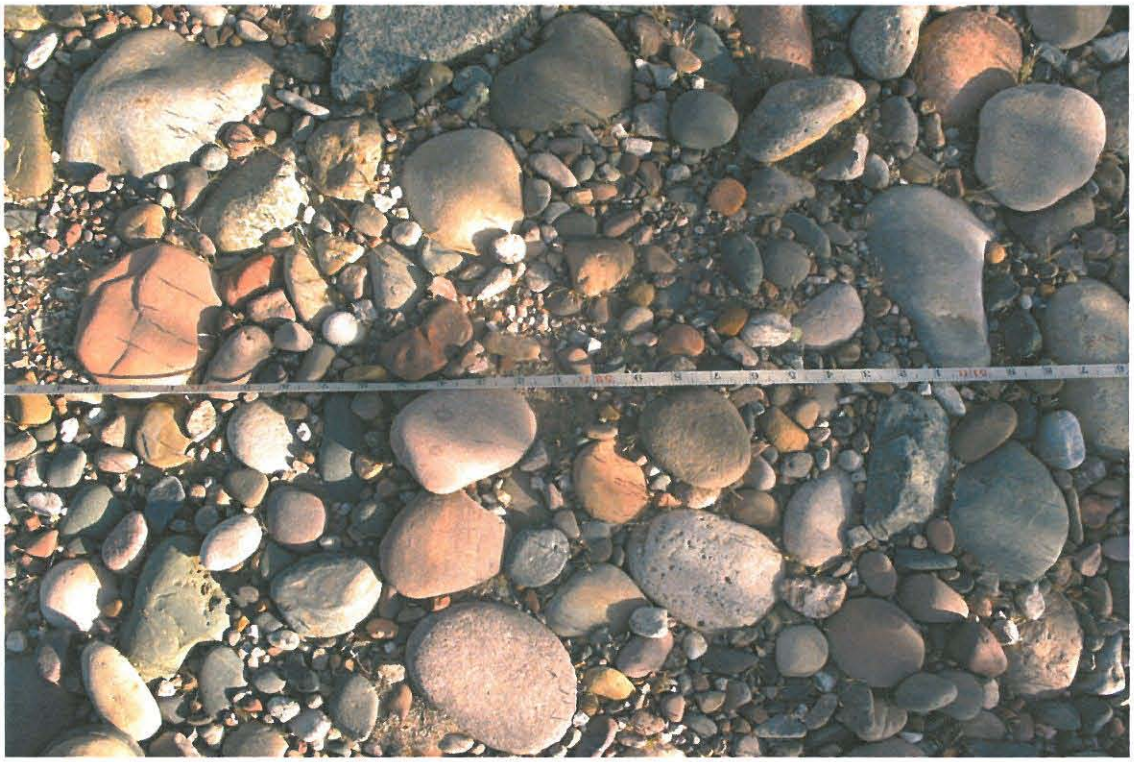
Site 10A - Looking Upstream

Site 10A - Looking Downstream

Site 10A - Ground

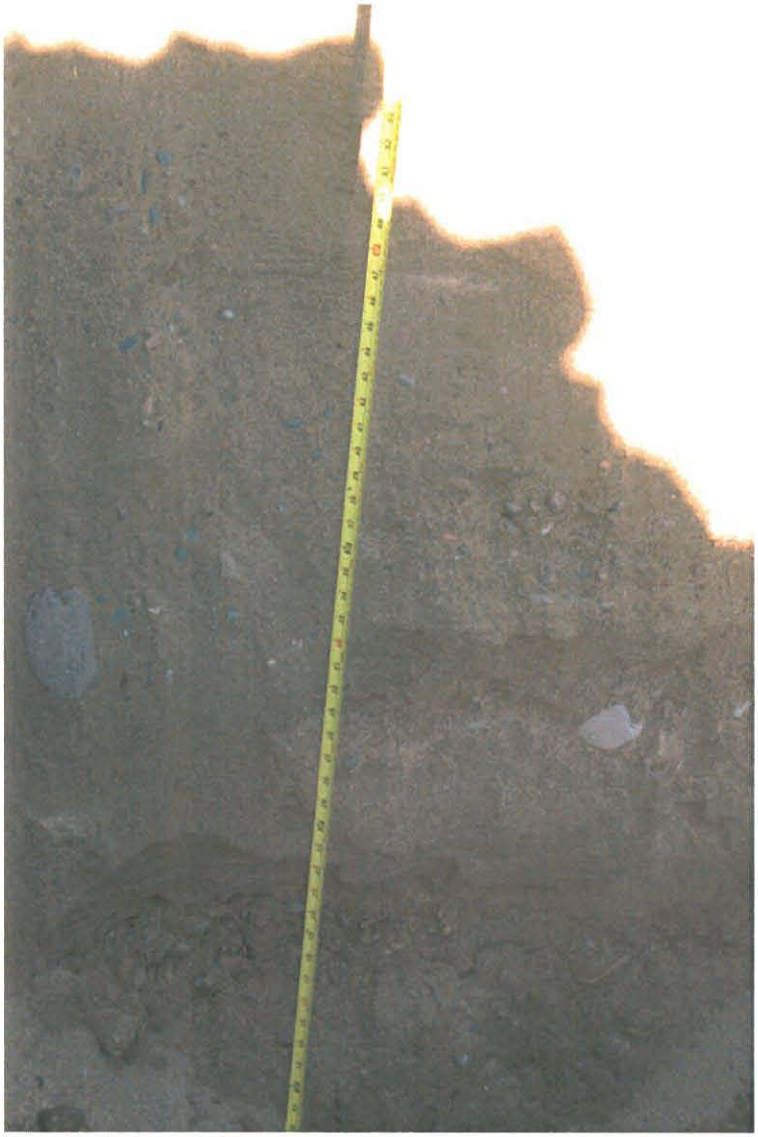


Site 10A - Test Pit



Site 10A - Ground

Site 10A - Test Pit

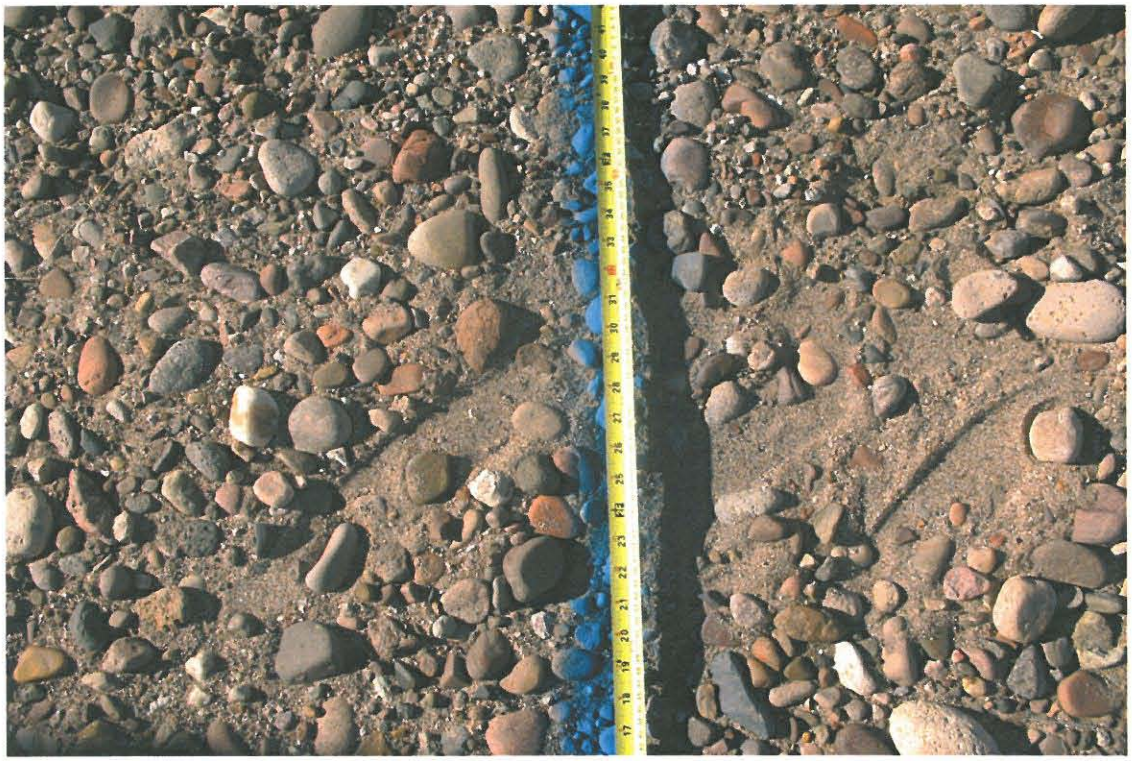


Site 10A - Bottom of Test Pit

Site 10A - Top of Test Pit

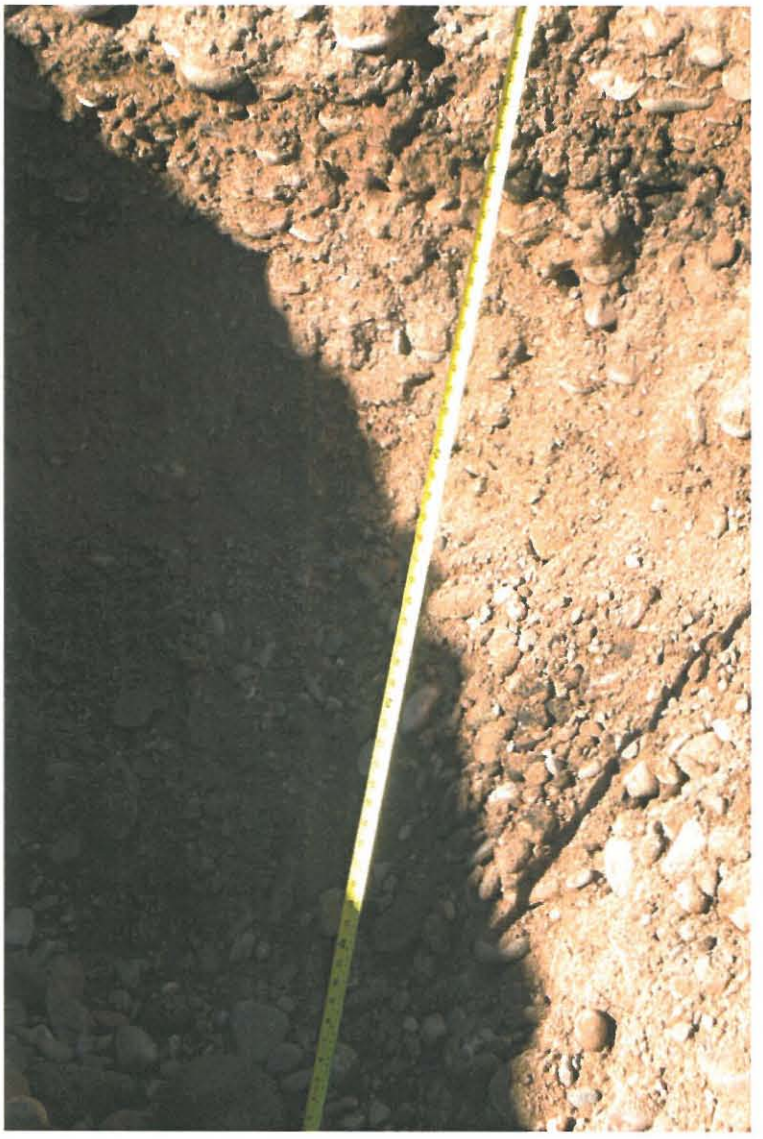
Site 10B - Looking Upstream

Site 10B - Looking Downstream



Site 10B - Ground

Site 10B - Test Pit

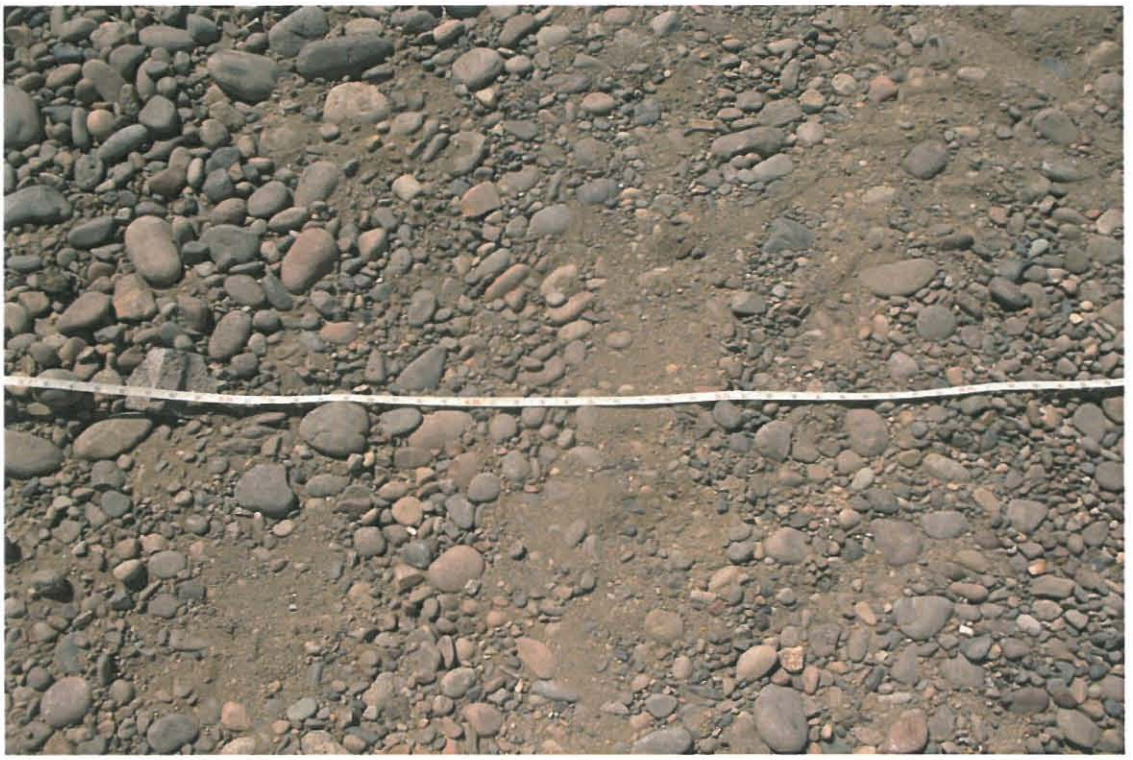


Site 10B - Bottom of Test Pit

Site 10B - Top of Test Pit

Site 11 - Looking Upstream

Site 11 - Looking Downstream



Site 11 - Ground

Site 11 - Test Pit

Site 11 - Top of Test Pit

Attachment D

Test Pit Logs

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	GP	Cobbles, boulders and gravel, predominantly coarse grained, subrounded to rounded gravel, rounded cobbles, uncemented, nonplastic, grayish brown, moist
5	x	G	GP	Sand with gravel and cobbles, predominantly medium to coarse grained, rounded cobbles, uncemented, nonplastic, grayish brown moist
10	x	G	GP	Sand with gravel and cobbles, predominantly medium to coarse grained, rounded cobbles, uncemented, nonplastic, grayish brown, wet Stopped bucket at 8.5 feet

Surface Elevation: _____ Groundwater Depth: 8.5'
Datum: _____ Date: 3/26/2009
Location: Main Channel Waypoint: 1

Test Pit 1

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	SM	Fine sand with silt, dry, light brown, no cementation
5			ML	Sandy silt, moist, light brown, no cementation
10	x	G		Stopped bucket at 10 feet

Surface Elevation: _____ Groundwater Depth: _____
Datum: _____ Date: 5/4/2009
Location: Overbank Waypoint: 2A

Test Pit 2A

Logged by: SRG / JG Backhoe Type: CAT 710

Stantec

Site:
Gila River Sediment Program

Sample Type:
B - undisturbed block sample
D - disturbed bulk sample
G - grab sample

Project Number: 182000565

LOG OF TEST PIT

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	SM	Medium sand with gravels and cobbles, light brown, dry, cobbles and gravel are subrounded to angular
	x	G	SP	Fine sand, light brown, dry, no cementation
5			SP	Medium sand with few gravels and cobbles, dry, subrounded to angular
	x	G		Stopped bucket at 8.5 feet
10				

Surface Elevation: _____ Groundwater Depth: _____
Datum: _____ Date: 5/4/2009
Location: Overbank Waypoint: 2B

Test Pit
2B

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	SP	Medium sand with some gravels, gravels are subangular, dry, no cementation
5	x	G	SP	Sand with gravels and cobbles, gravels and cobbles are rounded, wet, light brown, no cementation
10				Stopped bucket at 7.5 feet

Surface Elevation: _____ Groundwater Depth: 7.5'
Datum: _____ Date: 5/4/2009
Location: Channel Waypoint: 2C

Test Pit
2C

Logged by: SRG / JG Backhoe Type: CAT 710

Stantec

Site:
Gila River Sediment Program

Sample Type:
B - undisturbed block sample
D - disturbed bulk sample
G - grab sample

Project Number: 182000565

LOG OF TEST PIT

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	GP	Sand, gravels and cobbles, predominately sand, gravels and cobbles are subrounded, wet, no cementation Stopped bucket at 3 feet
5				
10				

Surface Elevation: _____ Groundwater Depth: 3'
Datum: _____ Date: 5/4/2009
Location: Channel Waypoint: 2D

Test Pit
2D

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	GP	Sand, gravel and cobbles, predominately sand, gravels and cobbles are rounded, wet, light brown Stopped bucket at 2 feet
5				
10				

Surface Elevation: _____ Groundwater Depth: 2'
Datum: _____ Date: 5/4/2009
Location: Channel Waypoint: 2E

Test Pit
2E

Logged by: SRG / JG Backhoe Type: CAT 710

Stantec

Site:
Gila River Sediment Program

Sample Type:
B - undisturbed block sample
D - disturbed bulk sample
G - grab sample

Project Number: 182000565

LOG OF TEST PIT

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0			ML	Silt, weak cementation, moist, light brown
	x	G		
5			ML	Silt with fine sand, weak cementation, moist, brown
10	x	G		Stopped bucket at 10 feet

Surface Elevation: _____ Groundwater Depth: _____
Datum: _____ Date: 3/25/2009
Location: Overbank Waypoint: 2C1

Test Pit
2C1

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0				
5				
10				

Surface Elevation: _____ Groundwater Depth: _____
Datum: _____ Date: _____
Location: _____ Waypoint: _____

Test Pit

Logged by: SRG / JG Backhoe Type: CAT 710

Stantec

Site:
Gila River Sediment Program

Sample Type:
B - undisturbed block sample
D - disturbed bulk sample
G - grab sample

Project Number: 182000565

LOG OF TEST PIT

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0			SM	Silty Sand with gravel, predominantly medium sand, subrounded cobbles, uncemented, nonplastic, brown, dry
5	x	G		Backhoe refusal at bedrock at 6 feet
10				

Surface Elevation: _____ Groundwater Depth: _____
Datum: _____ Date: 3/25/2009
Location: Overbank Waypoint: 3

Test Pit 3

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	SP	Sand with few gravels and cobbles, predominantly fine to medium sand, rounded gravels and cobbles, uncemented, nonplastic, brown, moist
5	x	G	SP	Sand with few gravels, predominantly fine sand, rounded gravels and cobbles, uncemented, nonplastic, brown, wet Stopped bucket at 7 feet
10				

Surface Elevation: _____ Groundwater Depth: 7'
Datum: _____ Date: 3/23/2009
Location: Main Channel Waypoint: 4

Test Pit 4

Logged by: SRG / JG Backhoe Type: CAT 710

Stantec

Site:
Gila River Sediment Program

Sample Type:
B - undisturbed block sample
D - disturbed bulk sample
G - grab sample

Project Number: 182000565

LOG OF TEST PIT

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0			ML	Silt, with weak cementation, dry, light brown
	x	G		
5				
	x	G		Stopped bucket at 8 feet
10				

Surface Elevation: _____ Groundwater Depth: _____
Datum: _____ Date: 3/24/2009
Location: Overbank Waypoint: 5A

Test Pit
5A

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0			ML	Silt, with no cementation, brown, dry
	x	G	ML	Silty Sand, fine sand, weakly cemented, brown, dry
	x	G		
5			SP	Sand with gravels and cobbles, predominantly fine sand, subrounded gravel, no cementation, dry, grayish brown
	x	G		
	x	G	SM	Fine sand with few gravel, predominantly fine sand, subrounded gravel, no cementation, dry, grayish brown
10				Stopped bucket at 9 feet

Surface Elevation: _____ Groundwater Depth: _____
Datum: _____ Date: 3/24/2009
Location: Overbank Waypoint: 5B

Test Pit
5B

Logged by: SRG / JG Backhoe Type: CAT 710

Stantec

Site:
Gila River Sediment Program

Sample Type:
B - undisturbed block sample
D - disturbed bulk sample
G - grab sample

Project Number: 182000565

LOG OF TEST PIT

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	GP	Gravel, Cobbles and Boulders, well rounded gravel, cobbles and boulders, no cementation, grayish brown, moist
5				
10	x	G	GP	Gravel with cobbles and boulders, well rounded gravel, cobbles and boulders, no cementation, grayish brown, wet Stopped bucket at 10 feet

Surface Elevation: _____ Groundwater Depth: 10'
Datum: _____ Date: 3/23/2009
Location: Main Channel Waypoint: 5C

Test Pit
5C

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	ML	Silt, moderately cemented, light brown, dry
5			ML	Sandy silt, fine sand, weakly cemented, light brown, dry
10	x	G		Stopped bucket at 11 feet

Surface Elevation: _____ Groundwater Depth: _____
Datum: _____ Date: 3/23/2009
Location: Overbank Waypoint: 5D

Test Pit
5D

Logged by: SRG / JG Backhoe Type: CAT 710

Stantec

Site:
Gila River Sediment Program

Sample Type:
B - undisturbed block sample
D - disturbed bulk sample
G - grab sample

Project Number: 182000565

LOG OF TEST PIT

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	ML	Silt, weakly cemented, light brown, dry
5			ML	Silt with some sand, fine sand, no cementation, light brown, moist
10	x	G		Stopped bucket at 8 feet

Surface Elevation: _____ Groundwater Depth: _____
Datum: _____ Date: 3/19/2009
Location: Overbank Waypoint: 11

Test Pit 6A

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0			GW	Gravel with sand and cobbles, well rounded cobbles and gravel, no cementation, dark brown, wet
5	x	G		Stopped bucket at 3.5 feet
10				

Surface Elevation: _____ Groundwater Depth: 3.5'
Datum: _____ Date: 3/23/2009
Location: Main Channel Waypoint: 6B

Test Pit 6B

Logged by: SRG / JG Backhoe Type: CAT 710

Stantec

Site:
Gila River Sediment Program

Sample Type:
B - undisturbed block sample
D - disturbed bulk sample
G - grab sample

Project Number: 182000565

LOG OF TEST PIT

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	GW	Gravel with sand and cobbles, well rounded gravel and cobbles, grayish brown, wet Stopped bucket at 4 feet
5				
10				

Surface Elevation: _____ Groundwater Depth: 4'
Datum: _____ Date: 3/23/2009
Location: Main Channel Waypoint: 6C

Test Pit
6C

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	SP	Sand with some gravel and few cobbles, fine to medium sand, well rounded gravel and cobbles, no cementation, light brown, moist
5				
10	x	G	SP	Sand with few gravel, fine to medium sand, no cementation, light brown, wet Stopped bucket at 9 feet

Surface Elevation: _____ Groundwater Depth: 9'
Datum: _____ Date: 3/23/2009
Location: Channel Waypoint: 6D

Test Pit
6D

Logged by: SRG / JG Backhoe Type: CAT 710

Stantec

Site:
Gila River Sediment Program

Sample Type:
B - undisturbed block sample
D - disturbed bulk sample
G - grab sample

Project Number: 182000565

LOG OF TEST PIT

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	SW	Sand with little fines and gravel, light brown, dry, no cementation
			SP	Sand, gravel and cobbles, predominately sand, subrounded gravel and cobbles, no cementation, light brown
10	x	G		Stopped bucket at 11 feet
20				

Surface Elevation: _____ Groundwater Depth: _____
Datum: _____ Date: 5/5/2009
Location: Channel Waypoint: 7A

Test Pit
7A

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	SP	Fine sand with few gravels and cobbles, subrounded to rounded gravels and cobbles, light brown, dry, no cementation
5			SP	Medium sand with some gravels and cobbles, subrounded to rounded gravels and cobbles, light brown, moist, no cementation
10	x	G		Stopped bucket at 10 feet

Surface Elevation: _____ Groundwater Depth: _____
Datum: _____ Date: 5/5/2009
Location: Channel Waypoint: 7B

Test Pit
7B

Logged by: SRG / JG Backhoe Type: CAT 710

Stantec

Site:
Gila River Sediment Program

Sample Type:
B - undisturbed block sample
D - disturbed bulk sample
G - grab sample

Project Number: 182000565

LOG OF TEST PIT

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	GP	Gravel with sand and cobbles, predominantly fine gravel and coarse sand, well rounded cobbles, no cementation, grayish brown, wet Stopped bucket at 3 feet
5				
10				

Surface Elevation: _____ Groundwater Depth: 3'
Datum: _____ Date: 3/24/2009
Location: Main Channel Waypoint: 7C

Test Pit
7C

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	SP	Sand with gravel and cobbles, predominantly medium to coarse sand, well rounded cobbles, grayish brown, wet Stopped bucket at 4 feet
5				
10				

Surface Elevation: _____ Groundwater Depth: 4'
Datum: _____ Date: 3/24/2009
Location: Main Channel Waypoint: 7D

Test Pit
7D

Logged by: SRG / JG Backhoe Type: CAT 710

Stantec

Site:
Gila River Sediment Program

Sample Type:
B - undisturbed block sample
D - disturbed bulk sample
G - grab sample

Project Number: 182000565

LOG OF TEST PIT

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0			SP	Sand with few gravels, no cementation, brown, dry
	x	G		
5	x	G	GP	Gravel with sand and cobbles, predominately fine to coarse gravel, well rounded cobbles, no cementation, grayish brown, wet Stopped bucket at 6 feet
10				

Surface Elevation: _____ Groundwater Depth: 6'
Datum: _____ Date: 3/24/2009
Location: Main Channel Waypoint: 7E

Test Pit
7E

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	SM	Medium Sand with few gravels, subangular gravel, light brown, dry, no cementation
5				
10	x	G		Stopped bucket at 10 feet

Surface Elevation: _____ Groundwater Depth: _____
Datum: _____ Date: 5/5/2009
Location: Channel Waypoint: 7F

Test Pit
7F

Logged by: SRG / JG Backhoe Type: CAT 710

Stantec

Site:
Gila River Sediment Program

Sample Type:
B - undisturbed block sample
D - disturbed bulk sample
G - grab sample

Project Number: 182000565

LOG OF TEST PIT

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	ML	Silt, light brown, weakly cemented, dry
	x	G	ML	Sandy silt, light brown, no cementation, dry
10	x	G	GP	Sand, gravel and cobbles, predominately gravel, gravel and cobbles rounded to subrounded, moist, no cementation, light brown
				Stopped bucket at 10 feet
20				

Surface Elevation: _____ Groundwater Depth: _____
Datum: _____ Date: 5/5/2009
Location: Overbank Waypoint: 7G

Test Pit
7G

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	GP	Gravel with cobbles and sand, well rounded cobbles and gravel, light brown, moist
5				
	x	G		
10				Stopped bucket at 8'

Surface Elevation: _____ Groundwater Depth: _____
Datum: _____ Date: 3/19/2009
Location: Main Channel Waypoint: 10

Test Pit
8

Logged by: SRG / JG Backhoe Type: CAT 710

Stantec

Site:
Gila River Sediment Program

Sample Type:
B - undisturbed block sample
D - disturbed bulk sample
G - grab sample

Project Number: 182000565

LOG OF TEST PIT

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	GP	Sandy gravel with cobbles, rounded cobbles, no cementation light brown, moist
5				
				Stopped bucket at 8 feet
10				

Surface Elevation: _____ Groundwater Depth: 8'
Datum: _____ Date: 3/18/2009
Location: Channel Waypoint: 5

Test Pit
9A

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	SP	Sand with silt, predominantly fine sand, light brown, no cementation, dry
5				
				Stopped bucket at 8 feet
10				

Surface Elevation: _____ Groundwater Depth: _____
Datum: _____ Date: 3/18/2009
Location: Overbank Waypoint: 5

Test Pit
9B

Logged by: SRG / JG Backhoe Type: CAT 710

Stantec

Site:
Gila River Sediment Program

Sample Type:
B - undisturbed block sample
D - disturbed bulk sample
G - grab sample

Project Number: 182000565

LOG OF TEST PIT

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	ML	Silty sand with few gravels, predominately fine sand, subrounded gravel, no cementation, moist
5				Stopped bucket at 5.5 feet
10				

Surface Elevation: _____ Groundwater Depth: 5.5'
Datum: _____ Date: 3/18/2009
Location: Channel Waypoint: 4

Test Pit
9C

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	ML	Silty sand, no cementation, brown moist
			SM	Silty sand with few gravel, predominately fine sand, grayish brown, moist
5	x	G		
	x	G	SM	Sand with gravel and cobbles, predominately coarse sand, rounded cobbles, wet
10				Stopped bucket at 8 feet

Surface Elevation: _____ Groundwater Depth: 8'
Datum: _____ Date: 3/18/2009
Location: Channel Waypoint: 3

Test Pit
9D

Logged by: SRG / JG Backhoe Type: CAT 710

Stantec

Site:
Gila River Sediment Program

Sample Type:
B - undisturbed block sample
D - disturbed bulk sample
G - grab sample

Project Number: 182000565

LOG OF TEST PIT

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	GP	Gravel with sand and cobbles, rounded gravel and cobbles, no cementation, dark brown, moist
5	x	G		Stopped bucket at 8.5 feet
10				

Surface Elevation: _____ Groundwater Depth: 8.5'
Datum: _____ Date: 3/19/2009
Location: Main Channel Waypoint: 8

Test Pit
10A

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	GP	Gravel, sand and cobbles, predominately fine gravel, well rounded gravel and cobbles, no cementation, moist
5	x	G	GP	Cobbles with gravel, well rounded cobbles, no cementation, wet Stopped bucket at 8.5 feet
10				

Surface Elevation: _____ Groundwater Depth: 8.5'
Datum: _____ Date: 3/19/2009
Location: Main channel Waypoint: 9

Test Pit
10B

Logged by: SRG / JG Backhoe Type: CAT 710

Stantec

Site:
Gila River Sediment Program

Sample Type:
B - undisturbed block sample
D - disturbed bulk sample
G - grab sample

Project Number: 182000565

LOG OF TEST PIT

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0	x	G	GP	Gravel with sand and cobbles, well rounded gravel and cobbles, light brown, no cementation, moist
				Stopped bucket at 4.5 feet
5				
10				

Surface Elevation: _____ Groundwater Depth: 4.5'
Datum: _____ Date: 3/18/2009
Location: Main channel Waypoint: 7

Test Pit 11

Depth (feet)	Sample	Sample Type	Unified Soil Classification	Soil Description
0				
5				
10				

Surface Elevation: _____ Groundwater Depth: _____
Datum: _____ Date: _____
Location: _____ Waypoint: _____

Test Pit

Logged by: SRG / JG Backhoe Type: CAT 710

Stantec

Site:
Gila River Sediment Program

Sample Type:
B - undisturbed block sample
D - disturbed bulk sample
G - grab sample

Project Number: 182000565

LOG OF TEST PIT

Attachment E

AMEC Laboratory Reports

PROJECT:	Gila River Sediment (182000565)	**JOB NO:**	08-117-01055
LOCATION:	Phoenix, Arizona	**WORK ORDER NO:**	1
SAMPLE SOURCE:	SEE BELOW	**DATE ASSIGNED:**	3/18/09

MECHANICAL SIEVE ANALYSIS
GROUP SYMBOL, USCS (ASTM D-2487)

	Silt or	SAND								GRAVEL									COBBLES	
	Clay	Fine			Medium			Coarse		Fine				Coarse						
Location & Depth	**#200**	**#100**	**#50**	**#40**	**#30**	**#16**	**#10**	**#8**	**#4**	**1/4"**	**3/8"**	**1/2"**	**3/4"**	**1"**	**1 1/4"**	**1 1/2"**	**2"**	**3"**	**6"**	**Lab #**

PERCENT PASSING BY WEIGHT

TP-9A	1.0	2	9	20	30	39	42	44	48	50	56	61	69	78	83	90	98	100	100	1
TP-9B	7.2	15	40	58	75	94	97	97	99	99	99	99	100	100	100	100	100	100	100	2
TP-9C-1'	19	50	70	75	78	80	81	81	82	82	83	83	85	86	87	87	100	100	100	3
TP-9D-1'	48	60	72	77	81	88	91	92	94	95	96	97	99	100	100	100	100	100	100	4
TP-9D-5.5'	33	55	63	66	68	72	76	77	83	85	89	92	94	96	100	100	100	100	100	5
TP-9D-8'	11	18	27	32	37	45	49	50	55	57	61	63	70	75	79	85	94	100	100	6
TP-11	1.7	3	8	12	18	31	36	37	40	42	47	51	59	65	72	75	80	100	100	7

AASHTO R18

REVIEWED BY

PROJECT:	Gila River Sediment (182000565)	**JOB NO:**	08-117-01055
LOCATION:	Phoenix, Arizona	**WORK ORDER NO:**	2
SAMPLE SOURCE:	SEE BELOW	**DATE ASSIGNED:**	3/18/09

MECHANICAL SIEVE ANALYSIS
GROUP SYMBOL, USCS (ASTM D-2487)

	Silt or	SAND								GRAVEL									COBBLES	
	Clay	Fine			Medium			Coarse		Fine				Coarse						
Location & Depth	**#200**	**#100**	**#50**	**#40**	**#30**	**#16**	**#10**	**#8**	**#4**	**1/4"**	**3/8"**	**1/2"**	**3/4"**	**1"**	**1 1/4"**	**1 1/2"**	**2"**	**3"**	**6"**	**Lab #**

PERCENT PASSING BY WEIGHT

TP-6A-1	61	85	94	97	98	99	99	99	99	99	99	99	100	100	100	100	100	100	100	8
TP-6A-8'	42	60	76	88	95	99	100	100	100	100	100	100	100	100	100	100	100	100	100	9
TP-8-1'	0.1	0	2	5	10	22	26	27	32	34	40	45	55	62	67	74	87	100	100	10
TP-8-8'	0.9	2	8	16	24	37	40	41	43	44	46	48	52	57	61	65	72	80	100	11
TP-10 @ 1-1'	0.6	2	7	11	17	26	28	29	35	37	43	49	59	66	74	76	79	88	100	12
TP-10A-1'	1.5	3	7	10	14	21	23	24	27	29	33	36	43	48	55	59	70	75	100	13
TP-10A-8'	0.7	2	6	11	18	33	36	37	40	42	46	49	55	60	66	69	83	90	100	14
TP-10B-8'	0.5	1	2	4	6	10	12	13	15	17	20	23	28	34	39	43	48	53	56	15

AASHTO R18

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PROJECT:	Gila River Job# 182000565	**JOB NO:**	7-119-000638
LOCATION:	Gila River, Arizona	**WORK ORDER NO:**	3
SAMPLE SOURCE:	SEE BELOW	**DATE ASSIGNED:**	5/5/09

MECHANICAL SIEVE ANALYSIS
GROUP SYMBOL, USCS (ASTM D-2487)

PERCENT PASSING BY WEIGHT

	Silt or	SAND								GRAVEL									COBBLES		
	Clay	Fine			Medium			Coarse		Fine				Coarse							
Location & Depth	**#200**	**#100**	**#50**	**#40**	**#30**	**#16**	**#10**	**#8**	**#4**	**1/4"**	**3/8"**	**1/2"**	**3/4"**	**1"**	**1 1/4"**	**1 1/2"**	**2"**	**3"**	**4"**	**6"**	**Lab #**
TP-2A-1'	21	82	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	8
TP-2A-10'	73	88	97	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	9
TP-2B-1'	7.3	11	31	51	66	78	79	80	81	82	84	85	88	89	91	91	92	100	100	100	10
TP-2B-3'	1.7	12	59	85	95	98	99	99	99	99	99	99	99	99	100	100	100	100	100	100	11
TP-2B-8.5'	3.3	15	55	74	85	90	91	91	91	92	92	93	93	94	95	96	96	100	100	100	12
TP-2C-1'	0.9	6	44	81	95	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	13
TP-2C-7.5'	0.9	3	16	29	42	56	59	59	61	62	64	65	67	69	70	71	76	82	100	100	14
TP-2D-3'	0.3	1	3	7	12	21	24	24	28	29	35	41	54	67	76	86	90	100	100	100	15
TP-2E-1'	1.2	2	5	10	17	29	32	33	36	37	40	42	49	54	57	60	65	80	92	100	16

AASHTO R18

REVIEWED BY

PROJECT:	Gila River Job# 182000565	**JOB NO:**	7-119-000638
LOCATION:	Gila River, Arizona	**WORK ORDER NO:**	4
SAMPLE SOURCE:	SEE BELOW	**DATE ASSIGNED:**	5/6/09

MECHANICAL SIEVE ANALYSIS
GROUP SYMBOL, USCS (ASTM D-2487)

	Silt or	SAND								GRAVEL									COBBLES	
	Clay	Fine			Medium			Coarse		Fine				Coarse						
Location & Depth	#200	#100	#50	#40	#30	#16	#10	#8	#4	1/4"	3/8"	1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	3"	6"	Lab #

PERCENT PASSING BY WEIGHT

TP-7A-1'	0.3	1	13	27	42	80	92	94	100	100	100	100	100	100	100	100	100	100	100	17
TP-7A-11'	1.8	3	12	22	35	53	58	59	63	65	68	70	75	78	81	84	90	100	100	18
TP-7B-1'	0.6	3	11	22	44	80	86	87	89	90	91	93	94	95	95	97	98	100	100	19
TP-7B-10'	1.0	3	9	19	30	45	50	52	56	58	62	65	71	75	79	83	88	94	100	20
TP-7F-1'	6.0	11	35	66	85	98	99	99	100	100	100	100	100	100	100	100	100	100	100	21
TP-7F-10'	4.7	12	39	62	80	96	98	98	99	99	99	100	100	100	100	100	100	100	100	22
TP-7G-1'	87	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	23
TP-7G-4'	59	67	94	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	24
TP-7G-10'	1.7	3	8	13	18	24	27	28	33	36	42	47	57	65	71	76	85	89	89	25

AASHTO R18

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PROJECT:	Gila River Sediment (182000565)	**JOB NO:**	08-117-01055
LOCATION:	Phoenix, Arizona	**WORK ORDER NO:**	5
SAMPLE SOURCE:	SEE BELOW	**DATE ASSIGNED:**	3/25/09

MECHANICAL SIEVE ANALYSIS
GROUP SYMBOL, USCS (ASTM D-2487)

	Silt or	SAND								GRAVEL									COBBLES	
	Clay	Fine			Medium			Coarse		Fine				Coarse						
Location & Depth	**#200**	**#100**	**#50**	**#40**	**#30**	**#16**	**#10**	**#8**	**#4**	**1/4"**	**3/8"**	**1/2"**	**3/4"**	**1"**	**1 1/4"**	**1 1/2"**	**2"**	**3"**	**6"**	**Lab #**

PERCENT PASSING BY WEIGHT

TP-2C1-2'	59	93	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	36
TP-2C1-10'	38	45	51	59	75	97	99	99	99	100	100	100	100	100	100	100	100	100	100	37
TP-3-6'	36	41	46	47	49	52	54	56	60	63	68	71	78	84	86	88	91	93	100	38

AASHTO R18

REVIEWED BY

amec

PROJECT:	Gila River Sediment (182000565)	**JOB NO:**	08-117-01055
LOCATION:	Phoenix, Arizona	**WORK ORDER NO:**	6
SAMPLE SOURCE:	SEE BELOW	**DATE ASSIGNED:**	3/26/09

MECHANICAL SIEVE ANALYSIS
GROUP SYMBOL, USCS (ASTM D-2487)

	Silt or	SAND								GRAVEL									COBBLES	
	Clay	Fine			Medium			Coarse		Fine				Coarse						
Location & Depth	**#200**	**#100**	**#50**	**#40**	**#30**	**#16**	**#10**	**#8**	**#4**	**1/4"**	**3/8"**	**1/2"**	**3/4"**	**1"**	**1 1/4"**	**1 1/2"**	**2"**	**3"**	**6"**	**Lab #**

PERCENT PASSING BY WEIGHT

TP-1-1.5	3.0	6	16	23	29	37	40	40	43	45	49	52	60	69	74	81	88	100	100	39
TP-1-4	0.6	4	18	31	47	69	73	74	77	78	81	84	88	92	95	98	99	100	100	40
TP-1-8.5	3.6	18	40	52	61	70	72	72	74	75	77	79	82	85	87	89	92	100	100	41

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PROJECT:	Gila River Sediment (182000565)	**JOB NO:**	08-117-01055
LOCATION:	Phoenix, Arizona	**WORK ORDER NO:**	4
SAMPLE SOURCE:	SEE BELOW	**DATE ASSIGNED:**	3/24/09

MECHANICAL SIEVE ANALYSIS
GROUP SYMBOL, USCS (ASTM D-2487)

	Silt or	SAND								GRAVEL									COBBLES	
	Clay	Fine			Medium			Coarse		Fine				Coarse						
Location & Depth	#200	#100	#50	#40	#30	#16	#10	#8	#4	1/4"	3/8"	1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	3"	6"	Lab #

PERCENT PASSING BY WEIGHT

TP-5A-2	65	97	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	26
TP-5A-8	48	92	98	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	27
TP-5B-1	37	90	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	28
TP-5B-4	7.1	38	85	95	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	29
TP-5B-7	6.1	15	40	55	63	69	70	71	73	73	75	77	80	85	88	89	94	100	100	30
TP-5B-9	9.8	27	59	73	81	89	90	90	91	92	93	94	97	98	100	100	100	100	100	31
TP-7C-3	1.0	2	5	9	15	29	35	37	42	44	48	52	59	65	69	74	80	88	90	32
TP-7D-2	2.2	5	19	35	47	57	59	60	62	63	66	68	74	77	80	86	92	95	100	33
TP-7E-2	0.4	1	7	19	34	74	88	91	96	97	98	99	100	100	100	100	100	100	100	34
TP-7E-6	0.7	1	4	9	16	32	38	39	42	43	45	47	51	54	57	59	65	78	100	35

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PROJECT:	Gila River Sediment (182000565)	**JOB NO:**	08-117-01055
LOCATION:	Phoenix, Arizona	**WORK ORDER NO:**	3
SAMPLE SOURCE:	SEE BELOW	**DATE ASSIGNED:**	3/23/09

MECHANICAL SIEVE ANALYSIS
GROUP SYMBOL, USCS (ASTM D-2487)

	Silt or	SAND								GRAVEL									COBBLES	
	Clay	Fine			Medium			Coarse		Fine				Coarse						
Location & Depth	#200	#100	#50	#40	#30	#16	#10	#8	#4	1/4"	3/8"	1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	3"	6"	Lab #

PERCENT PASSING BY WEIGHT

TP-5C-10	0.7	1	4	9	16	29	33	34	38	40	45	50	60	69	79	83	91	100	100	16
TP-5D-1	74	98	99	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	17
TP-SC-2	1.0	2	5	9	16	31	34	35	40	42	48	52	61	70	76	81	92	100	100	18
TP-5D-10	62	80	98	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	19
TP-4-7	1.1	5	35	63	80	91	92	92	93	93	94	94	96	97	98	99	99	100	100	20
TP-4-1	0.4	1	18	46	69	85	87	87	88	88	89	90	91	91	91	92	94	100	100	21
TP-6C-2	0.8	2	9	17	27	42	45	46	48	49	51	53	57	61	67	72	80	89	100	22
TP-6B-3.5	1.2	3	7	11	17	28	31	32	36	37	40	44	52	61	69	74	82	96	100	23
TP-6D-3	3.2	9	33	49	65	80	82	82	82	83	83	83	83	84	84	84	84	87	100	24
TP-6D-9	2.5	13	35	50	66	85	87	87	88	89	89	90	91	92	93	93	94	100	100	25

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Attachment F

MRPP Report by Julien, Mielke and Paris

GILA RIVER SEDIMENT ANALYSIS

P.Y. Julien[1], *P.W. Mielke*[2], *A. Paris*[3]

Introduction

The Multi-Response Permutation Procedure (MRPP) is used to identify 3 groups of particle size distributions that can be generically called *silt*, *sand* and *gravel* (Section 1). In Section 2, a Fortran executable code that applies this method has been written to determine which group a new generic sample belongs to. A range index has also been defined to determine how close the generic sample is to the range of the measured data. The explanation of how the code works is presented in Section 3, while application examples can be found in Section 4.

1 Three sediment groups

The particle size distribution of 41 samples were provided. We selected 29 distributions and sorted them in 3 distinct groups characterized by different ranges of the typical grain sizes: d_{10}, d_{16}, d_{50}, d_{84} and d_{90} (Figure 1):

- Group A (*silt*): 7 particle size distributions
- Group B (*sand*): 8 particle size distributions
- Group C (*gravel*): 14 particle size distributions

The values of d_{50} and d_{84} for these 29 particle size distributions separated into the 3 groups, are reported in Table 1. Since we did not have the d_{50} for 5 particle size distributions belonging to Group A, we extrapolated them linearly from the log-scale graph, as shown in Figure 1.

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[2]Emer. Prof., Dept. of Stat., Colorado State Univ., Fort Collins, CO 80523
[3]Vis. Scientist, Dept. of Civ. and Env. Engrg., Colorado State Univ., Fort Collins, CO 80523

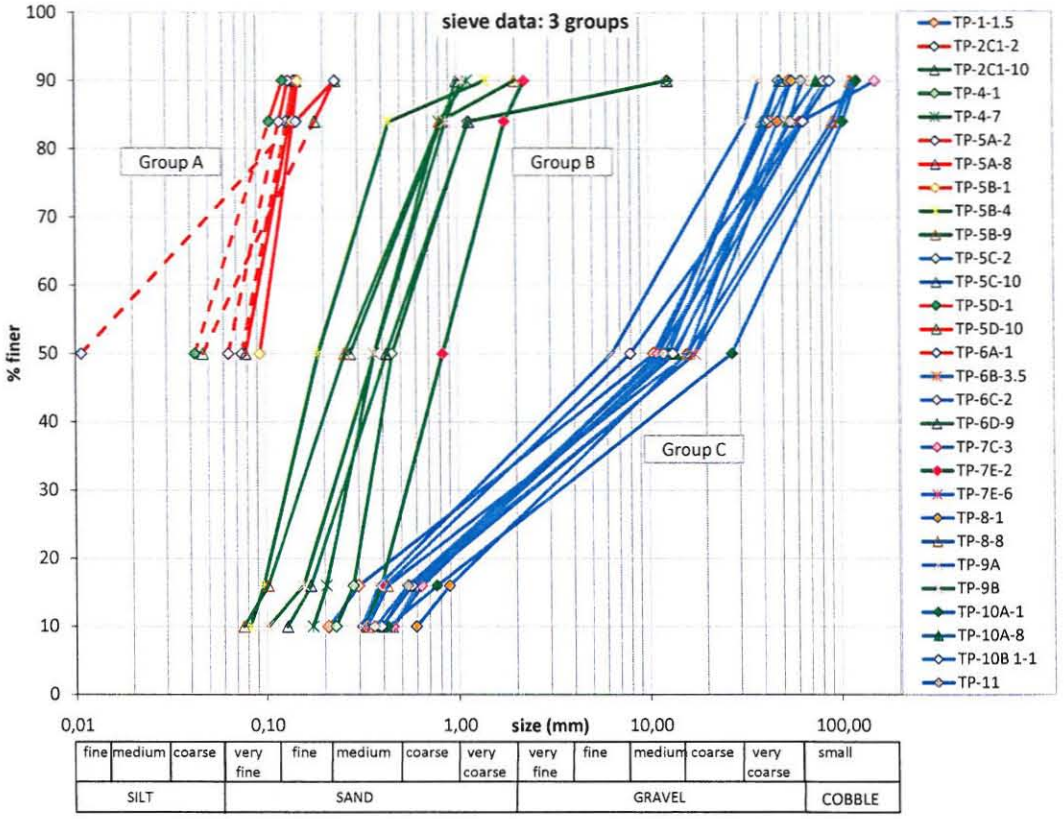

Figure 1: *Particle size distributions: Group A, Group B and Group C.*

Group A	(mm)	TP-2C1-2	TP-5A-2	TP-5A-8	TP-5B-1	TP-5D-1	TP-5D-10	TP-6A-1
	d50	0.075 (*)	0.064 (*)	0.08	0.09	0.042 (*)	0.047 (*)	0.011 (*)
	d84	0.13	0.12	0.14	0.14	0.11	0.18	0.15

Group B	(mm)	TP-2C1-10	TP-4-1	TP-4-7	TP-5B-4	TP-5B-9	TP-6D-9	TP-7E-2	TP-9B
	d50	0.27	0.45	0.36	0.19	0.26	0.42	0.83	0.37
	d84	0.83	1.14	0.81	0.44	0.81	1.15	1.77	0.87

Group C	(mm)	TP-1-1.5	TP-5C-2	TP-5C-10	TP-6B-3.5	TP-6C-2	TP-7C-3	TP-7E-6	TP-8-1
	d50	10.58	11.11	12.70	17.46	7.94	11.11	17.46	15.87
	d84	43.54	41.56	39.69	54.43	62.09	63.50	96.98	47.87
	(mm)	TP-8-8	TP-9A	TP-10A-1	TP-10A-8	TP-10B 1-1	TP-11		
	d50	15.87	6.35	27.21	13.76	13.33	11.91		
	d84	91.44	32.66	103.63	54.43	64.91	55.88		

Table 1: *d_{50} and d_{84} of the 3 grain size distribution groups .(*) indicates an extrapolated value.*

2 Methods and Procedures

2.1 Group Identification with MRPP procedure

We used the MRPP to calculate the P-value that is the probability of the data to be as extreme or more extreme than the observed data (see the details of the method from Mielke & Berry 2007 in the Appendix). We computed the P-value using the logarithmic values of d_{50} and d_{84} first separately and then together. We obtained that the couple d_{50}-d_{84} leads to the smallest P-value (P-value ¡ 10^{-6}), therefore we decided that these two parameters should be used together to identify which group the testing sample belongs to. It should be noticed that the value of the probability is really small indicating that the three groups are well-sorted and that the MRPP is well-suited to this analysis.

The MRPP procedure is then applied to determine which group a new sample characterized by a d_{50} and a d_{84} belongs to. These data are added to each sediment size group in turn and the P-value is computed each time. The sample then belongs to the group that gets the smallest P-value.

2.2 Range Index

For each group, H_{d_x} and L_{d_x} are respectively the highest and the lowest sediment size values for that d_x (Table 2) and R_{d_x} is the logarithmic average value of the range computed as:

$$R_{d_{50}} = \frac{\log H_{d_{50}} + \log L_{d_{50}}}{2} \tag{1}$$

$$R_{d_{84}} = \frac{\log H_{d_{84}} + \log L_{d_{84}}}{2} \tag{2}$$

	d_{50}		d_{84}	
Group	L_{d50}	H_{d50}	L_{d50}	H_{d50}
A	0.011	0.09	0.11	0.18
B	0.19	0.84	0.44	1.77
C	6.35	27.21	32.66	103.6

Table 2: *H_{d_x} and L_{d_x} values for each group for both d_{50} and d_{84} .*

For a new sample characterized by its d_{50} and d_{84}, a range index has been defined to measure how far the sample is from the measured range of the group determined by the MRPP procedure. In particular we defined 3 different range indexes for d_{50}, d_{84} and d_{50}-d_{84}:

- the d_{50} range index:

$$I_{d_{50}} = \frac{\log H_{d_{50}} - R_{d_{50}}}{|\log d_{50} - \log R_{d_{50}}|} * 100 \tag{3}$$

- the d_{84} range index:

$$I_{d_{84}} = \frac{\log H_{d_{84}} - R_{d_{84}}}{|\log d_{84} - \log R_{d_{84}}|} * 100 \tag{4}$$

- the composite range index:

$$I = \frac{I_{d_{50}} + I_{d_{84}}}{2} \tag{5}$$

Finally the composite index, I, is the average percentage value between the two range indexes, $I_{d_{50}}$ and $I_{d_{84}}$, and ranges between 0 and 100 %. We also established that if d_x falls within the group range values, between H_{d_x} and L_{d_x}, then I assumes the maximum value, i.e. 100 %.

For example, the characteristic grain sizes for the sample TP-2C-7.5 are:

$$d_{50} = 0.93 \text{ mm and } d_{84} = 79.02 \text{ mm}$$

Since the MRPP suggests that this sample belongs to Group C, we focus on this group. According to Table 2:

$$L_{d_{50}} = 6.35 \text{ mm and } H_{d_{50}} = 27.21 \text{ mm}$$

$$L_{d_{84}} = 32.66 \text{ mm and } H_{d_{84}} = 103.63 \text{ mm}$$

so we can compute:

$$R_{d_{50}} = \frac{\log 27.21 + \log 6.35}{2} = 0.32$$

$$R_{d_{84}} = \frac{\log 103.63 + \log 32.66}{2} = 0.25$$

Then the range indexes are:

$$I_{d_{50}} = \frac{\log 27.21 - 0.32}{|\log 0.93 - \log 0.32|} * 100 = 27.47\%$$

$$I_{d_{84}} = 100\%$$

$$I = \frac{27.47 + 100}{2} = 63.73\%$$

Since $d_{50} = 0.93$ mm is quite far from the range [6.35-27.21] mm, The d_{50} range index results to be small: $I_{d_{50}} = 27.47\%$. On the other hand, $d_{84} = 79.02$ mm is included inside the relative range [32.66-103.63] mm so the d_{84} range index assumes the highest value: $I_{d_{84}} = 100\%$. Finally, the procedure associates this sample with Group C, but the level of confidence is low: $I = 63.73\%$.

3 The Fortran Code

The executable Fortran program, *Code.exe*, has been created. The code can be presented schematically in 3 parts:

1. **user input**:

   - d_{50} and d_{84} of the new sample in mm: these values must be entered by the user on the display interface

2. **code**:

   - asks for the input data d_{50} and d_{84}
   - uses the file *OBS.D* based on the observed data for the 3 groups (Table 1)
   - adds the new sample data to each group A, B and C of observed data and computes the related 3 P-values using MRPP
   - identifies the group with the smallest P-value
   - computes the range indexes, $I_{d_{50}}$ and $I_{d_{84}}$ and the composite index, I
   - loops back for new input

3. **outputs**:

   - *OBSA.D, OBSB.D* and *OBSC.D*: these files are produced and then used by the code as input data for the MRPP calculations
   - the following results are reported on the program interface:
     - the d_{50} and d_{84} of the new sample
     - the P-values for each group: A, B and C
     - the computed range indexes values (%): $I_{d_{50}}$ and $I_{d_{84}}$
     - the group which the sample belongs to
     - the composite index value(%): I
   - code generates the output file *OUTPUT.D*

4 Application

4.1 Application example

Figure 2 presents a code interface example. The first 4 lines request *input* from the user. The code asks for the d_{50} and d_{84} of the new sample in mm. Then the codes writes down these grain sizes on the right side and computes the P-values for Group A, B and C applying the MRPP procedure. The smallest P-value is related to Group C meaning that the sample belongs to this group. The values of the range indexes are reported. Finally on the right side the group to which the sample belongs is indicated and associated to its composite range index.

```
 ENTER:D50 [mm]:
0.93
 ENTER:D84 [mm]:
79.02

                                                D50=  0.93000    mm
                                                D84=   79.020    mm

P-VALUE GROUP A =       0.3879E-07
P-VALUE GROUP B =       0.1556E-07
P-VALUE GROUP C =       0.7375E-08

RANGE INDEX D50=        27.47    %
RANGE INDEX D84=        100.0    %
                                                     GROUP C

COMPOSITE RANGE INDEX=                               63.73    %
```

Figure 2: *Code interface example: results related to sample TP-2C-7.5.*

4.2 Application to the additional dataset

We used the most recent 18 sieve data (e-mails from STANTEC: 05-07-2009 and 05-11-2009) to determine the group to which they belong (A, B or C) and to compute the percentage that describes how far they are from the closest groups (I [%]). Table 3 reports the samples identification code joined by the colour of the group we expect it to belong to and the values of d_{50} and d_{84} for each sample. The MRPP results in terms of group A, B, C and their related colours. The values of the composite index, I, and the values of the range indexes, $I_{d_{50}}$ and $I_{d_{84}}$ are then listed. The samples TP-7G-1 and TP-7G-10 did not have all the information required so they could not be classified.

The MRPP predicts the correct group for all 16 samples. For instance the samples TP-2A-10, TP-2B-8.5, TP-2C-1, TP-2D-3, TP-2E-1, TP-7A-1, TP-7B-1, TP-7F-1 and TP-7F-10 clearly belong to their respective groups as the composite range index values are equal to 100 %. The samples that did not clearly belong to any of the groups, have lower composite index values.

	TP-2A-1	TP-2A-10	TP-2B-1	TP-2B-3	TP-2B-8.5	TP-2C-1	TP-2C-7.5	TP-2D-3	TP-2E-1	TP-7A-1	TP-7A-11	TP-7B-1	TP-7B-10	TP-7F-1	TP-7F-10	TP-7G-1	TP-7G-4	TP-7G-10
d50 (mm)	0.11	0.019 (*)	0.41	0.27	0.28	0.32	0.93	17.10	20.32	0.72	1.08	0.69	2.00	0.36	0.36		0.118 (*)	14.60
d84 (mm)	0.17	0.13	9.52	0.42	0.58	0.46	79.02	36.83	84.66	1.45	38.10	1.73	40.64	0.59	0.74		0.24	
MRPP	A	A	B	B	B	B	C	C	C	B	C	B	C	B	B		A	
I	**91.98**	**100**	**64.6**	**96.87**	**100**	**100**	**63.73**	**100**	**100**	**100**	**64.56**	**100**	**69.32**	**100**	**100**		**62.81**	
I_{d50}	83.97	100	100	100	100	100	27.47	100	100	100	29.11	100	38.64	100	100		79.51	
I_{d84}	100	100	29.2	93.73	100	100	100	100	100	100	100	100	100	100	100		46.12	

Table 3: *Application of the model to the recent samples. (*) indicates an extrapolated value.*

Appendix

A BRIEF DESCRIPTION OF MRPP

While a detailed description of Multi-Response Permutation Procedures (MRPP) is given elsewhere (Mielke & Berry, 2007), the following presentation provides the basic concepts of these procedures. Let

$$\Omega = \{\omega_1, \ldots, \omega_N\}$$

be a finite collection (sample) of objects which are drawn from a target population of interest. Let

$$x_I' = (x_{1I}, \ldots, x_{rI})$$

denote r commensurate response measurements of object ω_I for I = 1,…,N and let $S_1,\ldots,S_{g+1}$ represent an exhaustive partitioning of the N objects comprising Ω into g + 1 disjoint groups. Also let $\Delta_{I,J}$ represent a symmetric distance function value of the response measurements associated with objects ω_I and ω_J. The MRPP statistic is given by

$$\delta = \sum_{i=1}^{g} C_i \xi_i$$

where

$$\xi_i = \binom{n_i}{2}^{-1} \sum_{I<J} \Delta_{I,J} \Psi_i(\omega_I) \Psi_i(\omega_J)$$

is the average distance function for all distinct pairs of objects in group S_i (i = 1,…,g), $n_i \geq 2$ is the number of a priori objects classified into group S_i (i = 1,…,g), $K = n_1+\ldots+n_g$ is the total number of classified objects, $n_{g+1} = N\text{-}K \geq 0$ is the number of remaining (i.e., unclassified) objects in the excess group S_{g+1} which is an empty group in many applications, $\sum_{I<J}$ is the sum over all I and J such that $1 \leq I < J \leq N$, $\Psi_i(\omega_I) = 1$ if ω_I belongs to S_i and 0 otherwise, $C_i > 0$ for i = 1,…,g are the classified group weights, and $C_1+\ldots+C_g = 1$. The null hypothesis (H_0) specifies that equal probabilities are assigned to each of the

$$M = \frac{N!}{\prod_{i=1}^{g+1} n_i!}$$

possible allocations of the N objects to the g+1 groups. Thus the statistic δ compares the within-group clumping of the response measurements with the response measurements specified by the random allocation model under H_0.

The choice of the classified group weights ($C_1,\ldots,C_g$) and the symmetric distance function $\Delta_{I,J}$ specifies the version of MRPP to be employed. While $C_i = n_i/K$ (i = 1,…,g) is the recommended classified group weight that it is associated with efficient versions of MRPP, other choices of classified group weights such as $C_i = (n_i - 1)/(K - g)$, $C_i = 1/g$,

and $C_i = n_i(n_i-1)/[n_1(n_1-1)+\ldots+n_g(n_g-1)]$ have also been considered. In many applications of MRPP the symmetric distance function is given by

$$\Delta_{I,J} = \begin{cases} d_{I,J} & \text{if } d_{I,J} \leq B \\ B & \text{otherwise} \end{cases}$$

where

$$d_{I,J} = \left[\sum_{h=1}^{r} (x_{hI} - x_{hJ})^2 \right]^{\frac{v}{2}},$$

$B > 0$ is a specified truncation constant, and $v > 0$ is a specified power constant (note that $\Delta_{I,J}$ is ordinary Euclidean distance when B is ∞ and $v = 1$). The choice of B is purely subjective since its use includes the detection of multiple clumping of objects of a single group. Whereas the symmetric distance functions discussed here are confined to simple variations of Euclidean distance, many alternative choices of symmetric distances functions to include applications such as cyclic and autoregressive data are possible. Incidentally, the choice of $C_i = (n_i-1)/(K-g)$, $N = K$, and $v = 2$ includes one-way ANOVA as a special case. Since $v = 2$, the analysis space of MRPP is not a metric space in this case since the triangle inequality property of a metric is not satisfied. Because the data space is most likely a Euclidean space (i.e., $v = 1$), the analysis space of one-way ANOVA with $v = 2$ usually yields counter-intuitive interpretation problems for an investigator when one or more extreme values occur because the data and analysis spaces are not equivalent. This last comment unfortunately affects most of the presently used statistical techniques because they are based on $v = 2$. The reason for this problem with non-equivalent data and analysis spaces is primarily due to the fact that the majority of statistical techniques based on $v = 2$ were developed to simplify computations between 1900 and 1960 at a time that present day electronic computers were not available. As a consequence the statistical techniques used here are based on $v = 1$ where the data and analysis spaces are congruent to one another in moat cases.

The statistical inference of permutation tests are based on P-values. The exact P-value and two approximate P-values termed resampling and moment P-values are commonly used. The exact P-value is the probability of having a randomly selected statistic as or more extreme than the observed statistic under H_0 that all M possible allocations occur with equal chance. A resampling P-value approximation is the probability of having a without replacement randomly selected statistic among L allocations from the M possible allocations under H_0 (1,000,000 is a common choice for L). A moment P-value approximation is based on fitting the distribution of the statistic to a distribution such as the Pearson type III distribution which is characterized by its first three exact moments. In this approximation the first three exact moments are obtained from the empirical distribution of all M values of the MRPP statistic under H_0. While a special case of the Pearson type III distribution is the normal distribution (which is based on the first two exact moments), the empirical distribution in question is usually very skewed and consequently the Pearson type III is used to compensate for this property. While the exact P-value is the desired result, most samples yield a value of M that makes its evaluation unfeasible. The resampling P-value approximation is usually very good when the exact P-value is not too small. However, if M is very large and the exact P-value is

very small (i.e., examples such as a P-value = 10^{-15}), then the moment P-value approximation at least yields a crude approximation of the exact distribution which is obtainable even very extreme conditions. A simple classification for assigning a single object to one of g groups is first to obtain the P-values for each of the g ordered groups (i.e., $p_1,\ldots,p_g$) and second to select the group associated with the smallest value among the g P-values ($p_1,\ldots,p_g$). If the difference between each pair of two or more of the smallest P-values is very small, then the evidence for choosing one group over another is admittedly very weak. As previously mentioned, further details corresponding to MRPP along with many earlier references are given in Mielke and Berry (2007).

REFERENCE

Mielke, P.W., and K.J. Berry (2007). *Permutation Methods: A Distance Function Approach.* (2nd Ed.). New York: Springer Verlag.