# Scour Evaluation for Pipeline Crossing of Bulldozer Wash at Verrado Way

## Maricopa County, Arizona

WEST

CONSULTANTS, INC.

**W**ater • **E**nvironmental • **S**edimentation • **T**echnology

**Hydraulics · Hydrology · Sedimentation · Water Quality · Erosion Control · Environmental Services**

# Scour Evaluation for Pipeline Crossing of Bulldozer Wash at Verrado Way

## Maricopa County, Arizona

**Prepared for:**

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**Mesa, AZ 85210**

**Prepared by:**

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CONSULTANTS, INC.

**WEST Consultants, Inc.**
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**Tempe, AZ 85284**

**May 2007**

Registered Professional Engineer (Civil)
CERTIFICATE NO.
41980
BRIAN THOMAS
WAHLIN
Date Signed 5/1/07
ARIZONA, U.S.A.

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# INTRODUCTION

WEST Consultants, Inc. (WEST) was retained by Sunrise Engineering, Inc. to conduct the 100-year flow event scour evaluation for the 6-inch natural gas pipeline crossing of Bulldozer Wash at a location approximately 50 feet upstream of Verrado Way. The Verrado Way crossing of Bulldozer Wash lies in the Section 31 of T2N R2W in Maricopa County, Arizona. The project location is shown in Figure 1.

In its natural condition, Bulldozer Wash conveyed flows from the north in a southeasterly direction and into McDowell Basin, which is an existing storage pit located northwest of the McDowell Road and Tuthill Dike Road intersection. In the initial stages of the Verrado Master Plan, Bulldozer Wash was re-aligned and channelized to accommodate future residential parcels. The new channel alignment was still referred to as Bulldozer Wash. An interim Bulldozer Wash was then mass graded into its new alignment with the construction of Verrado Phase 1. The new Bulldozer Wash channel crosses Verrado Way further north of McDowell Road than the natural channel did. Bulldozer Wash flows from west to east at the Verrado Way crossing. Final improvements for Bulldozer Wash have been established in order to improve its structural stability and increase its capacity. The wash improvements include three permanent drop structures and channel improvements to decrease the flow velocities and minimize the scour potential. As of the date of this report, the drop structures have not been added to the realigned Bulldozer Wash. The bottom width and side slopes of the realigned Bulldozer Wash vary with the width ranging from 35 to 60 feet and the side slopes having a maximum slope of 4 Horizontal (H) to 1 Vertical (V). Culvert crossings at Verrado Way and Acacia Way were also included in the Bulldozer Wash improvements.

In addition, there is a Zone A floodplain located near Verrado Way and Interstate 10 (I-10). The proposed pipeline will pass under this Zone A floodplain. The scour potential of crossing under this Zone A floodplain was also considered.

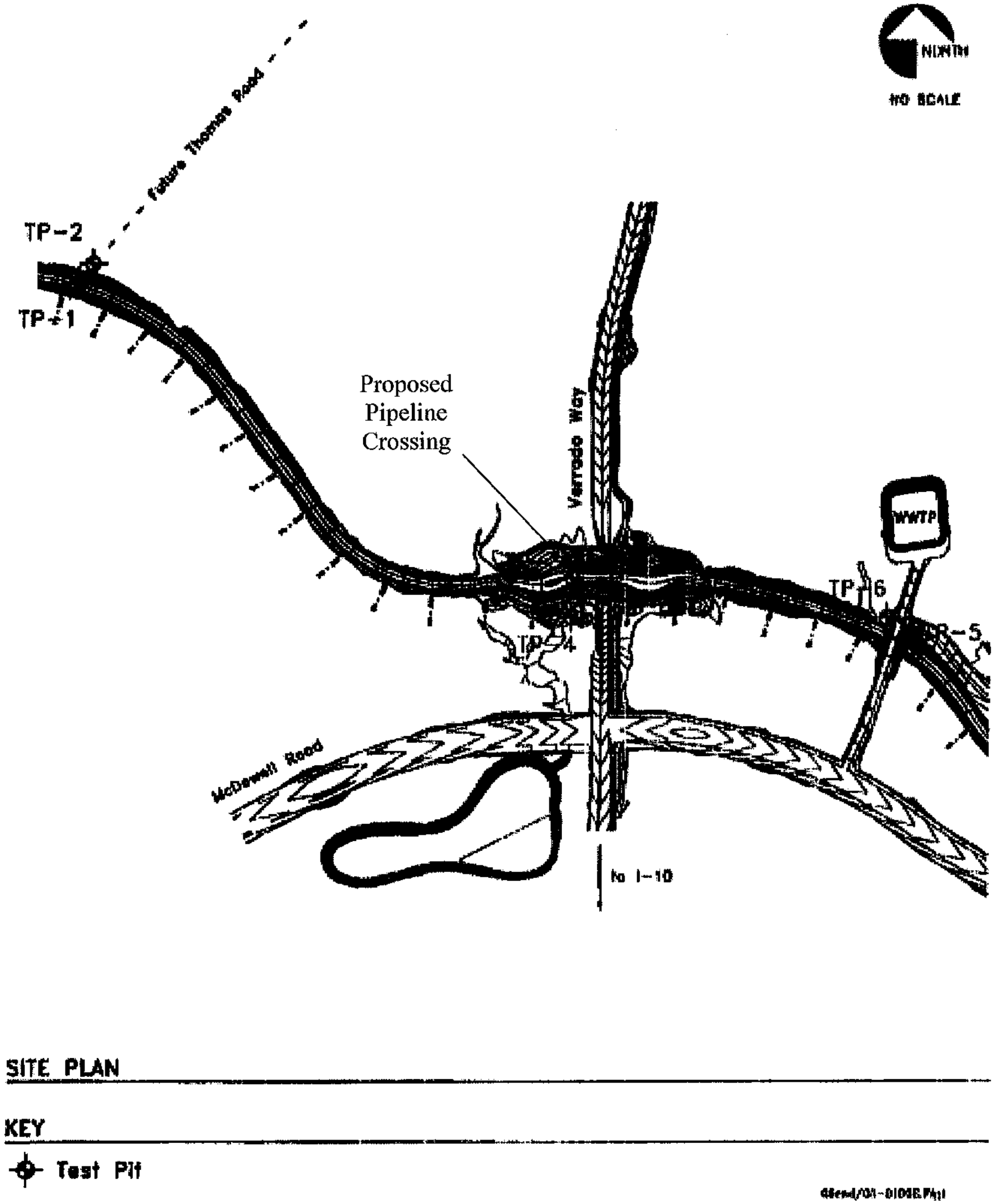



Figure 1. Project location map (Geotechnical and Environmental Consultants, Inc., 2005)

**Figure 2. Bulldozer Wash at Verrado Way looking upstream from top of the right overbank**

**Figure 3. Bulldozer Wash bed material near the Verrado Way crossing**

## DATA COLLECTION

Bulldozer Wash was re-aligned at the Verrado Way crossing (see Figure 2). In the area where the proposed natural gas pipeline crosses the Bulldozer Wash, the banks do not contain any resistive material to prevent bank erosion during flood events. Therefore, the new channels banks have the same erosion potential as the native bank material.

Bulldozer Wash is a sand and gravel bed channel (see Figure 3). Information regarding the particle size distribution of the bed material was found in the report *Results of Geotechnical Engineering Services, Verrado-Bulldozer Wash, Thomas Road to Waste Water Treatment Plant* (Geotechnical and Environmental Consultants, Inc., 2005). Their field exploration included the excavation of six exploratory test pits (Nos. TP-1 through TP-6) along Bulldozer Wash. The approximate locations of the exploratory test pits are shown on Figure 1. The project site is very close to the exploratory test pits TP-3 and TP-4.

Laboratory tests were performed by Geotechnical and Environmental Consultants, Inc. on the field exploration samples to obtain the information about the existing soil conditions. The laboratory results are presented in Appendix A. In summary, the $D_{50}$ of the bed material for TP-3 was 1.4 mm (0.0-5.0 ft depth) and 1.9 mm (5.0-10.0 ft depth). The $D_{50}$ of the bed material for TP-4 was 4.2 mm (0.0-5.0 ft depth) and 1.1 mm (5.0-10.0 ft depth). Based on field observations, the bed material in the study area ranges from coarse gravel to very fine sand (see Figure 3). Thus, the laboratory test results are consistent with field observation.

## HYDROLOGY

The base model for computation of the hydrology was provided by the Flood Control District of Maricopa County (FCDMC) from the *Loop 303 Corridor/White Tanks Area Drainage Master Plan Update* report (URS, 2001). The proposed condition land use plan, as prepared by EDAW for the entire Verrado development, was incorporated into the base model to determine the discharges for the future development. The scour analysis for this study was conducted only for the 100-year discharge. The 100-year discharge at the project site is 700 cfs, and this value was obtained from *Verrado Planning Unit Drainage Plan for Portions of Planning Unit V (Phase 3 North – South of Tractor Wash and Intrawest Resort) and Update to Master Drainage Plan* (Wood, Patel and Associates, 2006b).

## HYDRAULICS

The US Army Corps of Engineers' River Analysis System standard-step backwater computer program (HEC-RAS, Version 3.1.3) was used to the compute channel hydraulics (USACE 2005). The hydraulic model for the newly aligned Bulldozer Wash was developed by Wood, Patel and Associates (2006a) as part of the Design Report for Bulldozer Wash and McDowell Basin at Verrado (Wood, Patel and Associates, 2006a). The Wood, Patel and Associates' hydraulic model was reviewed by WEST. Small corrections were made to the model, which included:

- Entrance energy loss coefficient for the culverts were adjusted slightly.
- The expansion and contraction coefficients near the culverts were increased.
- Ineffective flow areas were added around the culverts.

These small changes did not have an impact the overall model results. The revised hydraulic model was used in the scour calculations. In the Wood, Patel and Associates' model, the Manning *n*-value used for the main channel in the hydraulic model of Bulldozer Wash ranges from 0.035 to 0.055. The proposed pipeline crossing of Bulldozer Wash is located at cross-section 3000, which has an *n*-value of 0.055. This value was used for the scour calculations.

## SCOUR CALCULATIONS

The proper consideration of scour at a site requires a determination of the total scour. Total scour refers to the total depth of scour at a given location and is the sum of all scour components that apply to the site of interest. These scour components can include:

- General scour or contraction scour

- Bed form scour
- Long-term degradation
- Bend scour
- Local scour

A factor of safety may be applied to account for uncertainty of the data, degree of variability of the channel conditions, level of risk, etc. The factor of safety may be applied to some or all of the scour components. In this study, a safety factor of 1.3 is used for all of the scour components. The total scour at a given location is the sum of the individual components that are applicable at that location.

The proposed pipeline crossing of Bulldozer Wash is located in a straight section of the wash approximately 50 feet upstream of the Verrado Way crossing. Thus, there would be no bend scour near the pipeline crossing and this scour component was not considered in the determination of the total scour depth.

## General Scour

General scour is the lowering of the streambed across the channel or stream over relatively short time periods (e.g., the general scour in a given reach after the passage of a single flood event). The lowering may be uniform across the bed or non-uniform (i.e., the depth of scour may be deeper in some parts of the cross-section).

General scour may result from concentration of the flow when the flow area of a stream is decreased from the normal either by a natural constriction or a manmade constriction (i.e., local encroachment, bridge, etc.). With the decrease in flow area there is an increase in average velocity and bed shear stress.

Several different equations can be used to calculate the general scour. Some of the more common equations include Lacey (1930), Blench (1969), Neill (1973), and Zeller (1981). All four of these equations were used to evaluate the general scour. The equation that resulted in the most conservative estimate of the general scour was the equation from Blench (1969). Blench's equation (1969) for general scour is given by:

$$y_{gs} = Z\left(\frac{q_f^{2/3}}{F_{b0}^{1/3}}\right)$$

where: $y_{gs}$ = general scour depth (ft),

$Z$ = multiplying factor, taken to be 0.6 for straight reaches,

$q_f$ = design discharge per unit width (cfs/ft), and

$F_{b0}$ = Blench's "zero bed factor" from Figure 4 (ft/s$^2$).

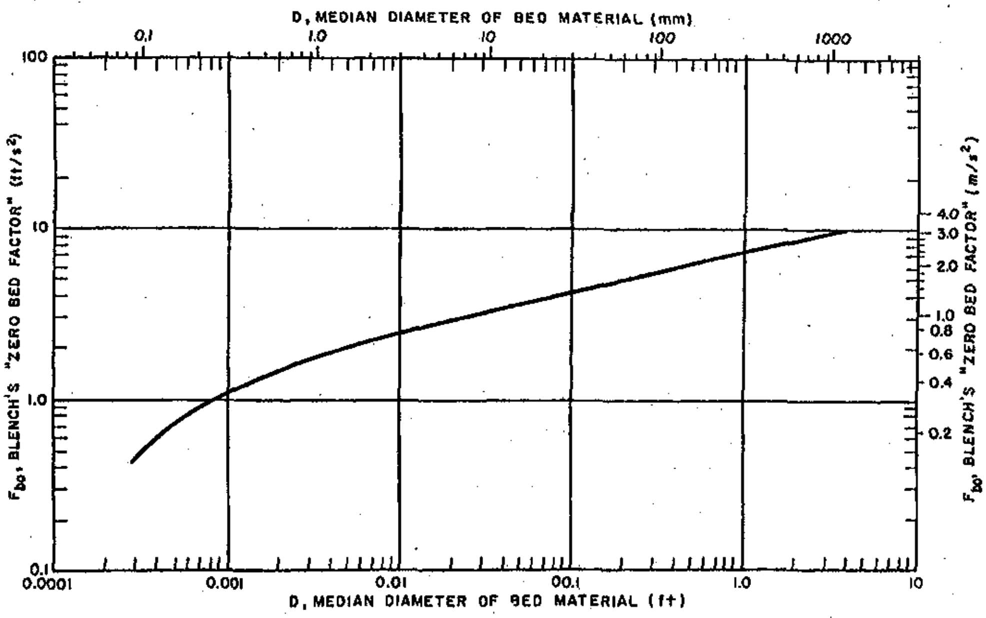



**Figure 4. Blench's "zero bed factor" (from Pemberton and Lara (1984))**

For a median grain diameter of 1.1 mm (0.00361 ft), $F_{b0}$ was determined from Figure 4 to be about 1.9 ft/s$^2$. General scour was evaluated using the average hydraulic parameters in the reach of Bulldozer Wash at the pipeline crossing (RS 3000). The unit discharge ($q_f$) at this location for the 100-year event was determined to be 11.81 cfs/ft, and the corresponding general scour was be calculated to be 2.5 feet:

$$y_{gs} = (0.6)\left[\frac{(11.81)^{2/3}}{(1.9)^{1/3}}\right] = 2.51 \text{ feet}$$

Using a factor of safety of 1.3, the general scour, $y_{gs}$, was estimated to be 3.3 feet.

Since there are four median grain size diameters from the samples measured near the project site (TP-3 and TP-4), the general scour analysis was performed for all of median grain size diameters and results are shown in Table 1. The results indicate that the general scour is not sensitivity to the $D_{50}$ value. The maximum calculated value of 3.3 feet was used as the general scour at the project site.

**Table 1. General scour results for all $D_{50}$ values**

| $D_{50}$ (mm) | $y_{gs}$ (ft) |
|---|---|
| 1.1 | 3.3 |
| 1.4 | 3.3 |
| 1.9 | 3.1 |
| 4.2 | 2.9 |

## Local Scour

Local scour is the scour that results from an obstruction and abrupt change in the direction of flow. Local scour is caused by an acceleration of flow and resulting vortices induced by the obstruction. It occurs at bridge piers, abutments, embankments, and other structures obstructing the flow. In the future, there will be a grade control structure located approximately 115 feet upstream of the proposed pipeline crossing. However, the proposed pipeline crossing is far enough downstream from the proposed grade control structure that local scour will not be an issue at crossing site. Thus, local scour was not considered in the determination of the total scour depth.

## Bedform Scour

For sand bed channels, natural or manmade, it is necessary to estimate the height of the bedforms moving through the channel. Dunes form in lower regime flow with antidunes forming in transitional or upper flow regime flow. The Froude number in Bulldozer Wash at cross-section 3000 for a 100-year event is approximately 0.4, which would indicate that the flow can be classified in the lower flow regime. The scour depth due to dunes may range from 0.1 to 0.5 times the maximum depth of flow based on studies conducted by Simons and Richardson (1960). Other studies by Yalin (1964) suggest a scour depth of one-sixth of the average flow depth.

From the HEC-RAS model (Wood, Patel and Associates, 2006a), the maximum flow depth in the area around the Verrado Way crossing is 3.51 feet. Therefore, using Simons and Richardson's (1960) method, bed form scour may range from 0.4 feet to 1.8 feet. Taking the greater of these values (1.8 ft), the bedform scour depth was estimated to be 2.3 feet when applying a factor of safety of 1.3.

### Long-Term Degradation

Long-term degradation can often be evaluated using equilibrium, or stable slope analysis and/or historic cross-section data. The existing culvert crossing at Verrado Way is the location of a stable or "pivot" point downstream of the proposed pipeline crossing since the culvert floor is concrete. Because the "pivot" point was located close to the proposed pipeline crossing, the long-term degradation was conservatively estimated by horizontally projecting the Verrado Way culvert invert elevation back to the location of the proposed pipeline crossing. The difference between the two elevations is an estimate of the long-term degradation. The elevation of the upstream culvert invert is 1,117.15 feet while the elevation of the ground at the proposed pipeline crossing is 1,117.53 feet. The difference between these two elevations is 0.38 feet. Using a factor of safety of 1.3, the long-term degradation was estimated to be 0.5 feet.

### Total Scour

The total scour at the proposed pipeline crossing near Verrado Way on Bulldozer Wash is the sum of the general scour, bedform scour, and long-term degradation, and it is estimated to be 6.0 feet (3.2 feet + 2.3 feet + 0.5 feet). Therefore, a burial depth of the crown of 6.0 feet below the thalweg of the channel is considered sufficient to protect the pipe from failure due to scour. Note that this evaluation does not take into account any local scour due to bridge piers and abutments that may exist in the future.

## SCOUR ANALYSIS FOR THE ZONE A AREA

The proposed pipeline will also cross a FEMA "Zone A" flood area just north of I-10. In this area, Southwest Gas will be using directional drilling underneath the existing sidewalk on the

Verrado Way overpass. Because the gas pipeline will be protected by the sidewalk, a scour analysis was not required for this area.

## LATERAL MIGRATION

To estimate the degree of lateral migration in Bulldozer Wash, it would be useful to review historic aerial photographs of the wash. However, since Bulldozer Wash was recently realigned, this review will not provide any useful information for lateral migration.

Simons, Li & Associates (1984) provides a procedure for estimating the "safe" setback or distance beyond the existing stream banks that the pipeline should remain at the design burial depth to prevent scour due to lateral migration of the channel. The equation recommended for straight channels is:

$$M_{LS} = 0.7(Q_D)^{0.5}$$

where: $M_{LS}$ = minimum "safe" setback distance necessary (ft), and
$Q_D$ = design discharge (cfs).

For this study, the design discharge, $Q_D$, was equal to the 100-year discharge, or 700 cfs. Using this information, the minimum "safe" setback distance necessary can be calculated to be 18.5 feet:

$$M_{LS} = 0.7(700)^{0.5} = 18.52 \text{ feet}$$

Using a factor of safety of 1.3, a minimum setback distance was estimated to be 24.1 feet.

## SUMMARY

A scour analysis and lateral migration analysis for a 6-inch natural gas pipeline crossing of Bulldozer Wash at Verrado Way was conducted. The total scour depth at the proposed pipeline crossing was determined to be 6.0 feet for the 100-year event. Therefore, it is recommended that the crown of the pipeline at the proposed crossing be a minimum of 6.0 feet below the thalweg of the channel.

The minimum "safe" setback distance is 24.1 feet from the existing unprotected banks. Regulatory agency criteria may require extending the natural gas pipeline burial depth 10 feet beyond the boundary of the 100-year event. With this requirement, the recommended distance to extend beyond the boundary of both the north bank and the south bank of Bulldozer Wash is 34.1 feet.

# REFERENCES

Blench, T. (1969). *Mobile-Bed Fluviology.* University of Alberta Press, Edmonton, Canada.

FEMA (2005). *Flood Insurance Study, Maricopa Country, Arizona, and incorporated areas,* September 30, 2005.

Geotechnical and Environmental Consultants, Inc. (2005). *Results of Geotechnical Engineering Services, Verrado-Bulldozer Wash, Thomas Road to Waste Water Treatment Plant (WWTP),* May 17, 2005.

Lacey, G. (1930). "Stable Channels in Alluvium." *Proceedings of the Institution of Civil Engineers*, v. 229.

Neill, C.R. (1973). *Guide to Bridge Hydraulics.* Published for the Roads and Transportation Association of Canada.

Pemberton, E. L. and J. M. Lara. (1984). *Computing Degradation and Local Scour*, Technical Guideline for Bureau of Reclamation, US Department of Interior, Denver, CO.

Simons, Li & Associates, Inc. (1984). *Simplified, Step-by-Step, Hydraulic Design Procedure for the Placement of Pipelines Across and/or Parallel to Alluvial Drainage Channels.* Prepared for Pima County Wastewater Management Department, December 1984, Tucson, AZ.

Simons, D.B., and Richardson, E.V. (1960). "Resistance to Flow in Alluvial Channels." *Journal of the Hydraulics Division*, ASCE, v. 86, n. HY5.

URS. (2001). *Loop 303 Corridor / White Tanks Area Drainage Master Plan Update, Contract FCD99-40*, June 2001.

U.S. Army Corps of Engineers. (2005). *HEC-RAS River Analysis System, User's Manual*, version 3.1.3, May 2005.

Wood, Patel and Associates, Inc. (2006a). *Design Report for Bulldozer Wash and McDowell Basin at Verrado,* February 2006, Phoenix, AZ.

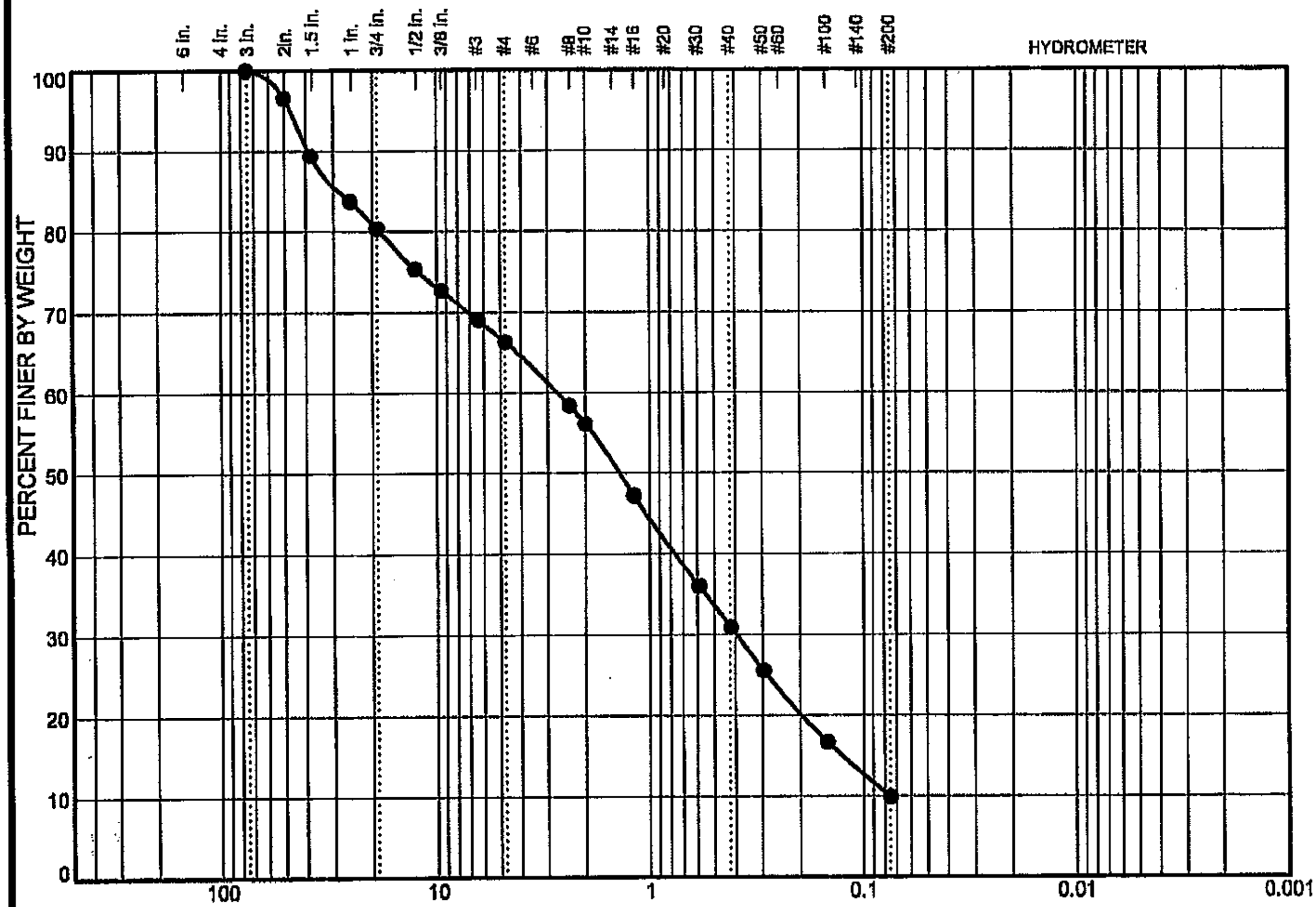
Wood, Patel and Associates, Inc. (2006b). *Verrado Planning Unit Drainage Plan for Portions of Planning Unit V (Phase 3 North – South of Tractor Wash and Intrawest Resort) and Update to Master Drainage Plan*, February 2006, Phoenix, AZ.

Yalin, M.S. (1964). "Geometric Properties of Sand Waves." *Proceedings, American Society of Civil Engineers*, v. 90, HY5.

Zeller, M.E. (1981). *Scour Depth Formula for Estimation of Toe Protection Against General Scour*. Pima County Department of Transportation and Flood Control District, Tucson, AZ.

# APPENDIX A: SOIL GRADATION INFORMATION

# PARTICLE SIZE DISTRIBUTION




| SAMPLE REFERENCE | |
|---|---|
| Source | Depth |
| 3 | 0.0 - 5.0 ft. |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| % Cobbles | % Gravel | % Sand | % Silt | % Clay |
| 0 | 34 | 56 | 9.9 | |

| Sieve Size | Percent Finer |
|---|---|
| 3" | 100 |
| 2" | 97 |
| 1-1/2" | 89 |
| 1" | 84 |
| 3/4" | 80 |
| 1/2" | 75 |
| 3/8" | 73 |
| 1/4" | 69 |
| #4 | 66 |
| #8 | 58 |
| #10 | 56 |
| #16 | 47 |
| #30 | 36 |
| #40 | 31 |
| #50 | 26 |
| #100 | 17 |
| #200 | 10 |

| COEFFICIENTS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| D100 | D85 | D60 | D50 | D30 | D15 | D10 | Cu | Cc |
| 76.2 | 27.803 | 2.731 | 1.401 | 0.397 | 0.126 | 0.076 | 35.98 | 0.76 |

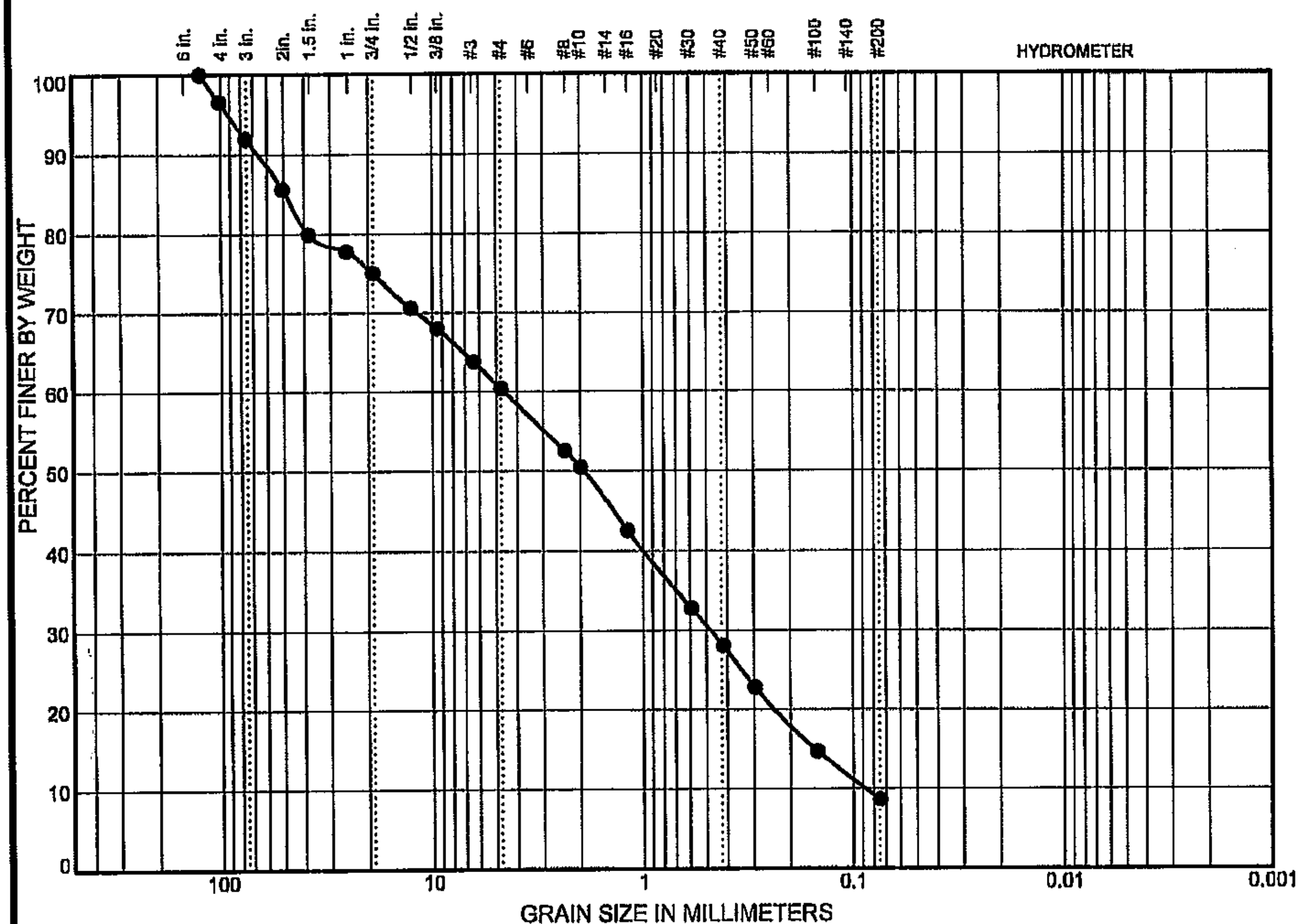
| SAMPLE DATA | | | |
|---|---|---|---|
| PI | LL | USCS | Description |
| NP | NV | SP-SM | Gravelly Sand |

Sampled by:
Date Sampled:
Tested by:
Reviewed by:


GEC - SA&B
2801 South 35th Street
Phoenix, AZ 85034
Phone: (602) 393-4800
Fax: (602) 393-4801


| | | | |
|---|---|---|---|
| Client: | DMB Contract Administrative Services, Inc. | Project No.: | 05-0100E |
| Project: | Verrado - Bulldozer Wash | | |
| Location: | Thomas Road to WWTP, Buckeye, AZ | | |

# PARTICLE SIZE DISTRIBUTION




| SAMPLE REFERENCE | |
|---|---|
| Source | Depth |
| 3 | 5.0 - 10.0 ft. |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| % Cobbles | % Gravel | % Sand | % Silt | % Clay |
| 8 | 31 | 52 | 8.7 | |

| Sieve Size | Percent Finer |
|---|---|
| 5" | 100 |
| 4" | 97 |
| 3" | 92 |
| 2" | 86 |
| 1-1/2" | 80 |
| 1" | 78 |
| 3/4" | 75 |
| 1/2" | 71 |
| 3/8" | 68 |
| 1/4" | 64 |
| #4 | 60 |
| #8 | 52 |
| #10 | 50 |
| #16 | 43 |
| #30 | 33 |
| #40 | 28 |
| #50 | 23 |
| #100 | 15 |
| #200 | 9 |

| COEFFICIENTS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| D100 | D85 | D60 | D50 | D30 | D15 | D10 | Cu | Cc |
| 127 | 49.286 | 4.594 | 1.939 | 0.482 | 0.153 | 0.087 | 52.61 | 0.58 |

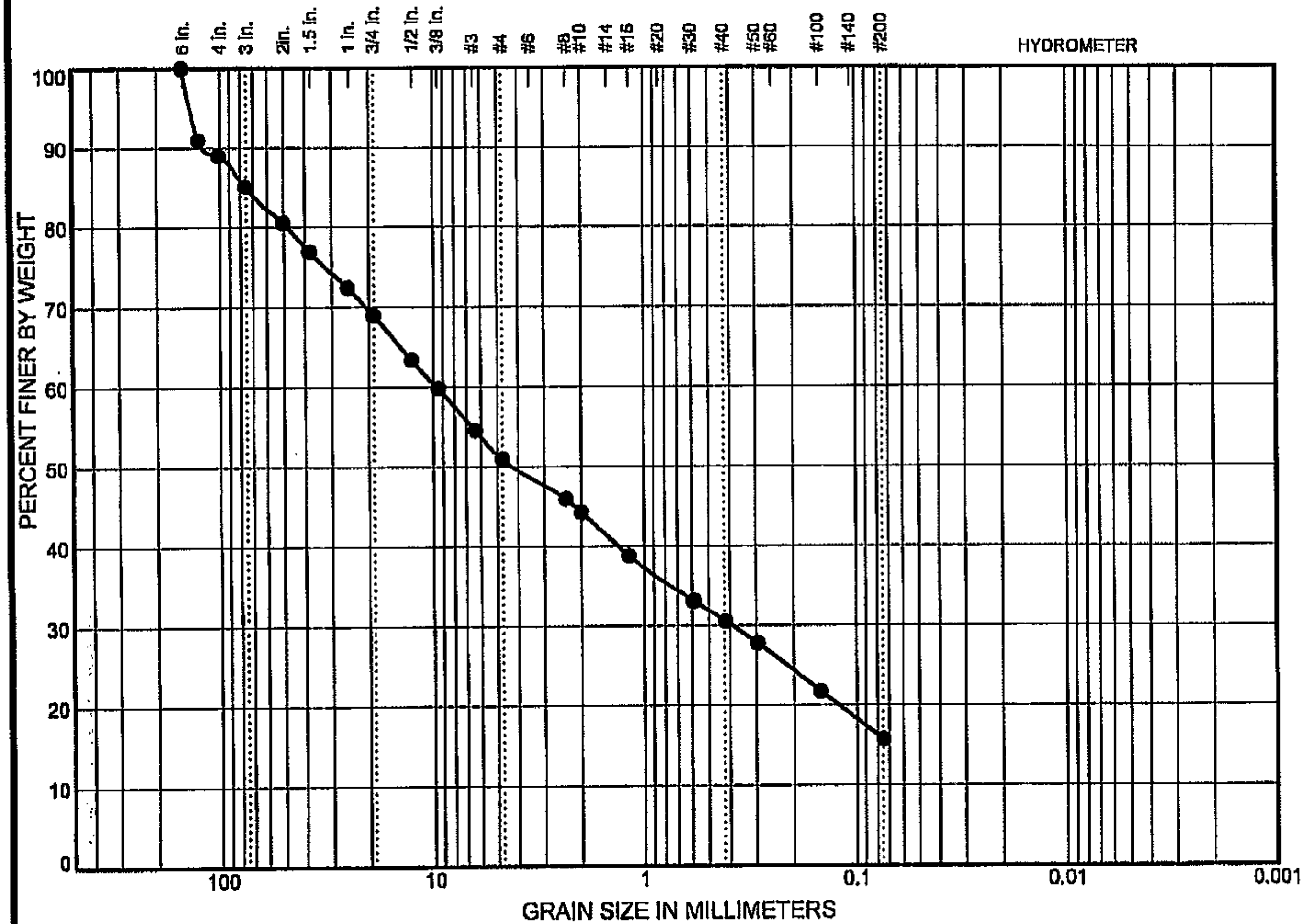
| SAMPLE DATA | | | |
|---|---|---|---|
| PI | LL | USCS | Description |
| NP | NV | SP-SM | Gravelly Sand |

Sampled by:
Date Sampled:
Tested by:
Reviewed by:


GEC - SA&B
2801 South 35th Street
Phoenix, AZ 85034
Phone: (602) 393-4800
Fax: (602) 393-4801


| | | | |
|---|---|---|---|
| Client: | DMB Contract Administrative Services, Inc. | Project No.: | 05-0100E |
| Project: | Verrado - Bulldozer Wash | | |
| Location: | Thomas Road to WWTP, Buckeye, AZ | | |

# PARTICLE SIZE DISTRIBUTION




| SAMPLE REFERENCE | |
|---|---|
| Source | Depth |
| 4 | 0.0 - 3.0 ft. |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| % Cobbles | % Gravel | % Sand | % Silt | % Clay |
| 15 | 34 | 35 | 16 | |

| Sieve Size | Percent Finer |
|---|---|
| 6" | 100 |
| 5" | 91 |
| 4" | 89 |
| 3" | 85 |
| 2" | 81 |
| 1-1/2" | 77 |
| 1" | 72 |
| 3/4" | 69 |
| 1/2" | 63 |
| 3/8" | 60 |
| 1/4" | 55 |
| #4 | 51 |
| #8 | 46 |
| #10 | 44 |
| #16 | 39 |
| #30 | 33 |
| #40 | 31 |
| #50 | 28 |
| #100 | 22 |

| COEFFICIENTS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| D100 | D85 | D60 | D50 | D30 | D15 | D10 | Cu | Cc |
| 152.4 | 75.687 | 9.637 | 4.172 | 0.392 | | | | |

| SAMPLE DATA | | | |
|---|---|---|---|
| PI | LL | USCS | Description |
| 4 | 21 | GM-GC | Sandy Clayey Silty Gravel |

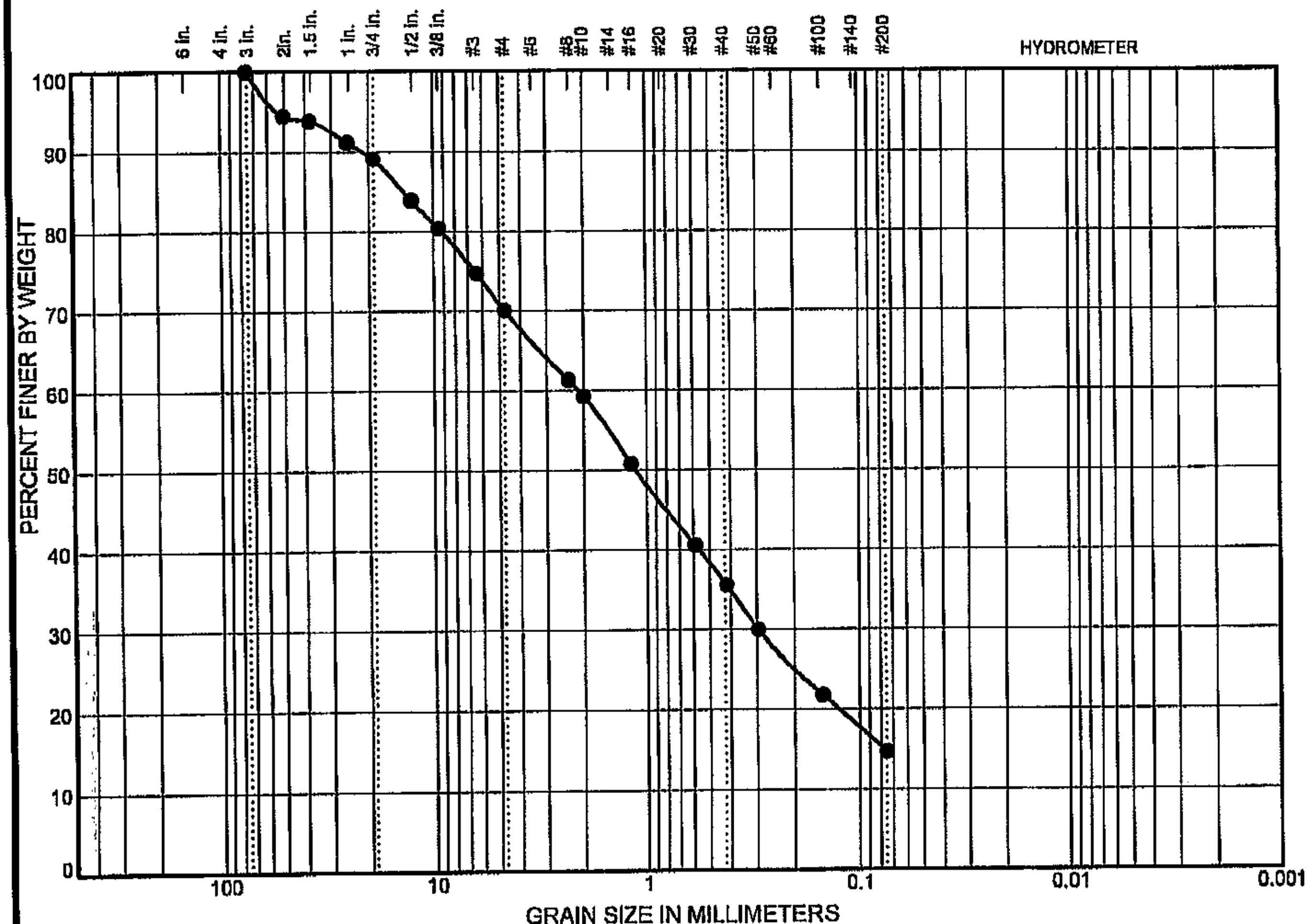
Sampled by:
Date Sampled:
Tested by:
Reviewed by:


GEC - SA&B
2801 South 35th Street
Phoenix, AZ 85034
Phone: (602) 393-4800
Fax: (602) 393-4801


| Client: | DMB Contract Administrative Services, Inc. | Project No.: 05-0100E |
|---|---|---|
| Project: | Verrado - Bulldozer Wash | |
| Location: | Thomas Road to WWTP, Buckeye, AZ | |

GEOTECH GRAIN SIZE SINGLE 05-0100E.GPJ GEC.GDT 5/13/05

# PARTICLE SIZE DISTRIBUTION




| SAMPLE REFERENCE | |
|---|---|
| Source | Depth |
| 4 | 3.0 - 10.0 ft. |

| TEST RESULTS | | | | |
|---|---|---|---|---|
| % Cobbles | % Gravel | % Sand | % Silt | % Clay |
| 0 | 30 | 55 | 15 | |

| COEFFICIENTS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| D100 | D85 | D60 | D50 | D30 | D15 | D10 | Cu | Cc |
| 76.2 | 13.852 | 2.124 | 1.128 | 0.297 | 0.077 | | | |

| SAMPLE DATA | | | |
|---|---|---|---|
| PI | LL | USCS | Description |
| NP | NV | SM | Gravelly Silty Sand |

Sampled by:
Date Sampled:
Tested by:
Reviewed by:

| Sieve Size | Percent Finer |
|---|---|
| 3" | 100 |
| 2" | 94 |
| 1-1/2" | 94 |
| 1" | 91 |
| 3/4" | 89 |
| 1/2" | 84 |
| 3/8" | 80 |
| 1/4" | 75 |
| #4 | 70 |
| #8 | 61 |
| #10 | 59 |
| #16 | 51 |
| #30 | 41 |
| #40 | 36 |
| #50 | 30 |
| #100 | 22 |
| #200 | 15 |

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| | | | |
|---|---|---|---|
| Client: | DMB Contract Administrative Services, Inc. | Project No.: | 05-0100E |
| Project: | Verrado - Bulldozer Wash | | |
| Location: | Thomas Road to WWTP, Buckeye, AZ | | |

# Flood Control District
of Maricopa County

INTEROFFICE MEMORANDUM

**Date:** July 30, 2007

**To:** Lynn Thomas, PE, CFM, Principal Engineer, Flood Hazard Management Branch, Regulatory Division

**From:** J. Rafael Pacheco, PhD, Assoc. Engineer, Engineering Application Development and River Mechanics Branch, Engineering Division

**CC:** Bing Zhao, PhD, PE, Engineering Application Development and River Mechanics Branch Manager, Engineering Division

**Subject:** "Scour evaluation for Pipeline Crossing of Bulldozer Wash at Verrado Way" Report dated 27th, 2007.

I have finished my review and I have the following comments on the above referenced document. The consultant should respond to each of these comments and provide a digital file back to the District with each of the comments and its response below it. This will allow for easier tracking by both, the consultant and the District. Those comments that have been addressed are grayed out.

1) (FCD 7/24/2007): On pp 5 penultimate paragraph "The scour components can included" should be corrected.

   (WEST 7/27/2007): The typographical error in the report was corrected.

   (FCD 7/30/2007): This comment has been resolved although we have not seen the final report.

2) (FCD 7/24/2007): Section Bedform Scour: The scour-depth value due to dunes was obtained from Simon and Richardson (1960). For consistency, please use the equation in the draft Drainage Manual of FCDMC. Please see the attached chapter from the draft manual for scour analysis.

   (WEST 7/27/2007): The draft drainage manual of the FCDMC reports that the dune height can be estimated as $d_h = 0.066Y_h^{1.21}$ where $Y_h$ is the hydraulic depth (ft). According to the HEC-RAS model, the hydraulic depth at the cross-section of interest (RS 3000) is 2.85 feet. Thus, the dune height can be estimated to be 0.23 feet. The bedform scour can then be estimated as $Z_{bedform} = 0.5d_h$. Using a factor of safety of 1.3, the bedform scour for dunes is estimated to be 0.15 feet.

This value is smaller than the value of 2.3 feet estimated by WEST. WEST would prefer to use their original bedform scour estimate as it is more conservative than the estimate obtained from following the FCDMC guidelines. The bedform scour equations presented in the Drainage Manual of the FCDMC will be used in future work.

(FCD 7/30/2007): We are in agreement with your calculations. Please use the most conservative number for calculations, but compare with those obtained following the FCDMC guidelines. This comment has been resolved.

3) (FCD 7/24/2007): In the antidune region, please use draft Drainage Manual of FCDMC. Please see the attached chapter from the draft manual for scour analysis.

(WEST 7/27/2007): The draft drainage manual of the FCDMC reports that the antidune height can be estimated as $d_h = 0.027V^2$ where V is the average channel velocity (ft/s). According to the HEC-RAS model, the velocity at the cross-section of interest (RS 3000) is 4.15 ft/s. Thus, the antidune height can be estimated to be 0.47 feet. The bedform scour can then be estimated as $Z_{bedform} = 0.5d_h$. Using a factor of safety of 1.3, the bedform scour for antidunes is estimated to be 0.30 feet. This value is smaller than the value of 2.3 feet estimated by WEST. WEST would prefer to use their original bedform scour estimate as it is more conservative than the estimate obtained from following the FCDMC guidelines. The bedform scour equations presented in the Drainage Manual of the FCDMC will be used in future work.

(FCD 7/30/2007): We are in agreement with your calculations. Please use the most conservative number for calculations, but compare with those obtained following the FCDMC guidelines. This comment has been resolved.

4) (FCD 7/24/2007): Section Lateral Migration: Please use the setback equation for straight channels from State Standard for Watercourse System Sediment Balance manual, instead of the equation provided by Simons et al. (1984). Please see the attached pdf file for the State Standard.

(WEST 7/27/2007): The State Standard for Watercourse System Sediment Balance reports that the setback for a straight channel is $1.0(Q_{100})^{0.5}$ where $Q_{100}$ is the 100-year discharge in cfs. For this study, $Q_{100}$ is 700 cfs. Thus, the setback is estimated to be 26.5 feet. This value is almost identical to the value of 24.1 feet obtained by WEST. Thus, we would prefer to use our original estimate of the setback. The equation presented in the state standard will be used for any future setback estimates.

(FCD 7/30/2007): We are in agreement with your calculations. Please use the most conservative number for calculations, but compare with those obtained following the FCDMC guidelines. This comment has been resolved.

5) (FCD 7/24/2007): Please provide the correct electronic file in excel format of this analysis after you perform the scour analysis based on the procedures recommended above.

(WEST 7/27/2007): *An electronic file in Excel format with updated calculations is included.*

(FCD 7/30/2007): Received. This comment has been resolved.

6) (FCD 7/24/2007): The peak flow rate for the proposed development is 700 cfs based on the hydrology report by Wood Patel (2006). Our hydrology/hydraulics branch staff (Mr. John Holmes) is reviewing the accuracy of this peak flow rate. He will provide comments later.

(WEST 7/27/2007): The hydrology was based on a CLOMR prepared by Wood Patel that was approved by FEMA on June 5, 2006.

(FCD 7/30/2007): This comment has been resolved.