Appendix G.
Downhole Geophysics

Appendix G.
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Appendix G-1
Downhole Geophysics
(P- and S-wave Velocities) Plots – Phase II

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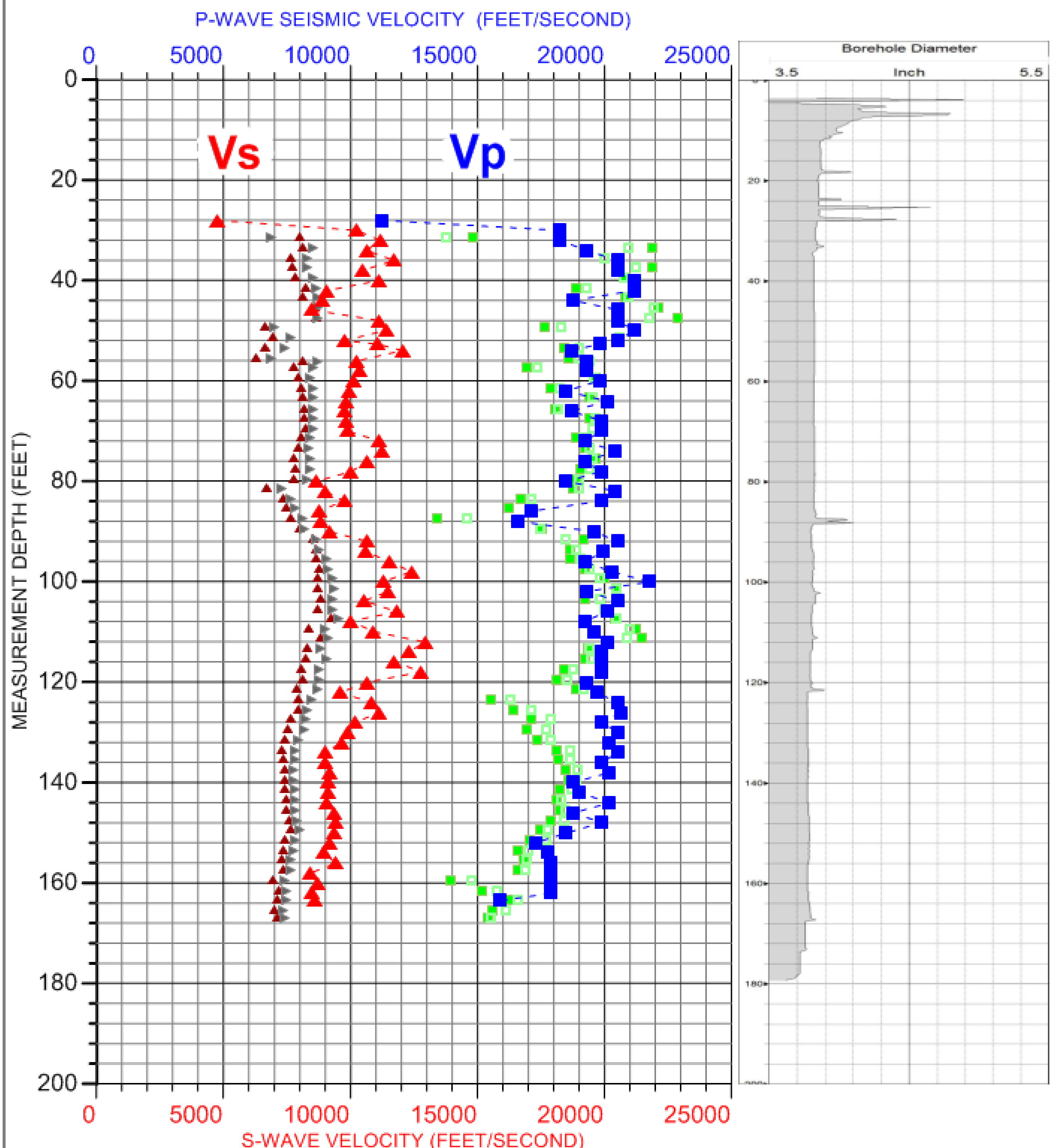
(P- and S-wave Velocities) Plots – Phase II



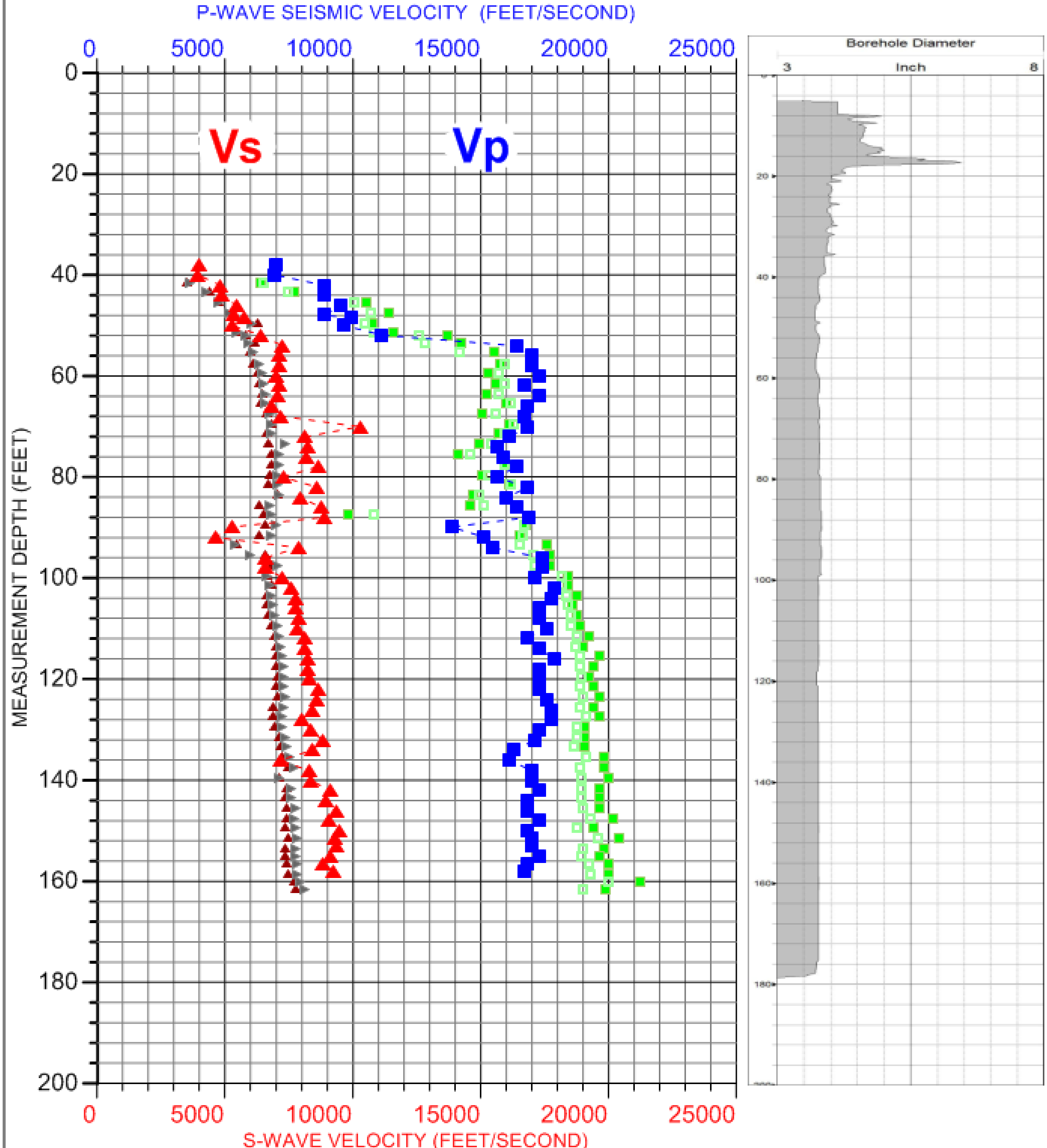
*Interval velocities should be used to calculate elastic moduli values

P- & S-WAVE VELOCITY LEGEND

- *Vs- R1-R2 interval
- Vs- Tx-R1 direct
- Vs- Tx-R2 direct
- *Vp- R1-R2 interval
- Vp- Tx-R1 direct
- Vp- Tx-R2 direct

NORCAL

SUSPENSION P- AND S-WAVE VELOCITY PROFILE BOREHOLE CB-2		
LOCATION: Centenial Dam Project, Placer Co.		
CLIENT: AECOM		PLATE 1
JOB #: 15-533.73B	NORCAL GEOPHYSICAL CONSULTANTS INC.	
DATE: NOV., 2015	DRAWN BY: W. HENRICH	APPROVED BY: WJH



*Interval velocities should be used to calculate elastic moduli values

P- & S-WAVE VELOCITY LEGEND

- *Vs- R1-R2 interval
- Vs- Tx-R1 direct
- Vs- Tx-R2 direct
- *Vp- R1-R2 interval
- Vp- Tx-R1 direct
- Vp- Tx-R2 direct

NORCAL

SUSPENSION P- AND S-WAVE VELOCITY PROFILE BOREHOLE CB-5

LOCATION: Centenial Dam Project, Placer Co., CA		PLATE 2
CLIENT: AECOM		
JOB #: 15-533.73B	NORCAL GEOPHYSICAL CONSULTANTS INC.	
DATE: Nov., 2015	DRAWN BY: W. HENRICH	APPROVED BY: WJH

Appendix G-2
Downhole Geophysics (P-wave Velocities) Report – Phase III

Appendix G-2
Downhole Geophysics (P-wave Velocities) Report – Phase III

NORCAL
GEOPHYSICAL CONSULTANTS INC.
A Terracon COMPANY

September 7, 2016

AECOM
1333 Broadway, Suite 800
Oakland, CA 94612-1924

SUBJECT: BOREHOLE GEOPHYSICAL LOGGING REPORT
Centennial Dam, NID Phase 3 Geotechnical Investigation
North and South Borrow Areas
Nevada County, California

NORCAL JOB No. NS165019A

ATTN: Ms. Sheri Janowski, Project Engineering Geologist

This report summarizes the findings of a borehole geophysical investigation performed by NORCAL Geophysical Consultants, Inc. at the subject site for AECOM. The investigation was conducted in several separate mobilizations between the periods June 2 through June 28, 2016 by NORCAL Professional Geophysicist William J. Henrich (PGp No. 893). Ms. Kate Zeiger and Mr. Ben Kozlowiez Geologists of URS provided background information, coordination and on-site logistical support.

1.0 INTRODUCTION

At total of six boreholes were geophysically logged using a downhole sonic method. Four boreholes were completed at the South Borrow Area; two boreholes were completed at the North Borrow Area. The purpose of the geophysical logging was to profile P-wave velocities in underlying metamorphic basalt. These sonic velocity data will be used to locally characterize the rock mass in terms of depth of weathering and rock quality.

1.1 BOREHOLE CONDITIONS

Sonic full waveform logging was conducted in 4-inch diameter core holes (HQ size). Borehole depths ranged from 55-to 200- feet below ground surface (bgs). The boreholes penetrated shallow alluvium, intensely weathered to fresh, intensely fractured to un-fractured metamorphic basalt. Generally 3 to 19.5 feet of conductor casing (steel *hwt* casing at 4.25 inches in diameter) was installed in the upper section of the boreholes to prevent caving. All boreholes were flushed with water prior to geophysical logging. Water level in several boreholes dropped several tens of feet prior to surveying. In these instances, we added water to the boreholes just before and sometimes during the logging operation to raise the water level to surface. This water addition was required as sonic logging needs a water or drilling fluid column to operate.

AECOM
September 7, 2016
Page 2

1.2 BOREHOLE LOCATIONS

The sonic logging was distributed over two potential borrow sites. These sites are referred to as South and North Borrow Areas. The following figures show these areas, the location of the sonic logged borehole and these relationships to proposed seismic lines.

Figure 1. South Borrow Area

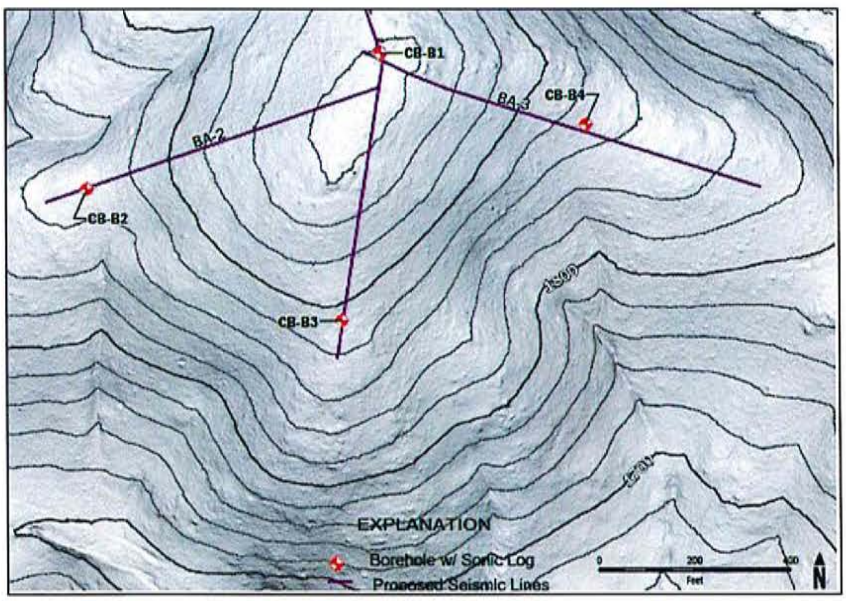
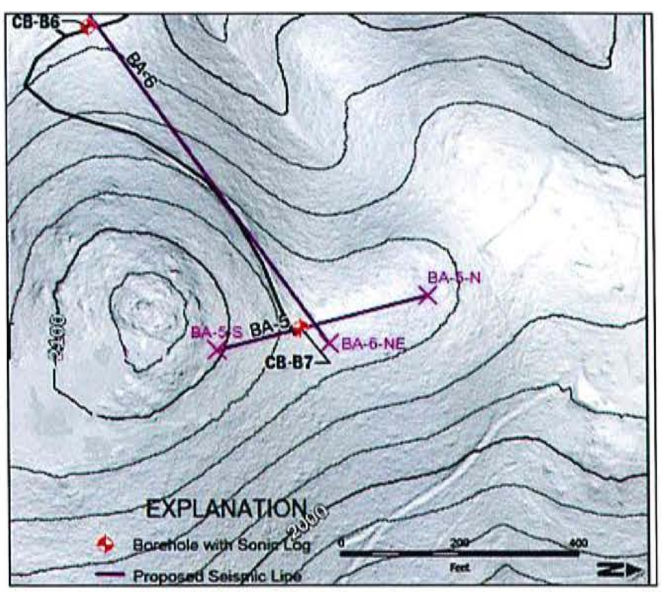


Figure 2. North Borrow Area



2.0 INSTRUMENTATION

NORCAL conducted geophysical borehole logging using a digital ***MICROLOGGER2*** System manufactured by **Robertson Geologging, Ltd.** This system consisted the following components:

- control console,
- computer,
- motorized cable winch,
- Sonic Probe
- Caliper Probe

3.0 METHODOLOGY-DATA ACQUISITION

3.1 Sonic Full Waveform

The compensated sonic full waveform logging for P-wave velocity profiling represents highly specialized down the borehole/well technology. Complete descriptions of the methodology, data acquisition and data analysis procedures are presented in Appendix A.

3.2 Caliper

Caliper logs are a measure of the borehole diameter versus depth. The tool was used both as a survey technique to assess borehole stability and quantify the relative consolidation of bedrock. The caliper tool consists of three interconnected mechanical arms that are spring loaded against the borehole wall. The horizontal deflections of the arms gauge the borehole diameter in units of inches with depth. The logging measurement was made in the up-hole direction at a speed of approximately 10-ft per minute. The data sampling rate for this instrument was every 0.5 feet.

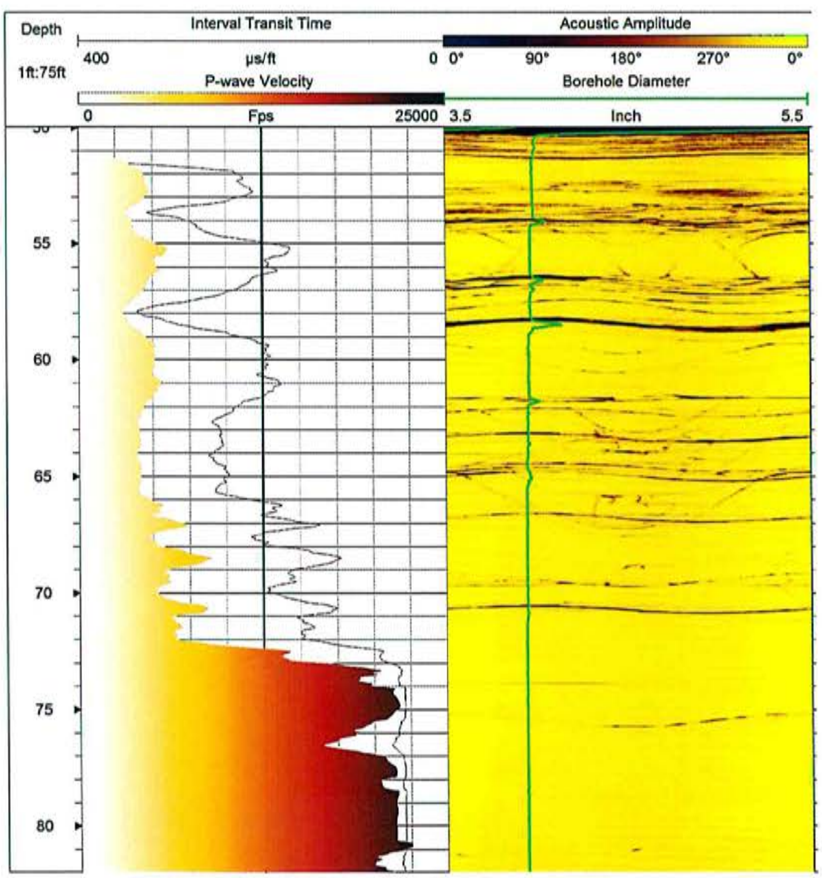
4.0 LOG PRESENTATIONS

Sonic logs for both borrow areas are present in Appendix B. These log plots show continuous transit times (slowness) and converted sonic P-wave velocities in the left track and full sonic waveforms associated at the near and far detector traces in tracks 2 and 3, respectively. For clarity, the transit times were plotted in reverse order, i.e. values decrease from left to right on the horizontal axis. This is to avoid overprinting on top of the P-wave velocity trace which has been shaded with a horizontal color gradient spectrum. The red-crimson color shades represent the highest P-wave velocity; lighter yellow color shades represent low P-wave velocities. Note, the near and far waveforms are plotted on one-foot depth increments. These are representative of the total log measurement. The transit times and converted P-wave velocities are actually measured every 0.02 feet. We have also shaded interval transit time curves that have apparent interval time values equal to or less than 200 micro-seconds. This is because 200 micro-seconds represents the lowest P-wave measurement threshold for a sonic tool. Implications of the 200 micro-second threshold are discussed in the following section.

Results of caliper logging are presented in the far right track labeled as Borehole Diameter. The logs horizontal scale ranges from 3.5- to 5.5-inches.

5.0 FORMATION EFFECTS ON SONIC LOGS

The frequency of fractures, occurrence of open fracture apertures, the intensity of weathering along fracture planes and water saturation have a large influence on sonic velocity. Without addressing the water saturation factor, the adjacent figure illustrates the effects of fractures on P-wave velocity. Visible fractures are indicated on the acoustic amplitude image (yellow) as dark sinusoidal bands (see rightmost track in figure). Analyzing this log, fractures in varying frequency are present from 50 to 71 feet. Deflections on the caliper log (green) suggest some of these fractures are open. The effect on P-wave velocity is dramatic. Below 72 feet the P-wave velocity ranges from 17500 to 22000 fps. These velocities represent hard, little weathered bedrock. Above the 72 feet, the P-wave velocities decrease significantly to a range of less than 5000 up to 7500 fps. This magnitude of velocity decrease correlates to moderate to highly fractured bedrock. Weathering of the bedrock via open fractures also may have contributed to the large P-wave velocity decrease.



6.0 INTERPRETATION

6.1 South Borrow Area

Sonic logging was conducted in Boreholes CB-B1,-B2,-B3 and CB-B4. Based on the P-wave velocity magnitudes, variations in the P-wave velocity profile, changes in signal amplitude of the near and far waveforms and to some extent, variations in borehole diameter, the bedrock was characterized into three velocity layers. Table 1 presented below quantifies the velocity ranges and depth intervals of these three velocity layers interpreted for the South Borrow Area.
The lower layer (3) has very high P-wave velocities and represents fresh to little weathered, strong metamorphic basalt. Going up the borehole, a sharp reduction in P-wave marks a transition to an intermediate P-wave velocity layer (2) that represents moderately weathered and fractured metamorphic basalt. This transition middle layer ranges from a few feet up to 18 feet in thickness depending on the borehole location. The upper P-wave velocity layer (1) shows P-wave velocities less than 5000 fps and loss of waveform signal. This upper layer represents highly weathered, slight to highly fractured basalt. Apparent P-wave velocities less than 5000 fps layer were shaded a brown color in Track 1 on the sonic plots in Appendix B. Note, velocities below 5000 fps are not quantifiable and should only be used an indication of highly weathered and fractured bedrock.

Table 1. South Borrow Area, Velocity Layers, P-Wave Velocities and Depth Ranges

Borehole Label	Velocity Layer	P-Wave Velocity Range (fps)	Depth Range (feet bgs)	Bedrock Description
CB-B1	1	< 5000 fps	26-64	Highly weathered & fractured
	2	5000-20000	64-75	Moderately weathered & fractured
	3	15000-22000	75-200	Fresh w/fracture zones
CB-B2	1	< 5000 fps	20-48.5	Highly weathered & fractured
	2	5000-20000	48.5-66	Moderately weathered & fractured
	3	15000-22000	66-89	Fresh with some fracture zones
CB-B3	1	< 5000 fps	22-66	Highly weathered & fractured
	2	5000-20000	66-72	Moderately weathered & fractured
	3	15000-22000	72-89	Fresh and very slightly fractured
CB-B4	1	< 5000 fps	20-56	Highly weathered & fractured
	2	5000-18000	56-68	Moderately weathered & fractured
	3	17000-18000	72-89	Fresh w/fracture zones

6.2 North Borrow Area

Sonic logging was conducted in Boreholes CB-B6 and CB-B7. The velocity layering configuration in this area is the same as the South Borrow Area. Our interpretation as to the velocity ranges and depth intervals are presented in Table 2. Note, that the depth to the high velocity layer is relatively shallow and the velocity transition velocity layers appears much thinner compared to the South Borrow Area.

Table 2. North Borrow Area, Velocity Layers, P-Wave velocity and Depth ranges

Borehole Label	Velocity Layer	P-Wave Velocity Range (fps)	Depth Range (feet bgs)	Bedrock Description
CB-B6	1	< 5000 fps	10-28	Highly weathered & fractured
	2	5000-15000	28-32	Moderately weathered & fractured
	3	15000-17500	32-52	Fresh w/fracture zones
CB-B7	1	< 5000 fps	3-7	Highly weathered & fractured
	2	5000-12500	7-9	Moderately weathered & fractured
	3	12500-18500	9-45	Mostly fresh, w/ significant fracture zones 18- to 21- and 38- to 44-ft bgs

The sonic log of Borehole CB-B7 (see Appendix B) shows significant reductions to P-wave velocities within the high velocity layer (Velocity Layer 3). The largest reduction in velocity is shown from 38- to 44- ft bgs. This velocity effect is the result of a fracture zone. The fracture zone is also indicated by washouts on the caliper log.

7.0 STANDARD CARE

The scope of NORCAL's services for this project consisted of using geophysical logging techniques to measure sonic P- wave velocities. The accuracy of our findings is subject to specific site conditions and limitations inherent to the techniques used. We performed our services in a manner consistent with the level of skill ordinarily exercised by members of the profession currently employing similar methods. No warranty, with respect to the performance of services or products delivered under this agreement, expressed or implied, is made by NORCAL.

We appreciate the opportunity to provide our services to AECOM for this project. If you have any questions, or require additional geophysical services, please do not hesitate to call on us.

Sincerely,

NORCAL Geophysical Consultants, Inc.

William J. Henrich PGp
Professional Geophysicist PGp893

REGISTERED GEOPHYSICIST WILLIAM J. HENRICH No. 893 STATE OF CALIFORNIA
Exp 05/31/2018

WJH/

Appendices: Appendix A: Sonic Full Waveform Logging
Appendix B: Sonic Logging Plots

Appendix A:

Sonic Full Waveform Logging

APPENDIX A

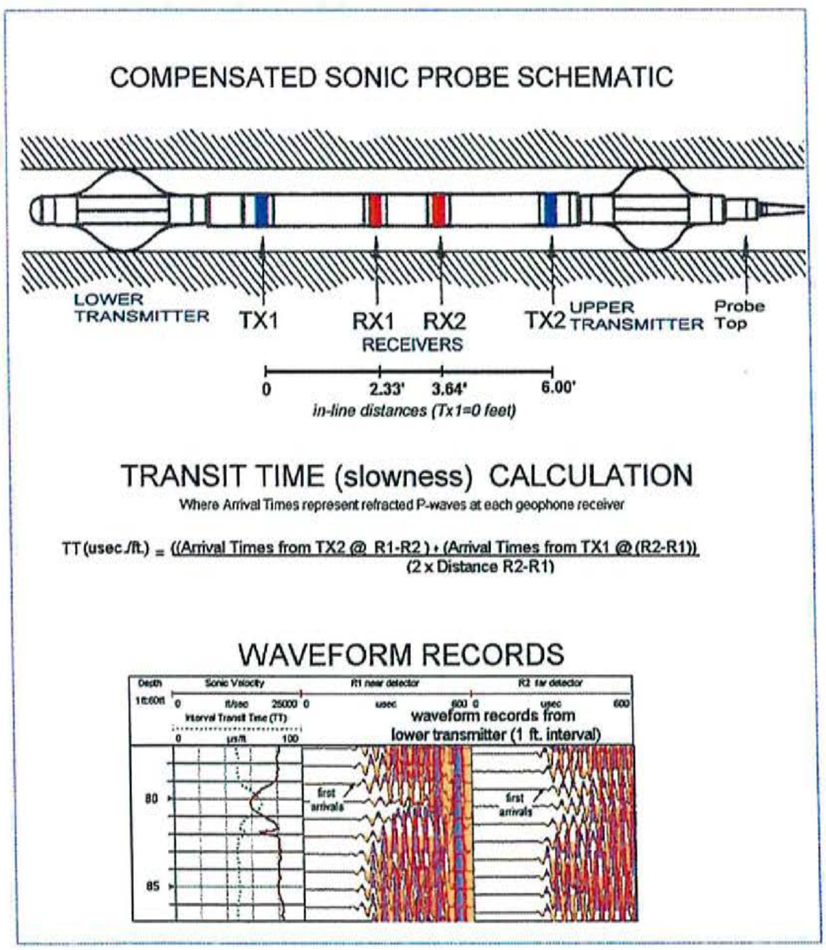
SONIC FULL-WAVEFORM LOGGING

1) Methodology–Data Acquisition

The sonic logging consists of measuring the transmission times from an acoustic energy source to a series of geophone detectors located at fixed distances along the probe. The acoustic energy is imparted to the borehole fluid in sound bursts at a center frequency of 20 kHz from a piezo metric designed transmitter. The energy travels through the borehole fluid and intersects the borehole wall setting up refracted P- and converted P- to S-wave energy that in "fast" formations, arrive at the geophone receivers before direct fluid waves. A fluid column is necessary to acquire sonic data.

Our sonic tool consisted of two transmitters and two receivers that schematically are represented on Figure 1. This acquisition system is set to measure transit times (difference in first arriving P-wave travel times between two receivers) in two phases. Initially, the lower transmitter fires into the two inner receivers (TX1 to RX1 & RX2); this is followed immediately by a second firing- recording sequence as the upper transmitter (TX2 to R2 & R1) fires into the same inner pair of receivers. Within the data acquisition system, first arrivals are detected by an internal zero-crossing threshold technique. These lower and upper interval transit times are averaged to produce a compensated formation interval transit time (slowness). The term "compensation" means that any timing errors associated with probe standoff or borehole washouts are effectively eliminated by this averaging process. The compensated interval transit time (TT) formula is presented in the adjacent figure.

Figure 1. Sonic Probe Schematic



Prior to logging, the apparent strength of the sonic signal is gauged by observing an assembled full waveform in test mode. Electronic gain is increased at each detector to boost signal amplitude.

Sonic interval transit data are acquired with the probe moving up the borehole at 8 feet per minute. The data sampling increment was every 0.02 feet. In addition to the interval transit time, sonic full waveform records from the near and far detectors relative to the lower transmitter are compiled every foot on the log plot. We acquired two logs in each borehole to verify consistency in the interval transit times.

2) Log Presentation

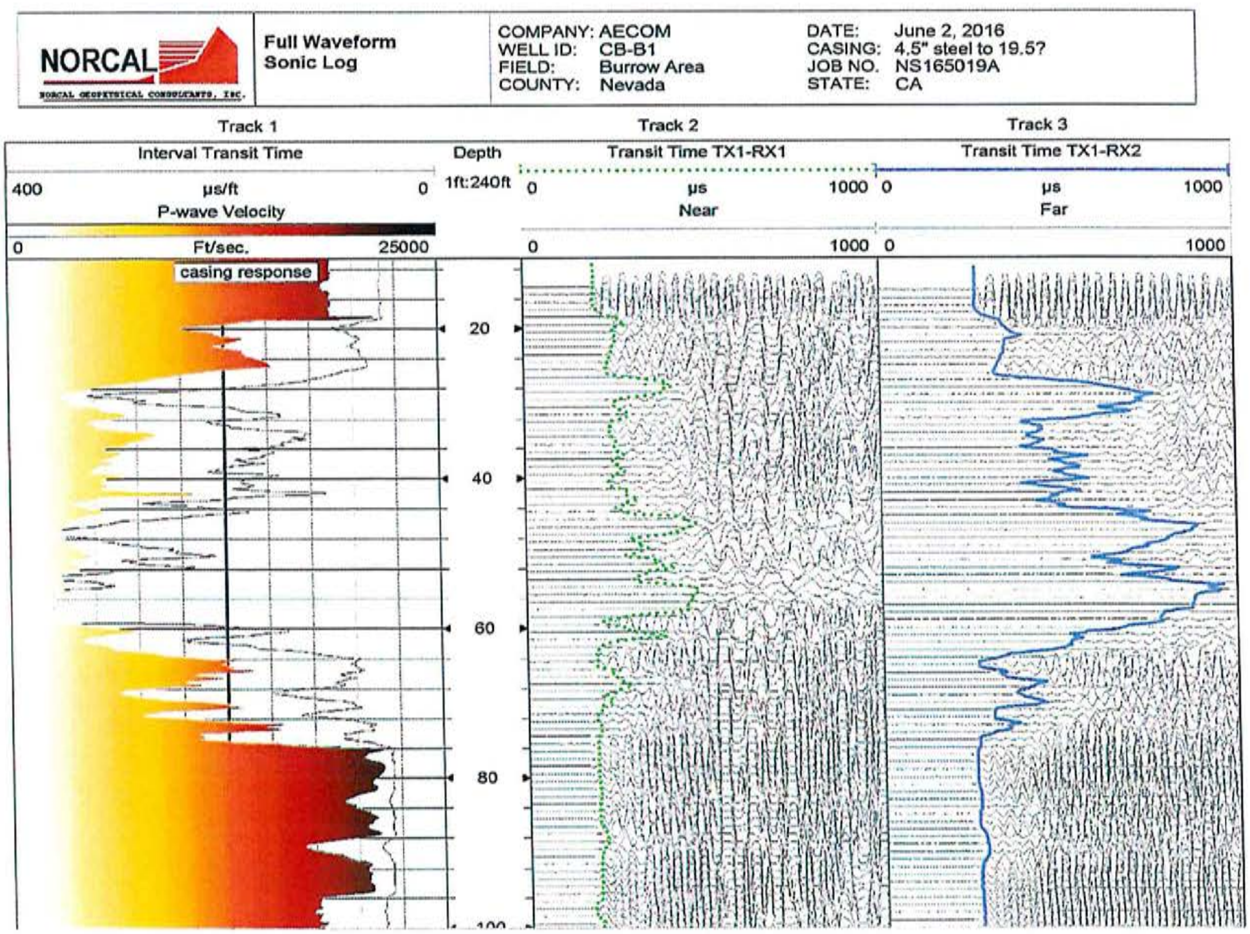
Referring to Figure 1, the basic log display consists of the following elements versus depth left to right as follows as:

Track 1- Interval transit time (TT) plotted in reverse scale
- P-wave velocity (reciprocal of transit time)

Track 2- Transit or arrival time in micro-seconds from the lower Transmitter to "Near 'receiver.
- Sonic waveforms recorded at the "Near' receiver plotted as wiggle traces

Track 3- Transit or arrival time in micro-seconds from the lower Transmitter to "Far' receiver
- Sonic waveforms recorded at the "Far' receiver plotted as wiggle traces

Figure 2. Full Waveform Sonic Log Plot



3) Data Reduction

We converted the interval transit times (TT) into sonic P-wave velocities using the reciprocal formula 1 / (.000001 x TT). This formula produces P-wave velocities in units of feet per second (fps). The lower limit velocity limit of detection with the borehole sonic method is 5000 fps. This velocity corresponds to direct fluid arrivals and not refractions from the formation. Velocities shown on the sonic log plot below 5000 are not factual and should not be taken as absolute velocity measurements. All plotting and velocity calculations we made using the computer program WELLCAD Version 5.1 published by ALT (Luxembourg).

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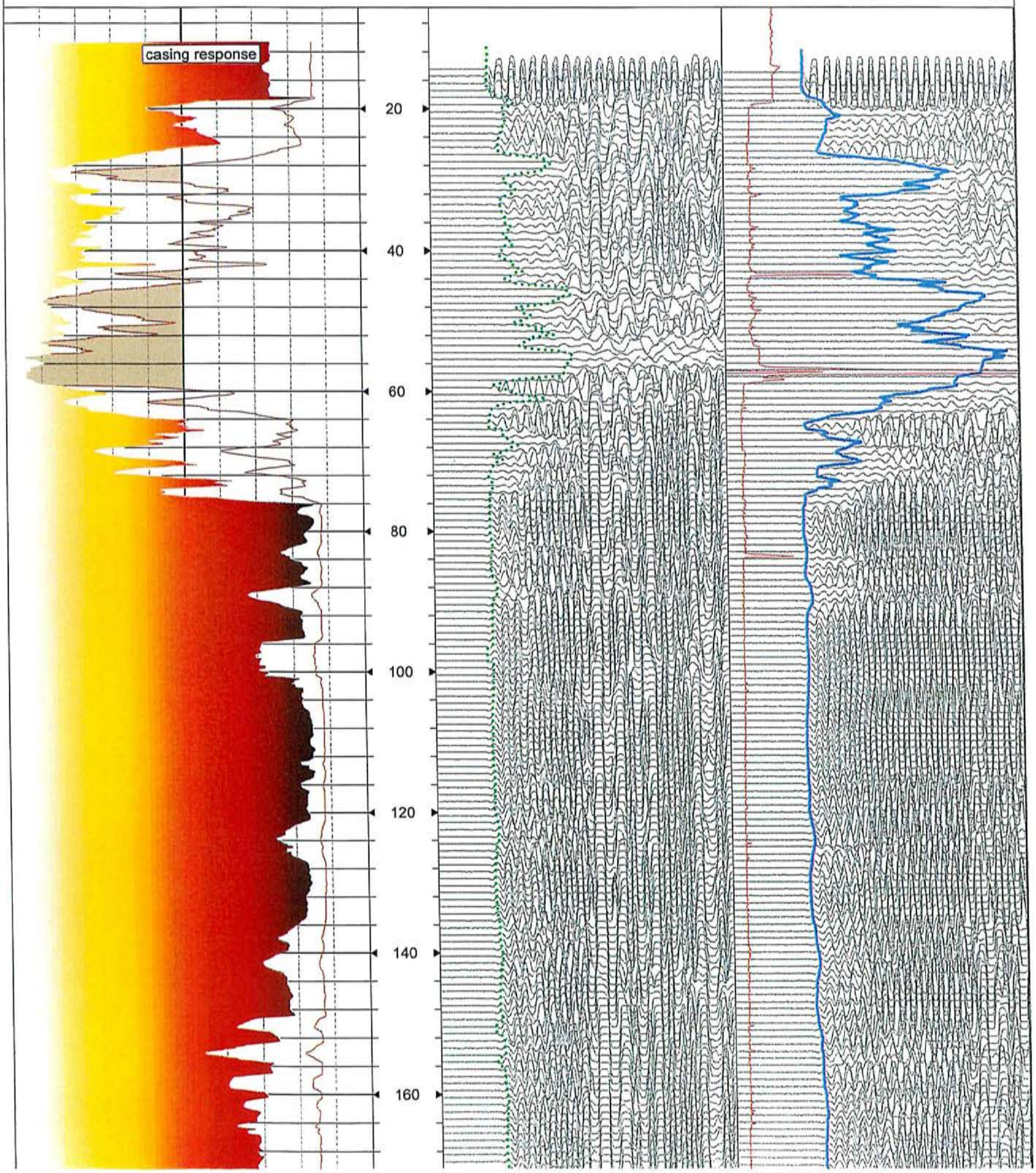
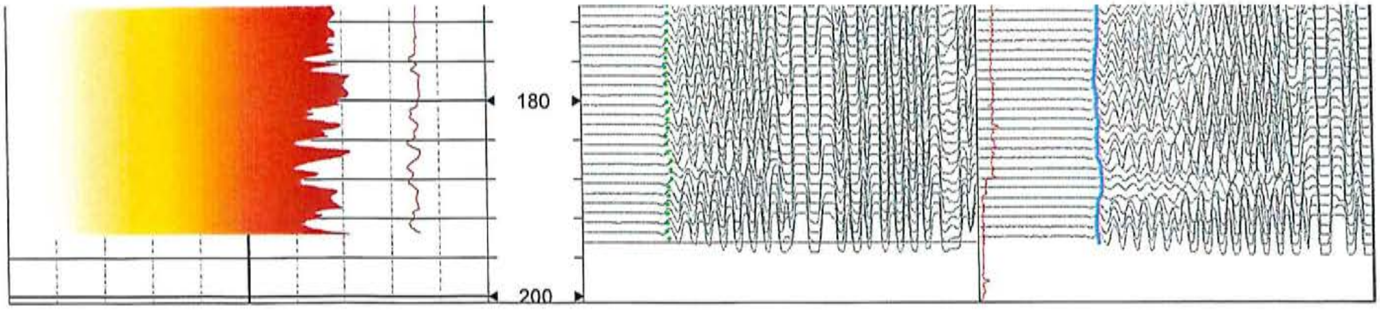
Appendix B:

Sonic Log Plots

NORCAL GEOPHYSICAL CONSULTANTS, INC.	Full Waveform Sonic Log	COMPANY: AECOM WELL ID: CB-B1 FIELD: South Borrow Area COUNTY: Nevada	DATE: June 2, 2016 CASING: 4.5" steel to 19.5 JOB NO. NS165019A STATE: CA

Track 1	Depth	Track 2	Track 3
Interval Transit Time 400 µs/ft 0	1ft:240ft	Transit Time TX1-RX1 0 µs 1000	Transit Time TX1-RX2 0 µs 1000
P-wave Velocity 0 Ft/sec. 25000		Near 0 1000	Far 0 1000
Very Weathered Rock <5000 fps			Borehole Diameter 3.5 INCH 5.5

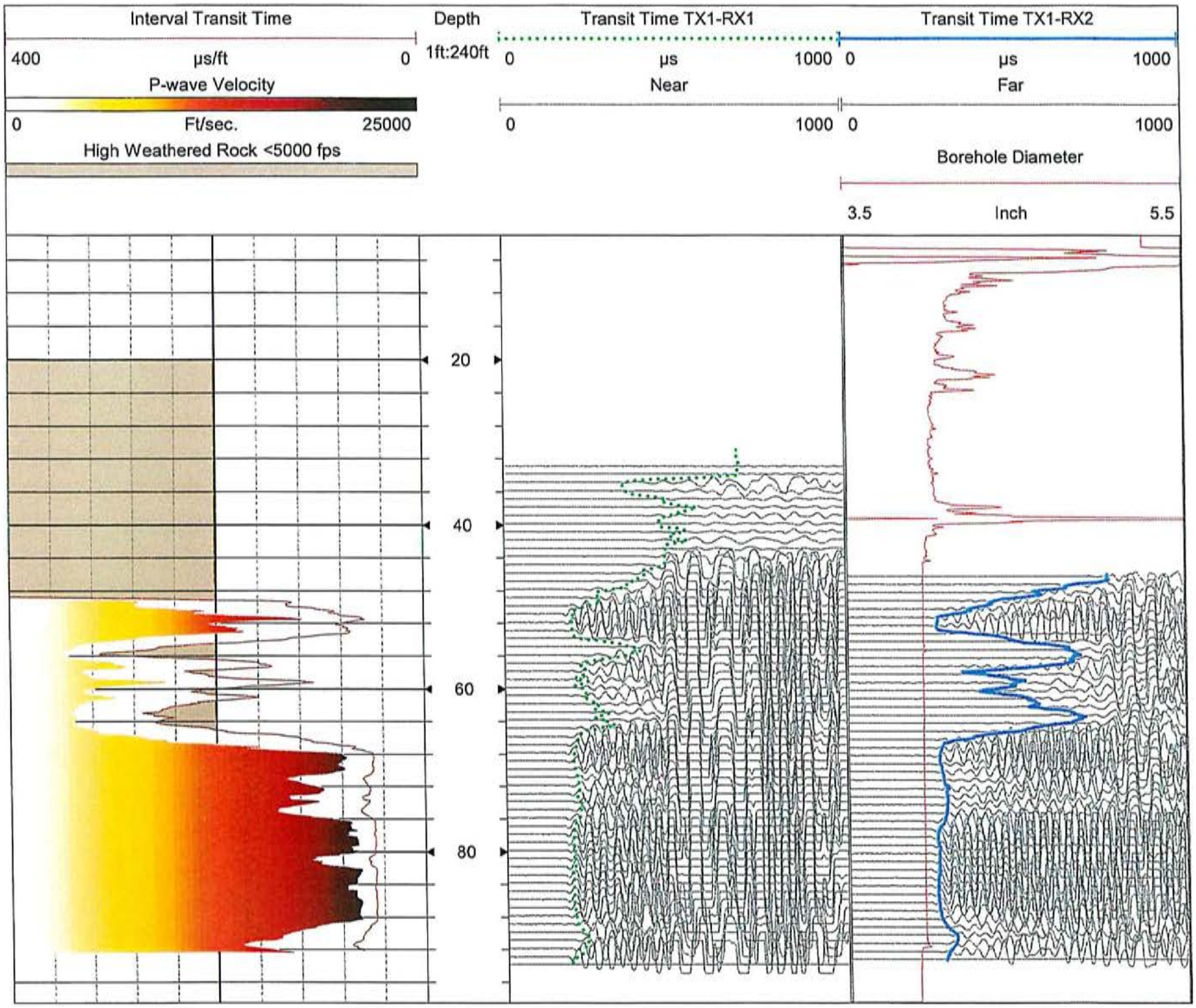




180
200

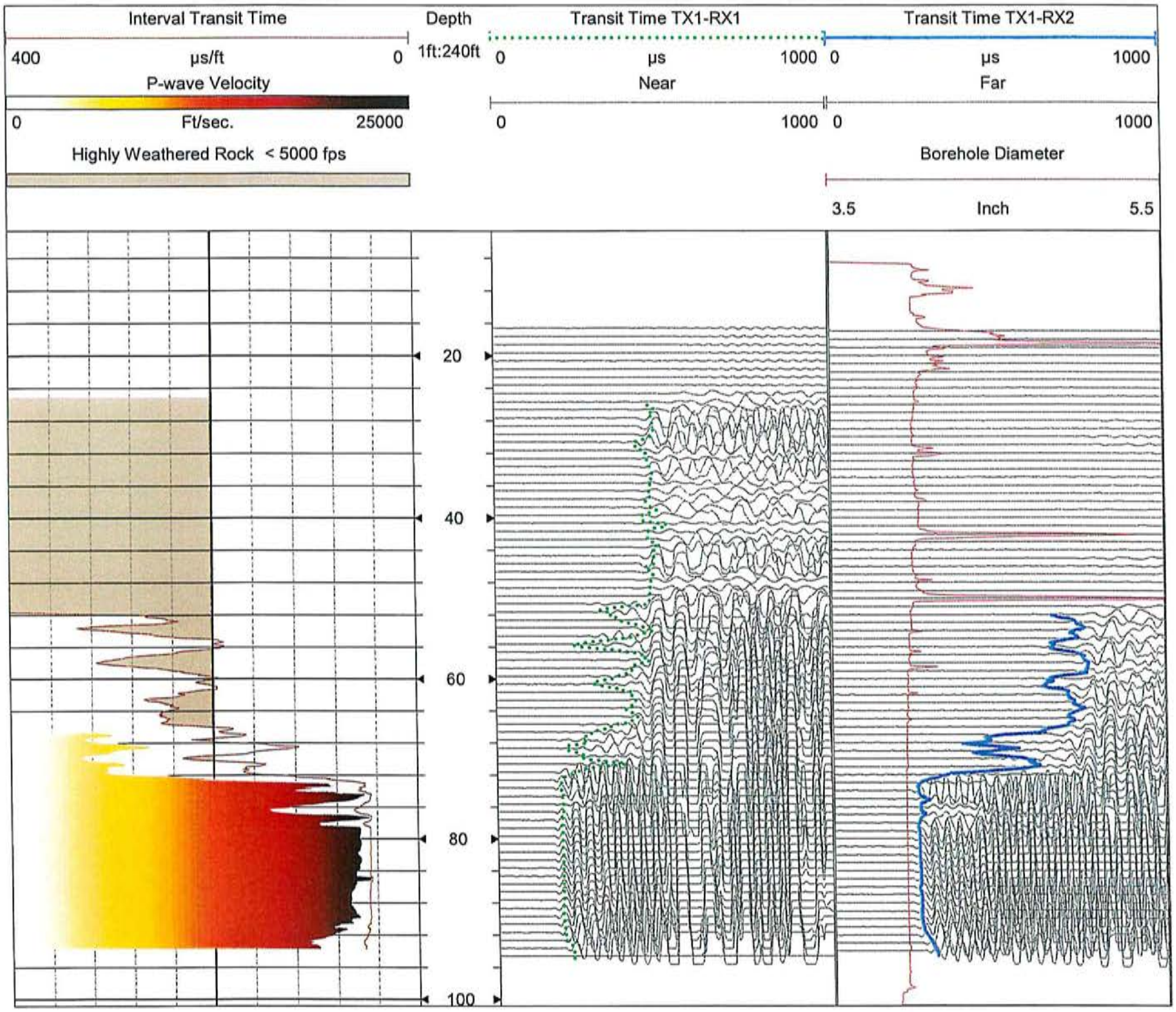
NORCAL Geophysical Consultants, Inc.	Fullwave Sonic Log	COMPANY: AECOM WELL ID: CB-B2 FIELD: South Borrow Area COUNTY: Nevada	DATE: June 9, 2016 CASING: 4.5" steel to 10 JOB NO. 165019A STATE: CA

NOTES: Run-2 Increase gain



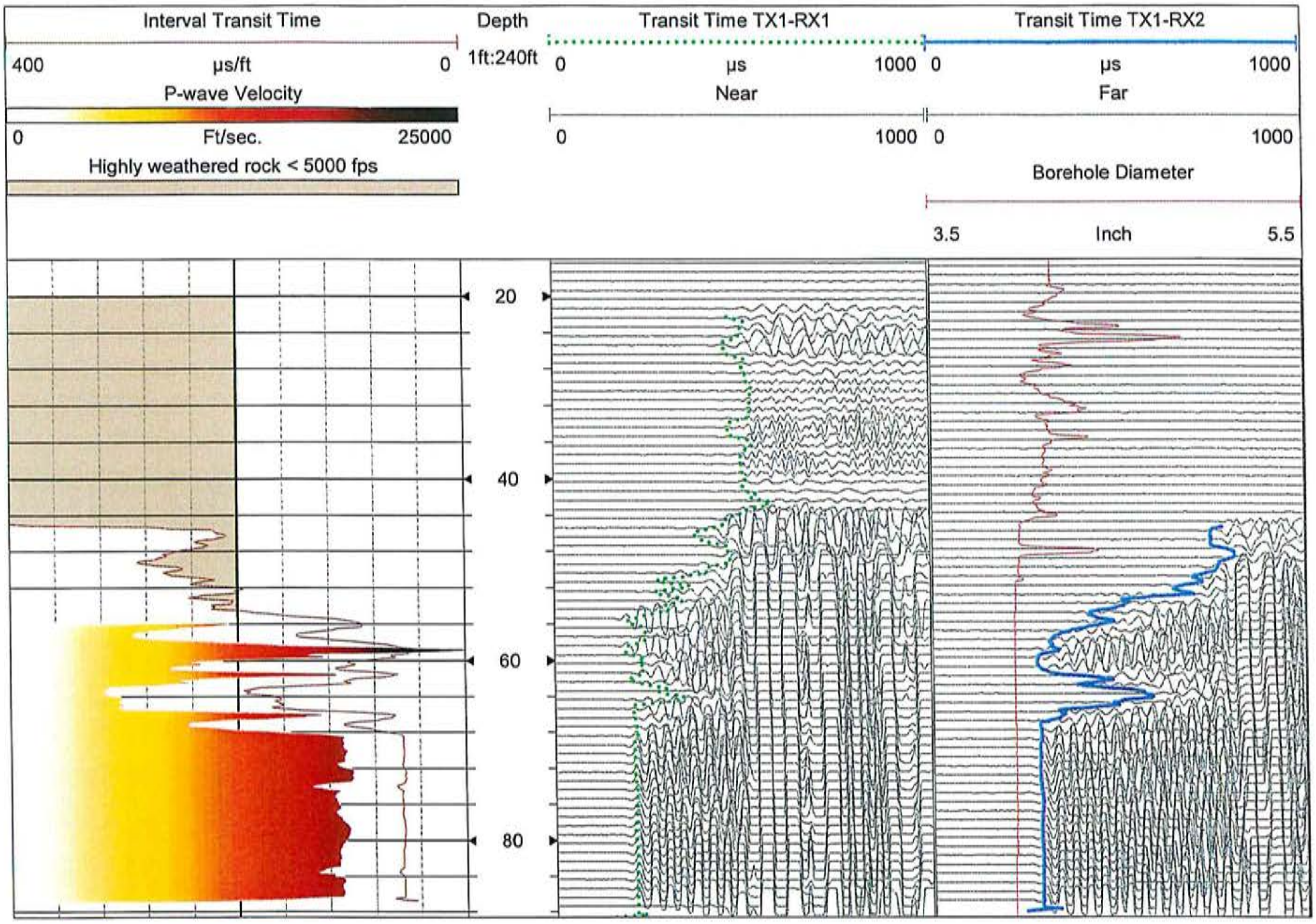
NORCAL GEOPHYSICAL CONSULTANTS, INC.	Fullwave Sonic Log	COMPANY: AECOM WELL ID: CB-B3 FIELD: South Borrow Area COUNTY: Nevada	DATE: June 11 2016 CASING: 4.5" steel to 10 ft JOB NO. NS165019A STATE: CA

NOTES: run-1



NORCAL GEOPHYSICAL CONSULTANTS, INC.	SONIC FULL WAVEFORM LOG	COMPANY: AECOM WELL ID: CB-B4 FIELD: South Borrow Area COUNTY: NEVADA	DATE: JUNE 9, 2016 CASING: HWT CASING to 9 ft JOB NO. NS165019A STATE: CA

NOTES: Run-2 Add water to borehole



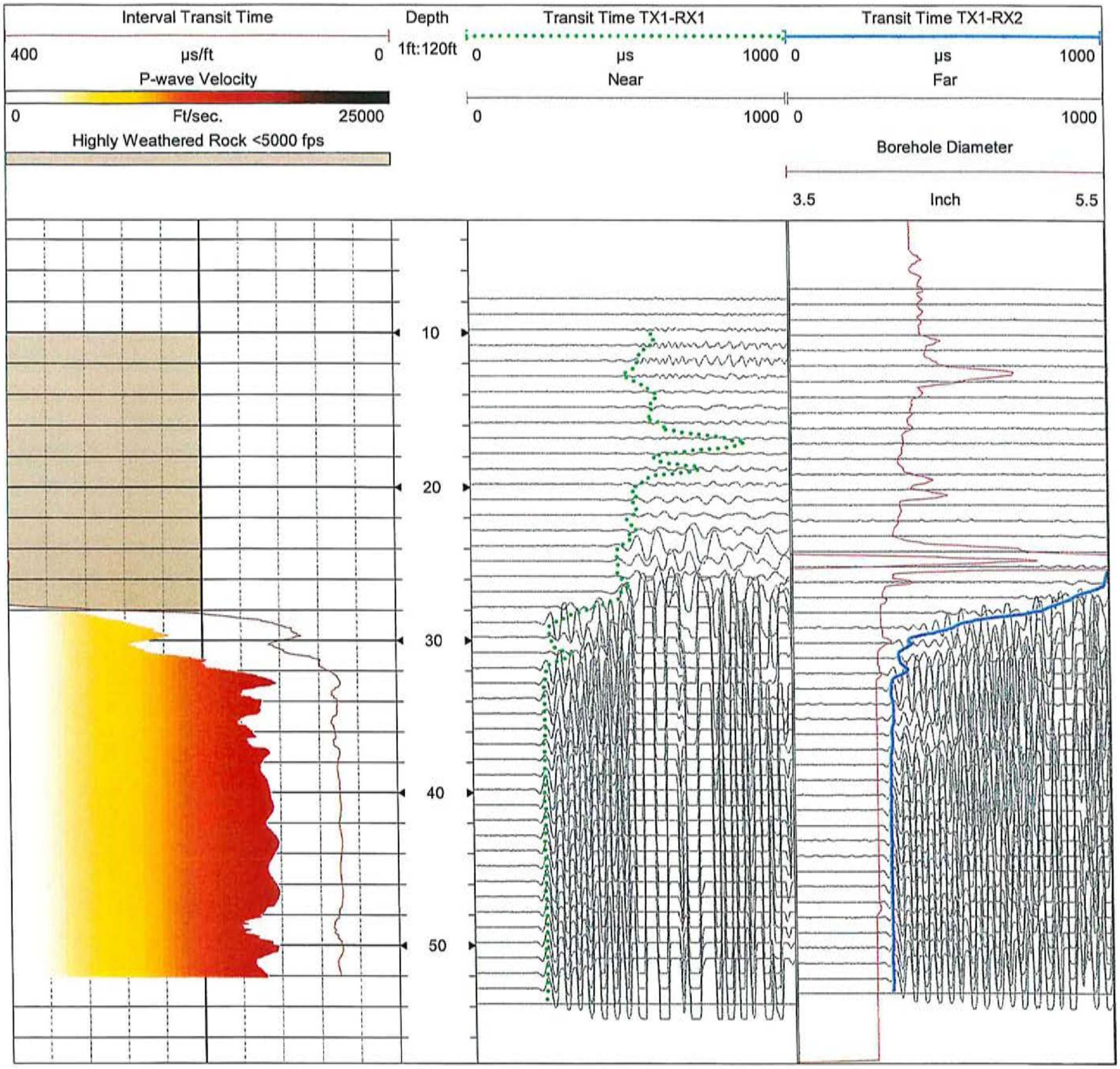
NORCAL

NORCAL GEOPHYSICAL CONSULTANTS, INC.

Fullwave Sonic Log

COMPANY:	AECOM	DATE:	June 25, 2016
WELL ID:	CB-B6	CASING:	4.5 in. diam steel to 5 ft
FIELD:	North Borrow Area	JOB NO.	NS165019A
COUNTY:	Nevada	STATE:	CA

NOTES:



NORCAL GEOPHYSICAL CONSULTANTS, INC.

Fullwave Sonic Log

COMPANY: AECOM
WELL ID: CB-B7
FIELD: North Borrow Area
COUNTY: Nevada

DATE: June 28, 2016
CASING: 4.5" steel to 3 ft.
JOB NO. 165019A
STATE: CA

NOTES: