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January 3, 2008 Our ref: 043-1213.000

Washington State Department of Transportation
Environmental and Engineering Programs, Material Laboratory
PO Box 47365
Olympia, Washington 98504-7365

Attention: Mike Mulhern

RE: REVISION TO THE GEOPHYSICAL SURVEY REPORT FOR THE HIGHWAY 20-QUIET COVE ROAD PROJECT, ANACORTES, WASHINGTON.

Dear Mr. Mulhern:

On July 6 and 7, 2004, Golder Associates Inc. (Golder) conducted a geophysical survey near MP 46 on Highway 20 near Anacortes, Washington. The objective of the investigation was to map the top of the bedrock along proposed road cuts that will be made to either side of the highway. This report is a revision of the preliminary draft report that was submitted in August 2004. The revisions to the interpretations are based on borehole data that were obtained by WSDOT in October 2007.

The geophysical investigation used a combination of ground penetrating radar (GPR) and seismic refraction to attempt to meet the project objective. Borehole information showing the depth to the top of bedrock was provided by WSDOT to assist in interpreting the geophysical data.

INSTRUMENTATION AND METHODOLOGY

Ground Penetrating Radar (GPR)

A GSSI SIR-2000 ground penetrating radar system, using a 400 and 200 MHz antenna, was used for this investigation. Ground penetrating radar uses electromagnetic waves to image subsurface geology and stratigraphy. An antenna that is pulled along the ground continuously transmits electromagnetic pulses into the subsurface. The pulses are reflected at soil/bedrock boundaries, from underground utilities, or from discrete objects such as boulders, etc. The reflected pulses are received by the antenna, processed, stored digitally and displayed on an LCD monitor or thermal paper printout. The image represents a cross-sectional view of the subsurface stratigraphy along the survey transects. The depth of subsurface penetration is a function of the material, but typically ranges from 10 to 50 feet. Sand and gravel provides the best subsurface penetration. Silt and clay size materials are electrically conductive and essentially short-circuit the signal resulting in poor subsurface penetration.

Seismic Refraction
The seismic refraction survey was conducted using a Geometric Geode 24-channel digital seismograph and Mark Products 8-Hz vertical geophones. The acoustic energy source used was a sledgehammer.

The seismic refraction method uses seismic waves introduced into the ground by an explosive or weight-drop source. As the seismic wave propagates through the earth, its direction and speed are changed or refracted as it passes through soil and rock. Geophones, placed at selected intervals along the ground surface, detect the ground motion and send an electrical signal, via a cable, to the seismograph. The seismograph digitizes, amplifies, filters and records the incoming signals. Analysis of the arrival times of the refracted wave fronts provides a means for determining the seismic velocity and modeling depths to subsurface layers.

FIELD PROCEDURES

Site Preparation and Stationing
WSDOT installed stakes at approximately 100-foot intervals from Station 126+00 to 132+75. Golder personal cleared brush along two transects (Line 1 on the north and Line 2 on the south) located near these stakes to conduct the geophysical survey (Figure 1). Pin flags and flagging tape were used to mark stationing along the cleared pathways at 25-foot intervals. Field notes were taken to record the offsets in stationing between the two positioning systems. WSDOT surveyed the x, y, z position of each pin flag and this information was used to map the actual transect location.

Ground Penetrating Radar
The GPR system was tested using the 200 and 400-MHz frequency antennas. The lower frequency antenna (200-MHz) produced the best results and was used for the investigation. The GPR profiles were collected along the cleared pathways and fiducial marks were entered into the data files at 25-foot intervals.

Seismic Refraction
Seismic refraction data were collected on Line 2 from approximately Station 130+93 to 133+38 which is an area where bedrock, based on field interpretation of the GPR data, appeared to be located deeper. The seismic refraction data were collected using 24-geophones spaced at 10-foot intervals. A sledgehammer was used as the seismic source.

Probing
Along both transects a metal bar was driven into the ground to refusal. A qualitative description of the nature of the refusal was noted (gravel, woody debris, bedrock etc.). This information was intended to be used to assist in interpreting the GPR data but proved to be unreliable since it was not possible to differentiate between bedrock, weathered bedrock and boulders.

RESULTS

Ground Penetrating Radar Results
The interpreted results of the GPR data suggests that the top of bedrock is located at variable depths on both transects. The ability to easily identify the contact between the alluvium and the top of bedrock was often very difficult because of attenuation and scatter of the radar signal (Figure 2).

On Line 1 , the transect located on the north side of Highway 20, the depth to the top of bedrock is quite variable ranging in depth from 2 to 18 feet below ground surface (Figure 1). The exception is between Stations 127+50 and 129+40 where the top of bedrock could not be identified on the geophysical data or in borehole H-21-07 which went to a depth of 16.5 feet. There may be a more conductive soil horizon in this area resulting in relatively high attenuation of the radar signal. The attenuation may be associated with an increase in conductivity (decrease in resistance) which would result from an increase in fine-grained sediment and/or water content. In addition, the highly irregular and weathered bedrock surface scattered the radar signal and consequently was a relatively poor reflector.

On Line 2, the transect located on the southeast side of the highway, subsurface penetration was somewhat better than on line one with the exception of the area in the vicinity of BH H-2-07. The depth to the top of bedrock is interpreted to be less than 1 foot near Station 125+00 and increases to approximately 13 feet at the north end of the line (Figure 1).

The photo in Figure 3 is a view of Line 1 in the immediate vicinity of Station 131+00. The top of bedrock, based on visual evidence and the GPR data, is highlighted with an orange line on the photograph.

Seismic Refraction Results

The interpreted results from the seismic refraction data suggests that the top of bedrock, between Stations 131+00 and 132+50, varies from approximately 9 to 18-feet below ground surface (Figure 4). The irregular surface, and weathering, made it difficult to clearly identify the first breaks. The seismic velocity of bedrock averaged around 16,000 feet per second and the compressional velocity of the overlying alluvium was approximately 1,500 feet per second.

Probing Results

Probing was conducted at selected locations to obtain information for assisting in interpreting the GPR data. The results from the probing provided a minimum possible depth to bedrock as the probe most likely met refusal on boulders, buried wood (logs-roots), debris or unknown hard contact other than the top of bedrock.

Based on the borehole and refraction data, as well as visual observation of the top of bedrock along the road cut, it was concluded that the probe measurements did not provide reliable calibration information.

SUMMARY

The geophysical and probing data, direct observation along the existing road cut and borehole data indicates that the top of bedrock ranges from surface exposure outcrops to a maximum depth of 20 feet. The GPR signal was highly attenuated in several areas along the two transects and in these areas the top of bedrock is inferred. In one area on the north line, in the vicinity of borehole H-21-07, top of bedrock was not detected by any of the investigation methods.

LIMITATIONS OF THE GEOPHYSICAL METHODS

Golder services were conducted in a manner consistent with the level of care and skill ordinarily exercised by other members of the geophysical community currently practicing under similar conditions subject to the time limits and financial and physical constraints applicable to the services.

Seismic refraction and ground penetrating radar are remote sensing geophysical methods that may not detect all subsurface changes in geology. Furthermore, it is possible that interpreted stratigraphic or geologic contacts may upon intrusive sampling prove to have been misinterpreted. Where interpretation from geophysical data is an important element for cost or safety of operations, it should always be checked for reasonableness against known or expected subsurface data, and verified at critical locations by physical means.

CLOSURE

Please contact the undersigned with any questions you have about this report.

Sincerely,

GOLDER ASSOCIATES INC.

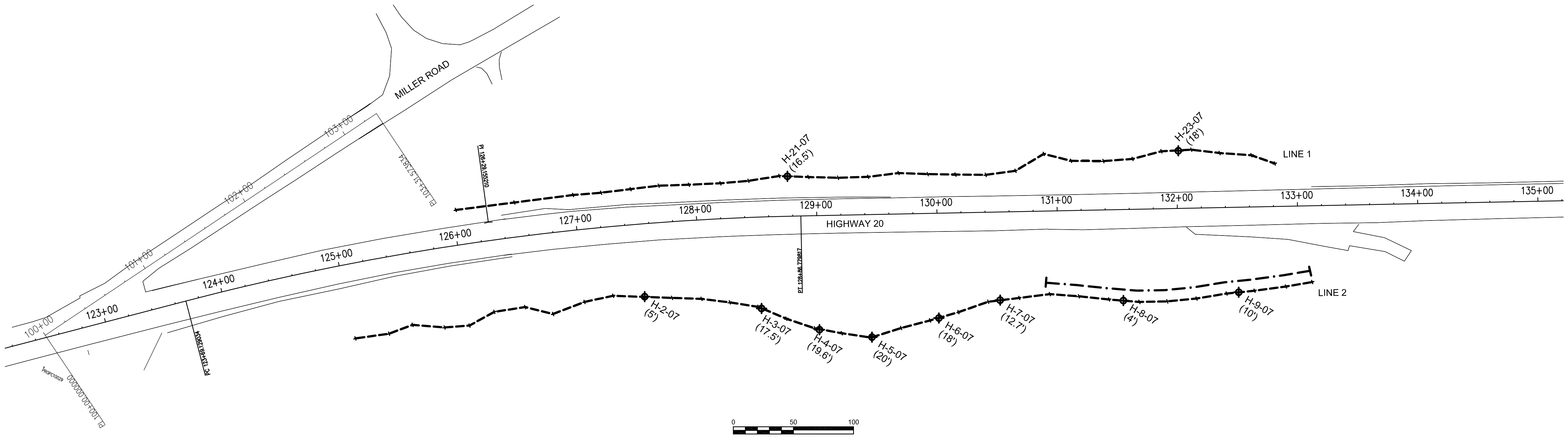
David Hrutfiord
Project Geophysicist

Dick Sylwester
Associate Geophysics

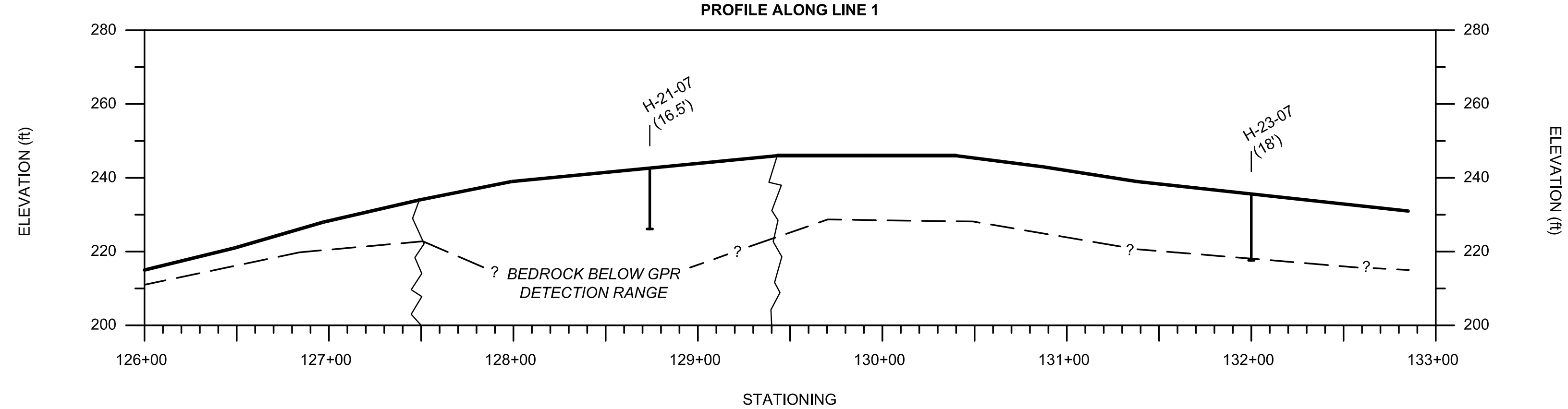
Attachments: Figures 1-4

DH/RES/sb

FIGURES

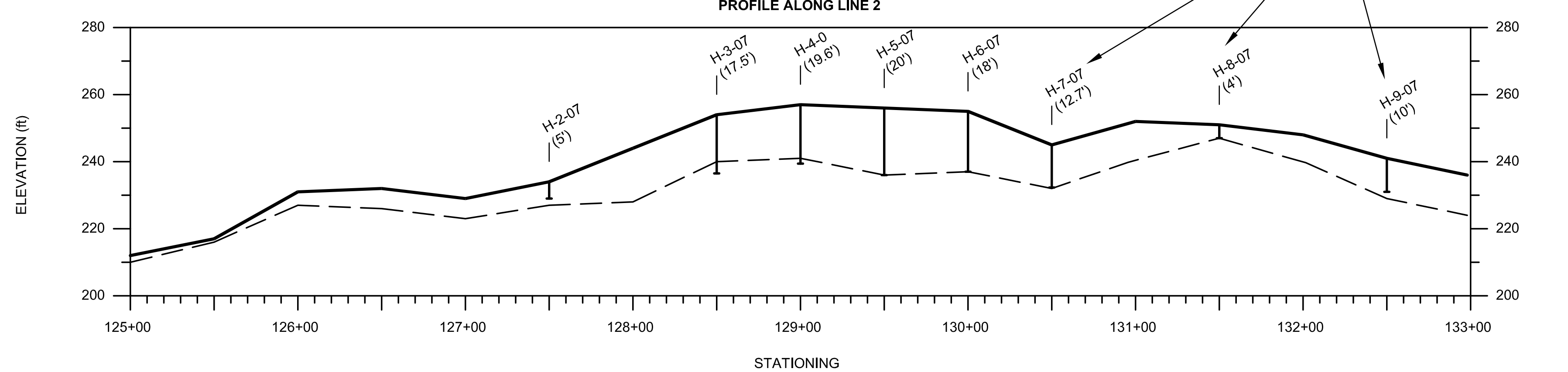


PROFILE ALONG LINE 1



BOREHOLE DATA UN-VERIFIED

PROFILE ALONG LINE 2



KEY MAP

LEGEND

- GPR SURVEY LINE
- SEISMIC REFRACTION LINE
- GROUND SURFACE
- INTERPRETED TOP OF BEDROCK
- H-9-07 (10') WSDOT BOREHOLE LOCATION AND DEPTH

NOTES

1. BASE MAP PROVIDED BY WSDOT. JULY 2007

GEODETIC PARAMETERS

VERT. DATUM: MSL
HORIZ. DATUM: LOCAL STATIONS

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SUBMITTED TO:

Washington State Department of Transportation

PROJECT:

WSDOT/Quiet Cove Rd Geophysical/WA

TITLE:

INTERPRETED GEOPHYSICAL PROFILE AND BOREHOLE LOCATIONS

REV	DATE	REVISION DESCRIPTION	SIGNED
–	–	–	–

PROJECT No.		043–1213.000
FILE No.		0431213000F02
REV. 0	SCALE	AS SHOWN
DESIGN	–	–
CADD	ACF	11–01–07
CHECK	DH	11–01–07
REVIEW	DH	11–01–07

FIGURE 1

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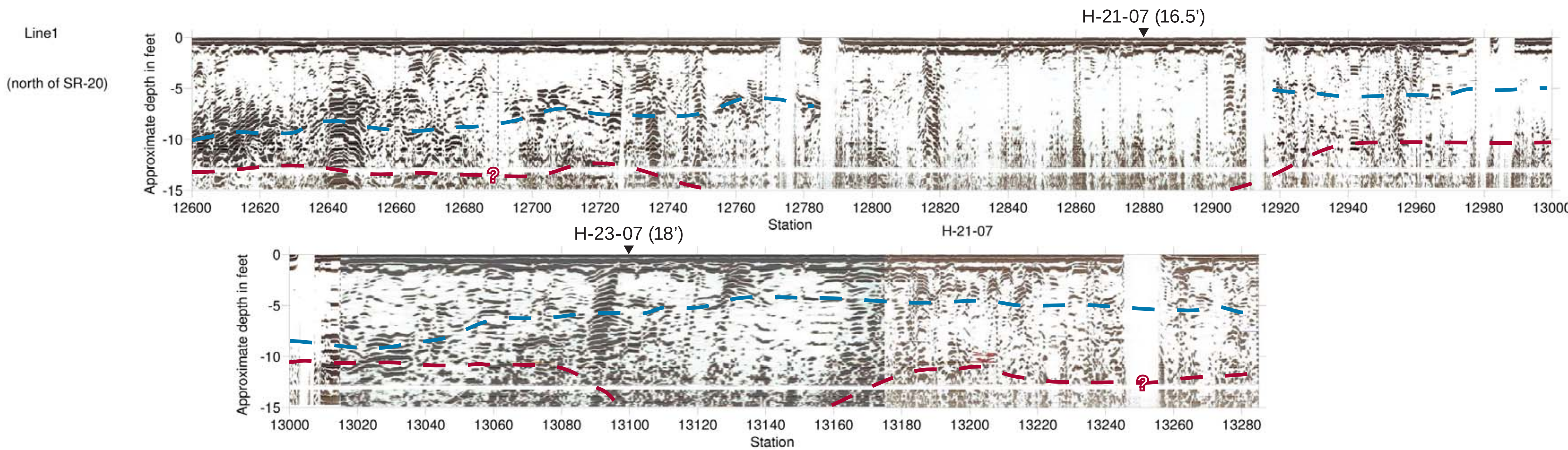

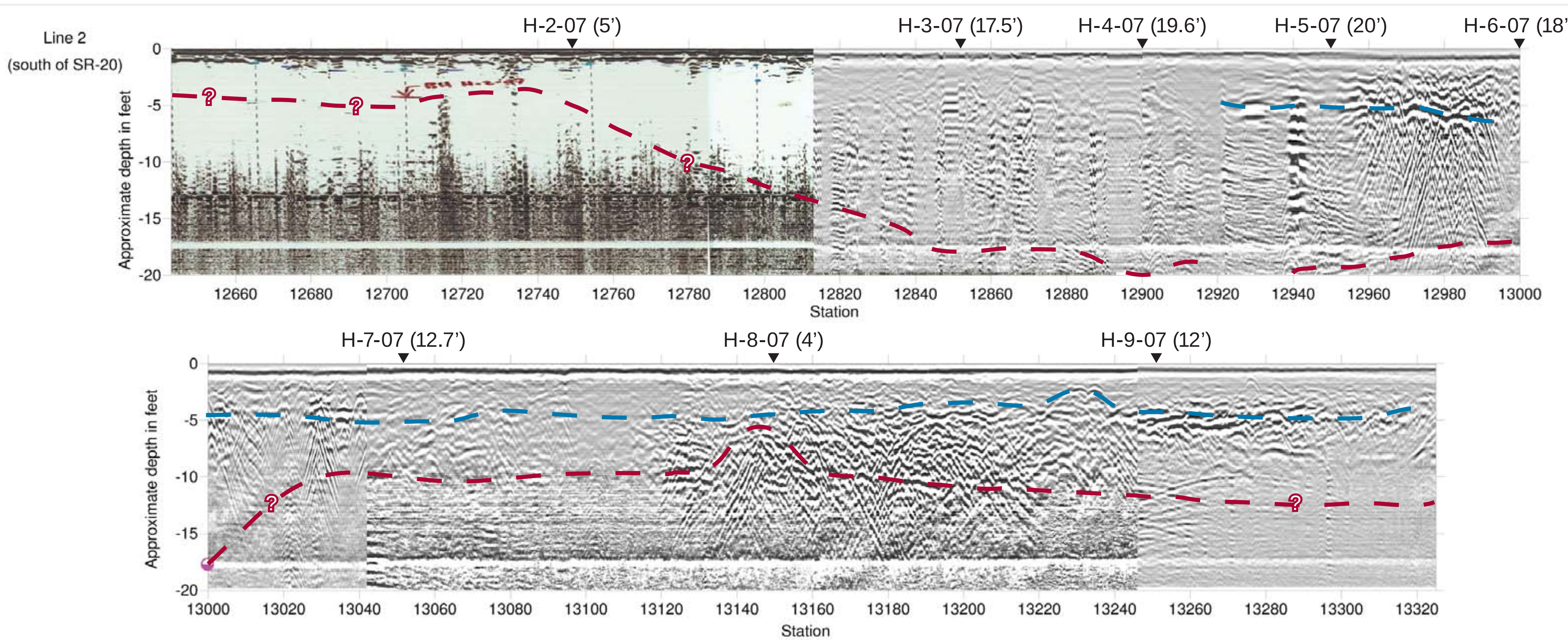

KEY MAP

LEGEND

- WSDOT BOREHOLE LOCATION AND DEPTH
- INTERPRETED TOP OF BEDROCK BASED ON GPR DATA
- TOP OF BEDROCK UNCERTAIN
- WEATHERED ROCK, BOULDERS, COBBLE

INSTRUMENTATION

GSSI SIR 8 GPR

GSSI SIR 2 GPR

10 MH3 ANTENNA

GEODETIC PARAMETERS

VERT. DATUM: MSL

HORIZ. DATUM: LOCAL STATIONS

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Washington State Department of Transportation

PROJECT:

WSDOT/QUITE COVE RD GEOPHYSICAL/WA

TITLE:

INTERPRETED GPR PROFILE AND BOREHOLE LOCATION

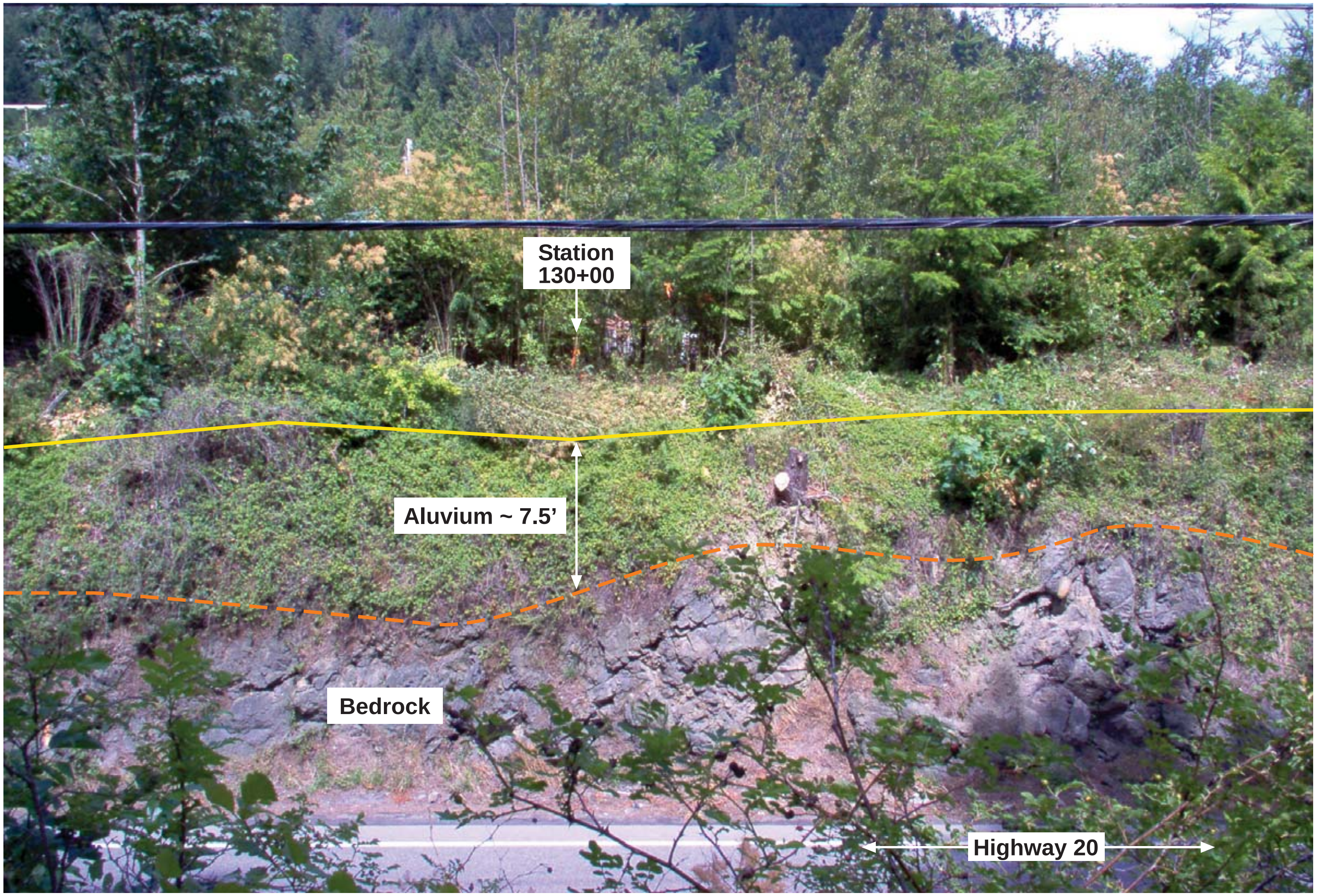
PROJECT	043-1213.000	DESIGN	XXX	-
FILE No.	0431213000fg02.ai	GPHX	AMP	-
REV.	0	CHECK	XXX	-
SCALE	AS SHOWN	REVIEW	XXX	-

FIGURE 2

0431213000fg02.ai

Southwest

Northeast



LEGEND

- - Approximate Location of Top of Bedrock

— Top of Bank

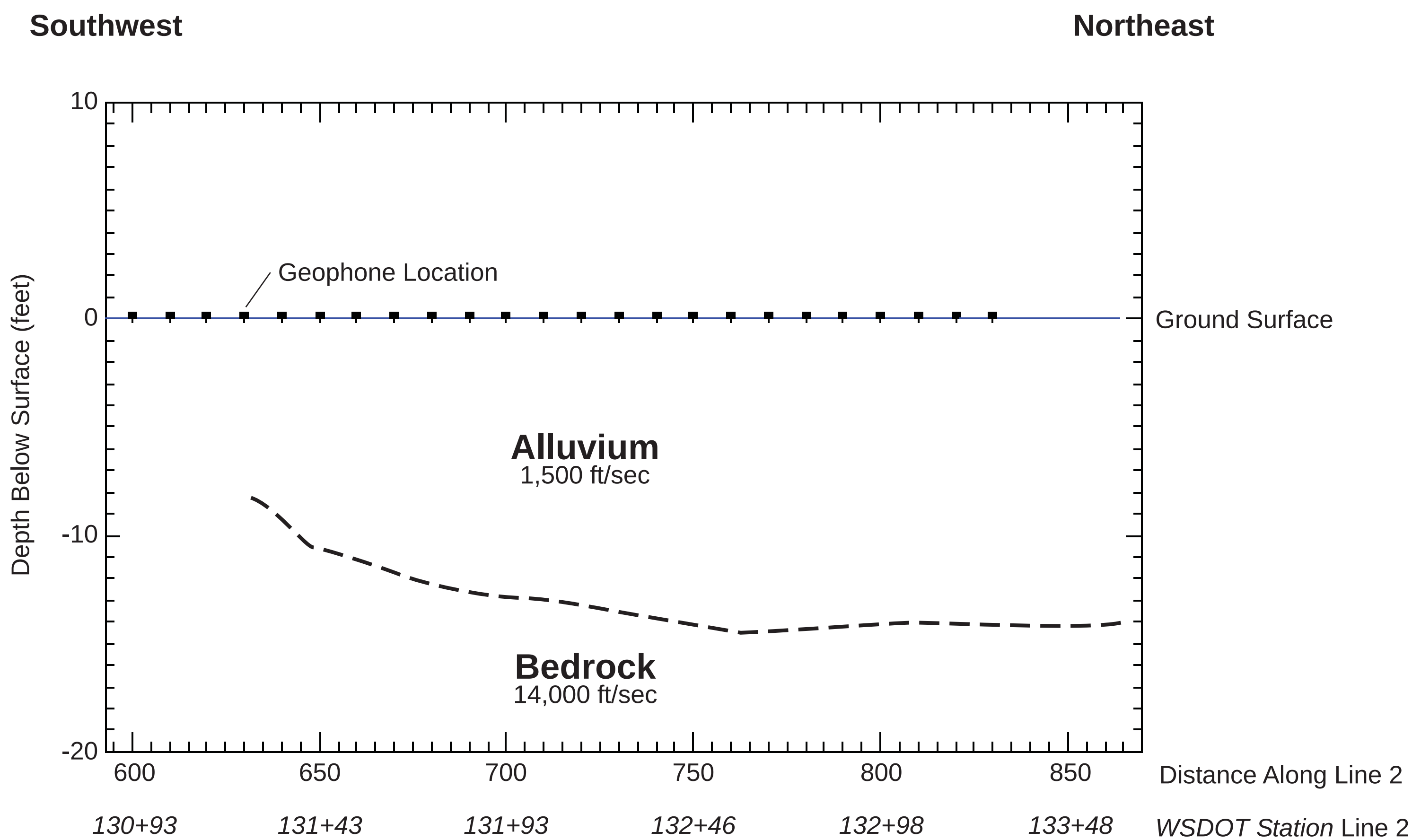
FIGURE 3

PHOTO LOOKING NORTHWEST TOWARDS LINE 1

WSDOT/QUITE COVE RD GEOPHYSICAL/WA

0431213000fg03_R1.ai DATE 11/29/07 DRAWN BY AMP

Golder Associates



See Figure 1 for line location

FIGURE 4

INTERPRETED SEISMIC REFRACTION PROFILE

WSDOT/QUITE COVE RD GEOPHYSICAL/WA