SEISMIC REFRACTION SURVEY REPORT

MASHEL RIVER RESTORATION PROJECT
PIERCE COUNTY, WASHINGTON

FOR

HERRERA ENVIRONMENTAL CONSULTANTS, INC.
SEATTLE, WASHINGTON

JULY 22, 2016

PHILIP H. DUOOS
GEOPHYSICAL CONSULTANT

July 22, 2016 Our Ref: 1185-16

Mr. Brian Scott
Herrera Environmental Consultants, Inc.
2200 Sixth Avenue, Suite 1100
Seattle, WA 98121

REPORT: Seismic Refraction Survey
Mashel River Restoration Project
Pierce County, Washington

Dear Mr. Scott:

This letter report provides the results of the seismic refraction survey that was performed at the Mashel River Site in the vicinity of the proposed Engineered Log Jams (ELJ). One seismic line was also located on the landslide area. The field work was performed during the period of May 30 – June 4, 2016. Preliminary interpretation results were provided to you on June 27. These final results have not changed, although the profiles have some changes such as the scale and nomenclature.

Five seismic lines were surveyed (SL-1, 2, 3, 5 and 6). Proposed seismic line SL-4 was not performed due to time and budget restraints. Ground penetrating radar (GPR) data were recorded along most of SL-2 and all of SL-3 to provide some additional information which was used to help interpret the seismic data. A brief description of the GPR and seismic refraction method is attached.

Map 1 shows the five seismic lines in black with blue labels. The ELJ locations are shown by a yellow dot and were located based on the map coordinates provided by Herrera. The seismic lines were referenced to nearby trees, the bend in the river (SL-6), and the large log to the north of SL-1. The two tree trunks near SL-2/SL-3 and SL-5 are indicated by the white circles. The lines were laid out with 300-foot tape measures and a Brunton compass. The marked locations are estimated to be within ten feet of the actual locations. Wire pin flags were used to mark each geophone location in the field. Two to three geophone locations along each line (usually at each end and near the middle) were also marked with wood stakes to provide a more permanent reference. On the Tweet property, west of the Little Mashel River, the wire pin flags were removed upon completion of the survey as that area was used for grazing.

Interpretation Results

The results of the seismic survey are shown on the interpretation profiles. The profiles show the geophone locations along the ground surface, the calculated depth points below each geophone, and the interpreted interfaces (dashed lines). The relative change in elevation between geophone locations were measured using a hand level, and referenced to an approximate elevation at some point along each line using Google Earth.

Results from intersecting seismic lines (red circles) are noted, as well as visual outcrops of claystone. The approximate location and offset of the ELJ locations are also shown. The interpreted compressional wave velocity range of the various seismic layers are provided for each profile.

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The profiles are not to scale, and the scales may vary between lines due to the variation in line length and elevation change. For seismic lines SL-2 and SL-3 I have included two profiles for both lines. One profile shows just the depth to the L2 interface, and the second profile includes the much deeper BX-High interface.

In addition to the profiles, a Table of Results (Table 2) is attached which shows the interpreted layer thicknesses that are in proximity to the proposed ELJ locations. The table also shows the estimated thickness of possible highly weathered claystone based on the seismic results over nearby claystone outcrops. These are very rough estimates. At the downstream end of SL-3 the claystone is interpreted as moderately competent based on the shallow nearby outcrop. Therefore, for SL-2 and SL-3, the claystone is interpreted as moderately competent below the entire line. However, it is also very possible that a thin layer (1 to 3 feet thick) of highly weathered claystone is present at other locations along the lines.

The basic geologic units were identified based on the interpreted compressional wave velocities (in feet/second), the site-specific information (outcrops and literature), and results from other seismic surveys I have performed in the region. Their probable classification is indicated on the following table.

TABLE 1
Seismic Velocity Classifications

SYMBOL	SEISMIC VELOCITY (feet per second)	PROBABLE CLASSIFICATION
L1	1,000 - 2,300	Unconsolidated wet/dry alluvium, highly weathered claystone (wet/dry).
L2-Low	3,900 - 4,200	Weathered claystone, fractured claystone, or former river channel filled with more consolidated alluvium.
L2	5,000 - 6,700	Moderately competent claystone, possibly water-saturated materials including alluvium.
L2-High	7,400 - 7,700	More competent claystone or possible siltstone or sandstone.
Bx - High	10,000 – 13,500	Very competent bedrock – possibly sandstone.

A more detailed discussion of the various seismic velocity layers follows.

Layer L1: 1,000 to 2,300 feet/sec

Layer L1 is interpreted as loose overburden materials or highly weathered claystone or siltstone. These low velocities are observed in areas with dry sandy, gravel, cobble soils; in areas that are water-saturated; and in areas with visible claystone outcrop.

In several areas with claystone outcrop, the upper few feet of claystone shows the lower L1 velocities, indicating the claystone is probably highly weathered for a few feet. On SL-1, the upper 3.5 feet or so of claystone is interpreted to be highly weathered. At SL-5 the weathered zone is about 2 feet thick, and at the downhill end of SL-6 the weathered zone is estimated to be about 3 feet thick. However, the claystone contact was not as visible to the eye on SL-6, so this is a rough estimate.

At the downstream end of SL-2, the approximate top of the claystone outcrop is visible in the river bank about 6 feet below SL-2, Geophone 1. The seismic data shows a thickness of about 5.1 feet for the L1 layer, so the claystone in this area is not interpreted to have much, if any, weathering.

Layer L2: 5,000 to 6,700 feet/sec.

Based on the seismic velocities alone, the 5,000 to 5,500 fps range could be water-saturated alluvium (sand, gravel, cobbles, and boulders) or it could be wet or dry claystone. The claystone may or may not be fractured or weathered with these velocities. According to the Caterpillar Rippability Charts (attached), claystone with seismic wave velocities of 4,900 to 5,700 fps are marginally rippable with a D7G Ripper. I imagine that a track hoe excavator would be much less capable than even a small bulldozer however. I'm not sure how they compare though, perhaps discussions with a good equipment operator would provide some answers.

While they are not conclusive, there are several indications that the L2 layer in the 5,000 to 5,500 fps range is probably claystone:

1) Lower seismic velocities (1,000 to 2,300 fps) are observed in areas with visible water-saturated alluvium.

2) The L2 layer has an irregular upper interface in many areas – if the L2 layer was primarily indicating water-saturated materials, one would anticipate a smoother interface (the "water table").

3) The top of the L2 layer correlates fairly well with the visible claystone outcrops at the site.

4) I was able to gather ground penetrating radar data along much of line SL-2 and all of SL-3. The GPR data indicates a reflective layer and then a loss of signal below this layer. This is typical of encountering fine-grained sediments or bedrock, and would be typical of encountering the top of the claystone (weathered or competent). The interpreted GPR depths of this reflective layer are very similar to the depths interpreted from the seismic data for Layer L2. If the seismic L2 Layer was water-saturated alluvium I would expect much deeper penetration of the GPR signal.

Due to the many variables present in any type of geophysical method, it is always best to have some type of ground-truthing (borings, test pits, etc.) to help confirm the geophysical interpretation. Ground-truthing at this site would be especially helpful due to the possibility that the moderately competent claystone and water-saturated alluvium may have similar seismic velocities. Some ELJ locations have a very shallow interpreted depth to moderately competent claystone which perhaps could be evaluated further with limited intrusive activities.

Layer L2-Low: 3,900 to 4,200 feet/sec.

These velocities were observed below SL-6 (Landslide). These lower velocities may indicate highly weathered or fractured claystone. Fractured claystone will have a lower velocity than more competent claystone (interpreted as the L2 layer). The refracted wave is traveling laterally across the top of this layer and extends to some limited depth into the layer. So while we can determine that this zone has lower-velocity materials, it is not possible to tell how steep the dip of a possible fracture zone is, or which way it is dipping.

This zone could also be caused by a channel with steeply dipping sides and filled in with material that has a lower velocity than the probable moderately competent claystone (Layer L2). It could perhaps be an old channel of the river filled in with course alluvium (gravels, cobbles, and boulders) or larger landslide debris.

Layer L2–High: 7,400 to 7,700 feet/sec.

These higher velocities may indicate more competent claystone, or perhaps a different type of material such as a siltstone or sandstone.

Layer Bx-High: 10,000 to 13,500 feet/sec.

This high velocity layer was observed at depth on Lines SL-2 and SL-3, and also at the upstream end of SL-5 (near ELJ 2-1). The approximate layer interface is shown. At SL-2 and SL-3 it is queried due to the fairly greater depth and the incomplete data from these depths (greater than 40 feet). These higher velocities may indicate a very competent sandstone or perhaps even metamorphic rock of some type.

At the upstream end of SL-5 (near ELJ 2-1) there is probable shallow bedrock that slopes steeply downstream. Because of the interpreted steep slope, and the location at the end of the line (observed on only the last eight geophones or so) it is difficult to determine the configuration of this zone. It does seem to be very shallow however.

Methodology

The seismic lines used geophone spacings ranging from 7 to 11 feet, and ranged in length from 150 to 500 feet. The field investigation was performed using a 48-channel digital seismograph to record the data. A slide-hammer source was used to generate a seismic wave at numerous locations along each line (40 to 100 foot intervals), and off the ends of each spread.

Field analysis of the data was done using manual calculations to determine that the seismic energy was refracting from bedrock, and to determine the required distance of the off-end shots so that the deeper layers could be imaged properly. Preliminary modeling of some of the data was performed in the evening as a check on the field data.

The final interpretation of the data was performed using a commercially available software package (SIP Win by Rimrock Geophysics). This software requires significant input from the user regarding velocity layer assignments. In addition, hand analysis of the data was also performed which provides a better estimate on the layer velocities than the computer model provides. These manually derived velocities were then used in the computer model. Additionally, hand-calculated depths using the manual data plots were used in numerous locations to confirm the computer modeling results.

Summary

The use of the seismic refraction method provided a relatively rapid and detailed means of determining the subsurface conditions. While the accuracy of the seismic interpretation depends on site-specific conditions, geophysical methods in general provide an accuracy of +/- 10% under good conditions. The data recorded from the site were typically of good quality due to the lack of wind noise and quiet conditions (no vehicle noise, etc.). Some degradation in signal quality at some geophone locations in or near the water was observed, but the data was still usable. Extreme changes in surface topography or the slope of subsurface interfaces will affect the accuracy.

As with any geophysical technique, these seismic results are interpretive in nature and represent the best estimate of subsurface conditions considering the limitations of the geophysical method employed. Only direct observations using borings or other means can ultimately characterize subsurface conditions, using the geophysical results as a guide. Review of this information by someone familiar with the geology of the area may also provide additional insight into the seismic results.

Please feel free to contact me if you have any questions or comments regarding this information, or if you require further assistance. I appreciated the opportunity to work with you on this project and look forward to providing you with geophysical services in the future.

Sincerely,

Philip H. Duoos
Geophysical Consultant

State of Washington
561
Licensed Geologist
Philip H. Duoos

ATTACHMENTS

Seismic Refraction Description
Ground Penetrating Radar Description
Caterpillar Rippability Charts

MAP 1, Seismic Survey Location Map
TABLE 2, Interpreted Layers Near ELJ Locations
SEISMIC VELOCITY PROFILES, SL-1, 2, 3, 5 and 6

SEISMIC REFRACTION METHODOLOGY

Overview

The seismic refraction method is used to evaluate numerous subsurface conditions; including depth to and strength (rippability) of rock, depth to water, and general subsurface stratigraphy.

The seismic refraction method uses an induced shock wave. As the shock wave propagates through the earth, it is affected by the materials through which it passes. Geophones placed on the ground surface record the ground motion caused by the resultant wave. A seismograph measures the time required for the resultant wave to arrive at each geophone. These geophones are located at selected distances from the wave source. Analysis of the data (travel times and distances) provides seismic velocities of subsurface material and depths to significant velocity interfaces.

Geologic conditions yielding higher seismic velocities include increased amounts of water, clay, cobbles, and rock fragments, greater compaction of overburden materials, and greater competency of rock. Several factors can affect the effectiveness of the seismic method including the proximity of cultural interferences (such as powerlines and traffic noise), surface conditions (such as loose soil), the size and depth of the target, and the seismic wave velocity contrast between stratigraphic units. Seismic velocities must increase with depth for a reliable interpretation of the data.

Calculations

The description of the travel of seismic refraction waves through the earth uses the same equation that describes the refraction of light: Snell's Law. The following is a brief summary of the basic theory for a simple two-layer geologic model as discussed by Redpath (Redpath, 1973).

Snell's Law is stated as:

$$\frac{SIN\alpha}{SIN\beta} = \frac{V_1}{V_2}$$

and at the critical angle of incidence for a refracted seismic wave (β=90°), it becomes:

$$SIN\alpha = \frac{V_1}{V_2}$$

where V_1 and V_2 are the seismic wave velocities for the upper and lower layers, respectively.

The seismic refraction method measures the amount of time it takes the seismic energy to travel from the energy source to the geophones placed along the ground surface. The arrival time for the seismic wave at each geophone is plotted corresponding to the distance of the geophone from the energy source, creating a time-distance graph (Figure 1).

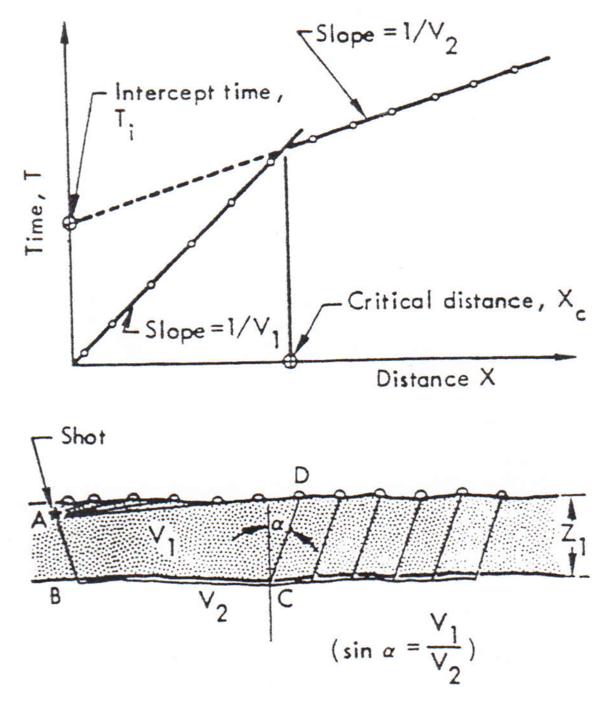


Figure 1: Two-layer geologic model and associated time-distance graph (Redpath, 1973).

The time required for the energy to reach the geophones near the source (direct wave arrivals) is based only on the seismic velocity of the energy traveling though the upper (low velocity) layer. At a certain distance from the source, called the critical distance, the first seismic waves to reach the geophones will be those that have refracted from a deeper, higher velocity layer. Although these waves have traveled a greater distance than the direct waves, they have traveled at a greater velocity over most of their path, and thus arrive before the slower direct arrivals to the geophones farther from the source. Successively deeper layers with higher velocities affect the time-distance graph in a similar manner.

Using the time-distance graph, the velocities of the layers can be calculated (based on the slope of the arrival times), and the layer thicknesses can be calculated using the intercept times. The equation used in the time-intercept method to determine thicknesses is:

$$Z_1 = \frac{T_1 V_1}{2COS(SIN^{-1} V_1 / V_2)} + \frac{\text{SHOT DEPTH}}{2};$$

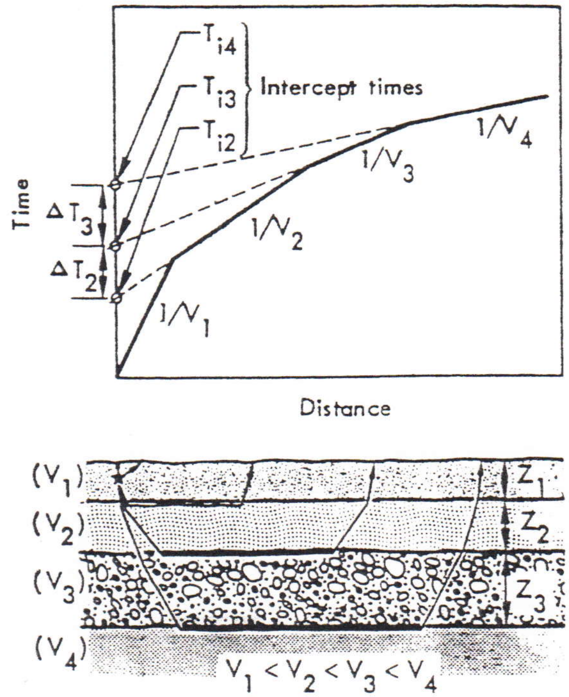


Figure 2: Multiple layer geologic model and associated time-distance graph (Redpath, 1973).

Figure 2 is a sketch of a multiple layer case and the corresponding time distance curve showing the intercept times.

For more complex geologic models, as is usually observed, additional energy source locations are required at both ends of a seismic line as was done for this survey. The layer velocities are calculated using the data from all of the time-distance curves (delay-time method).

Limitations

Two types of geologic conditions can cause a *hidden zone* problem. One type of hidden zone is a layer with a lower velocity than the layer above it. Energy approaching the layer at the critical angle will pass through the layer, and will not be refracted back to the surface until it encounters a deeper layer with a higher velocity, so no first arrivals are observed from the low-velocity layer. The presence of an unknown low-velocity layer will cause the calculated depths to be greater than the actual depths.

The other type of hidden zone is a layer with a greater velocity than the layer above it, but one that is too thin and/or does not have a large enough velocity contrast. The effect of a thin layer will cause the calculated depths to be shallower than the actual depths.

In areas with hidden zones, the amount of error can be determined based on direct observations (such as test pits or boreholes), and can be compensated for over the rest of the seismic lines.

References

Redpath, Bruce B. (1973). "Seismic Refraction Exploration for Engineering Site Investigations." *Technical Report E-73-4*, U.S. Army Engineer Waterways Experiment Station Explosive Excavation Research Laboratory, Livermore, California.

DESCRIPTION OF METHOD

GROUND PENETRATING RADAR

Some of the uses of GPR include locating buried tanks and drums, delineating boundaries of landfills and trenches, and defining voids and geologic stratigraphy. Although other techniques can also provide this information, GPR is less affected by cultural interferences such as overhead powerlines, buildings, and fences. GPR can also provide higher resolution of the target in many cases.

The antenna can either be moved manually by an operator or towed by a vehicle. Depths of exploration can vary widely, from less than a few feet in water-saturated clayey materials to hundreds of feet in glacial ice. A variety of antennas (ranging from 16 MHz to 2 GHz) can be used depending on subsurface conditions and the objective of the survey. Resolution of shallow objects requires higher frequencies, while lower frequencies work better for deeper investigations.

Several factors can affect the effectiveness of the GPR method including reinforced concrete at the surface, the presence of highly conductive materials (such as clays and water), the size, depth, and physical property of the target and; in stratigraphic investigations, the conductivity contrast between stratigraphic units. The presence of numerous buried objects may mask objects and/or stratigraphy below them. While the accuracy of the interpretation depends on site-specific conditions, geophysical methods in general provide an accuracy of +/- 10%.

USE OF SEISMIC VELOCITY CHARTS

The charts of ripper performance estimated by seismic wave velocities have been developed from field tests conducted in a variety of materials. Considering the extreme variations among materials and even among rocks of a specific classification, the charts must be recognized as being at best only one indicator of rippability.

Accordingly, consider the following precautions when evaluating the feasibility of ripping a given formation:

— Tooth penetration is often the key to ripping success, regardless of seismic velocity. This is particularly true in homogeneous materials such as mudstones and claystones and the fine-grained caliches. It is also true in tightly cemented formations such as conglomerates, some glacial tills and caliches containing rock fragments.

— Low seismic velocities of sedimentaries can indicate probable rippability. However, if the fractures and bedding joints do not allow tooth penetration, the material may not be ripped effectively.

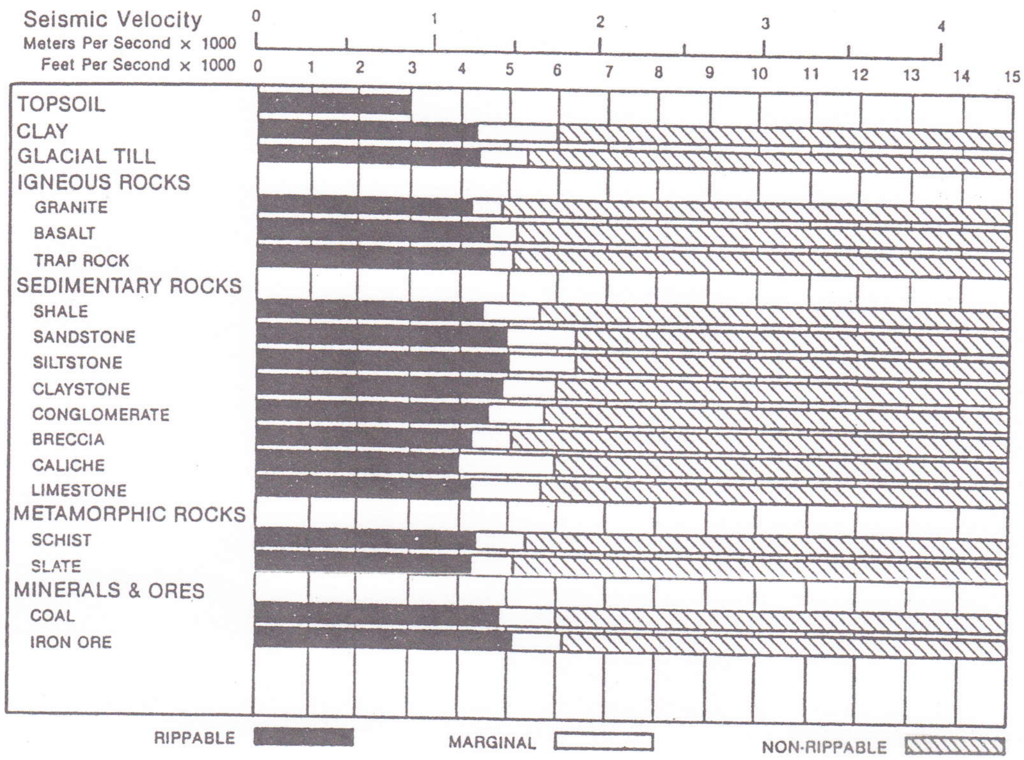
— Pre-blasting or "popping" may induce sufficient fracturing to permit tooth entry, particularly in the caliches, conglomerates and some other rocks; but the economics should be checked carefully when considering popping in the higher grades of sandstones, limestones and granites.

Ripping is still more art than science, and much will depend on the skill and experience of the tractor operator. Ripping for scraper loading may call for different techniques than if the same material is to be dozed away. If cross-ripping is called for, it, too, requires a change in approach. The number of shanks used, length and depth of shank and tooth angle, direction, throttle position — all must be adjusted according to field conditions encountered. Ripping success may well depend on the operator finding the proper combination for those conditions.

From Caterpillar Performance Handbook, October 1986
Caterpillar Inc., Peoria, Illinois, p. 97-102

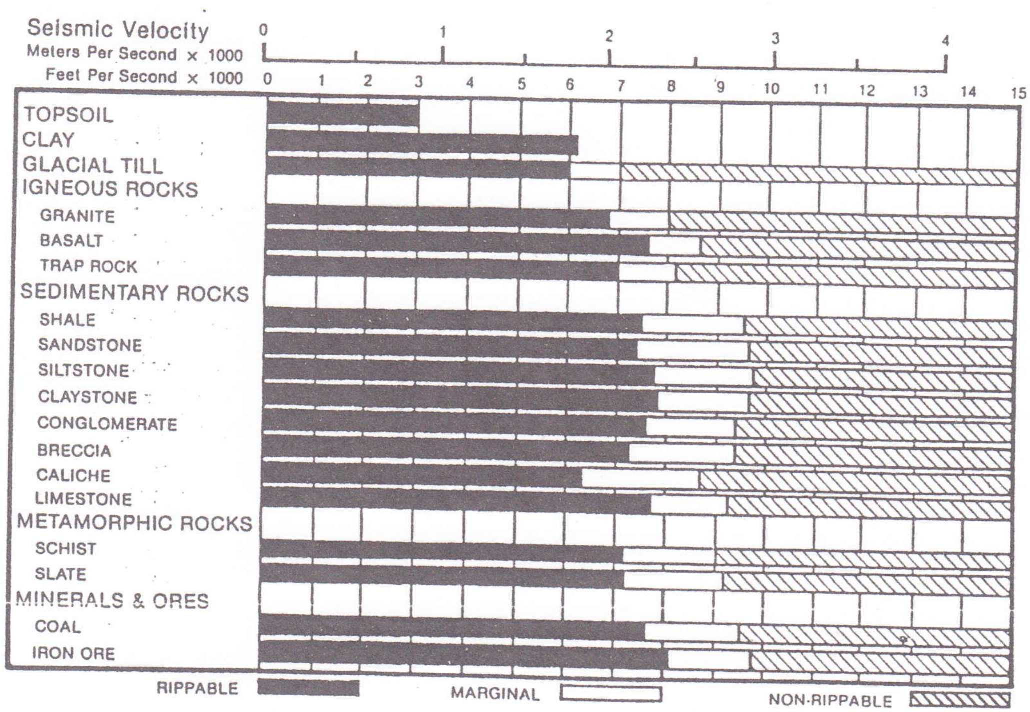
D7G Ripper Performance

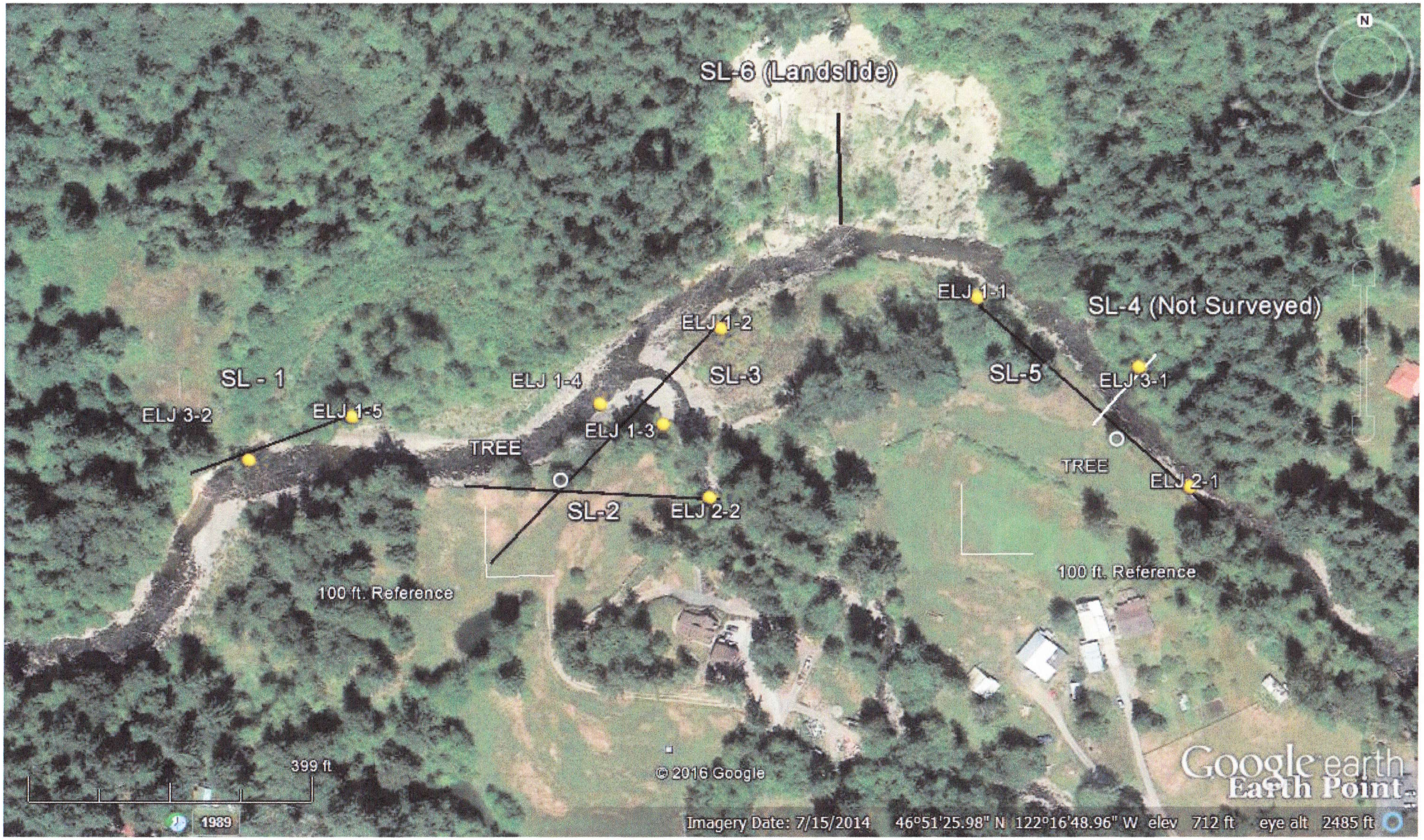
- Estimated by Seismic Wave Velocities



D8L Ripper Performance

- Multi or Single Shank No. 8 Ripper
- Estimated by Seismic Wave Velocities





Seismic Line Location

Engineered Log Jam Location

SEISMIC REFRACTION SURVEY LOCATION MAP
MASHEL RIVER RESTORATION PROJECT
PIERCE COUNTY, WASHINGTON

Philip H. Duoos, Geophysical Consultant
July, 2016 Job No. 1185-16

MAP 1

TABLE 2

INTERPRETATED LAYERS NEAR PROPOSED ELJ LOCATIONS

Estimated thickness of thin, highly weathered claystone layer is included. This layer is not observed in all of the seismic data, and is estimated based on the seismic results over nearby claystone outcrops.

ELJ Locations listed in approximate order moving upstream.

Layer depths estimated from nearby seismic profile station.

ELJ - 3-2
Seismic Line SL-1
~ 11 feet left of Sta. 85'
Claystone observed in river bed

Depth	**Layer**	**Interpreted Material**
0' to 3'	L1	Highly Wthrd. Claystone
> 3'	L2	Mod. Competent Claystone

ELJ - 1-5
Seismic Line SL-1
~ 3 feet left of Sta. 252'

Depth	**Layer**	**Interpreted Material**
0' to 5'?	L1	Loose alluvium overburden
5'? To 8'?	L1	Highly Wthrd. Claystone?
> 8'	L2	Mod. Competent Claystone

ELJ - 1-4
Seismic Line SL-3
~ 43 feet right of Sta. 278'

Depth	**Layer**	**Interpreted Material**
0' to 5'	L1	Loose alluvium overburden
> 5'	L2	Mod. Competent Claystone

ELJ - 1-3
Seismic Line SL-3
~ 43 feet left of Sta. 320'

Depth	**Layer**	**Interpreted Material**
0' to 6.5'	L1	Loose alluvium overburden
> 6.5'	L2	Mod. Competent Claystone

ELJ - 1-2
Seismic Line SL-3
~ 6 feet left of Sta. 473'

Depth	**Layer**	**Interpreted Material**
0' to 4.5'	L1	Loose alluvium overburden
> 4.5'	L2	Mod. Competent Claystone

ELJ - 2-2 Seismic Line SL-2
~ 2 feet right of Sta. 352'

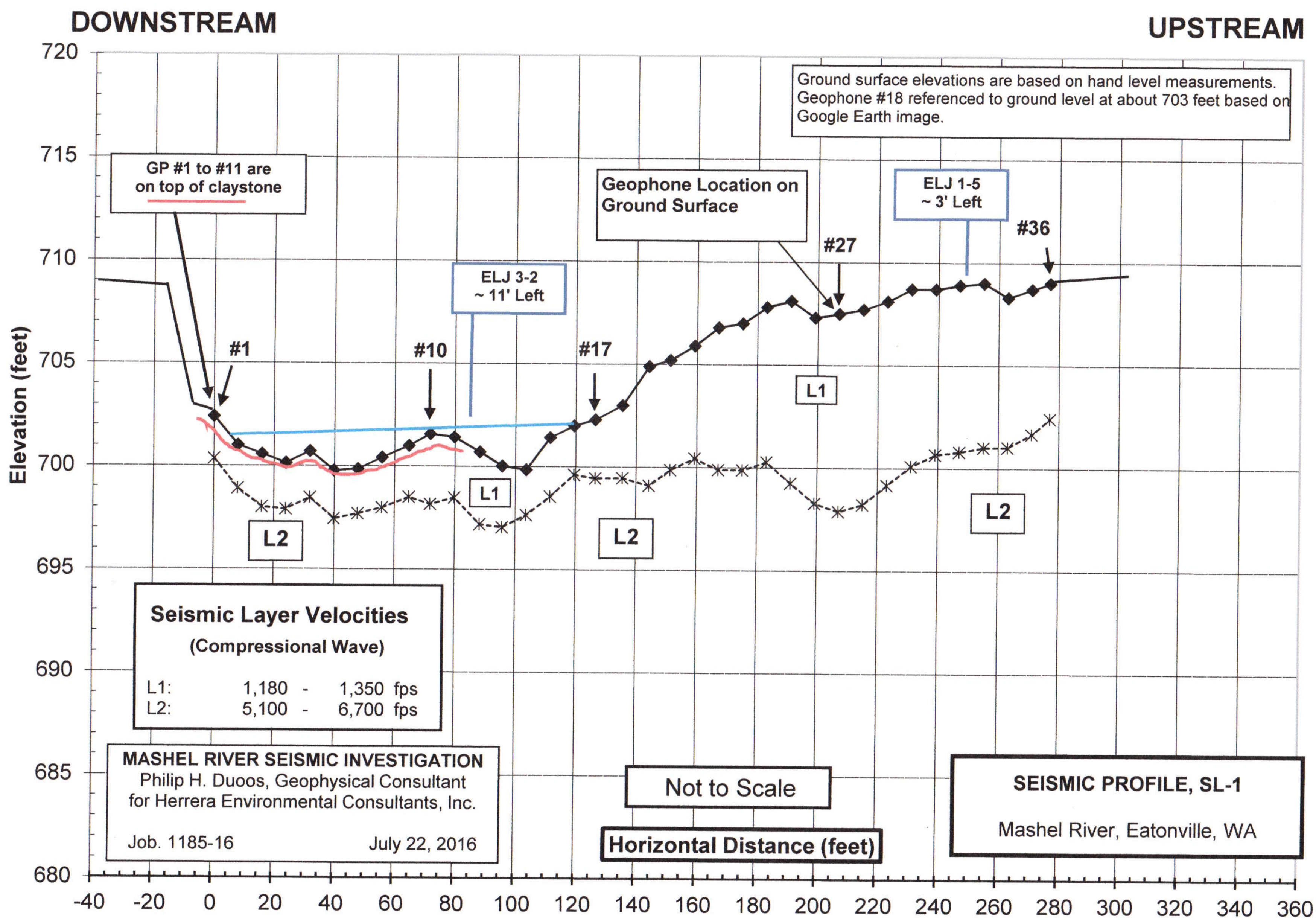
Depth	Layer	Interpreted Material
0' to 2.0'	L1	Loose alluvium overburden
> 2.0'	L2	Mod. Competent Claystone

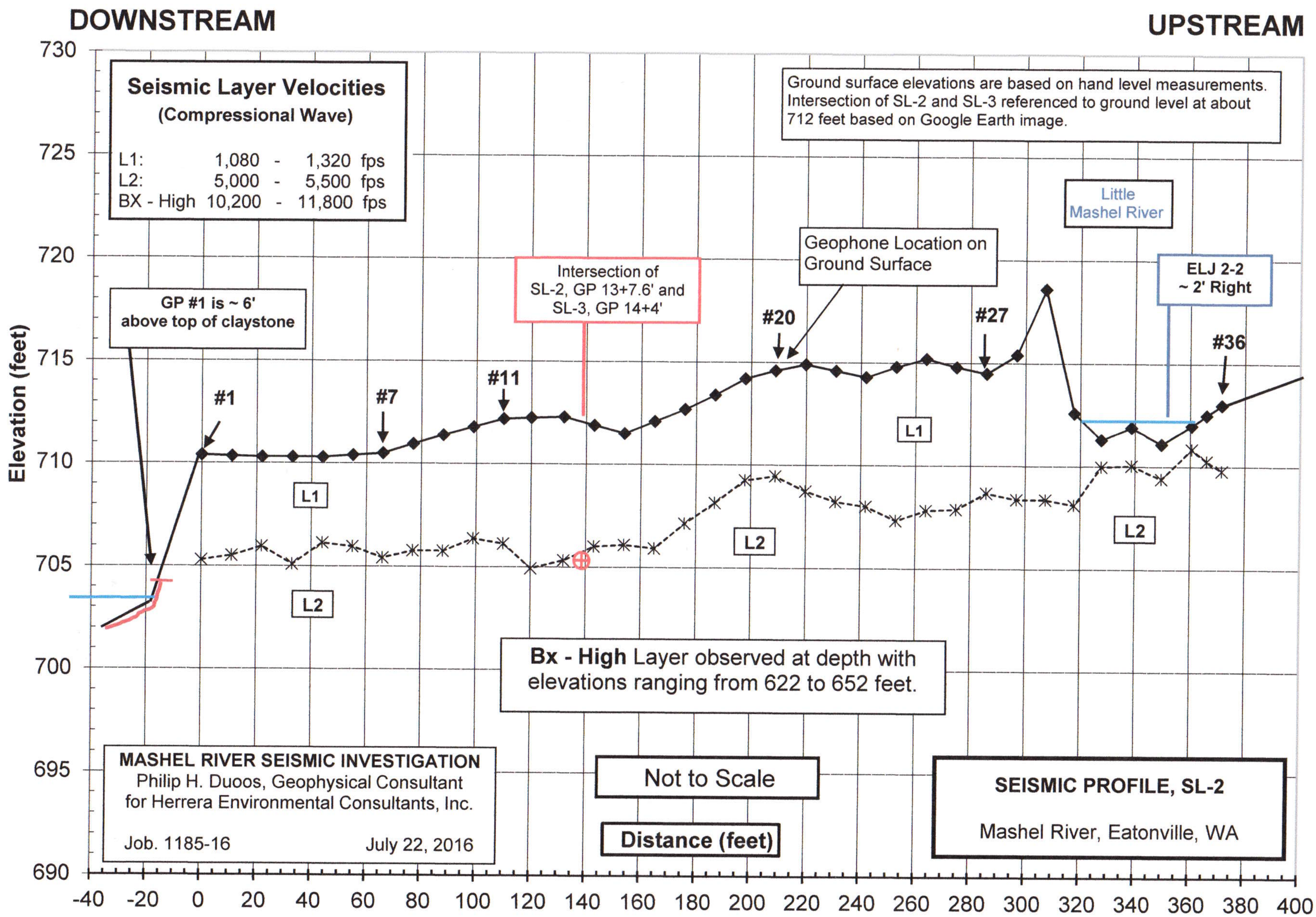
ELJ - 1-1 Seismic Line SL-5
~ 5 feet right of Sta. 24'

Depth	Layer	Interpreted Material
0' to 4'?	L1	Loose alluvium overburden
4'? To 6'?	L1	Highly Wthrd. Claystone?
> 6'	L2	Mod. Competent Claystone

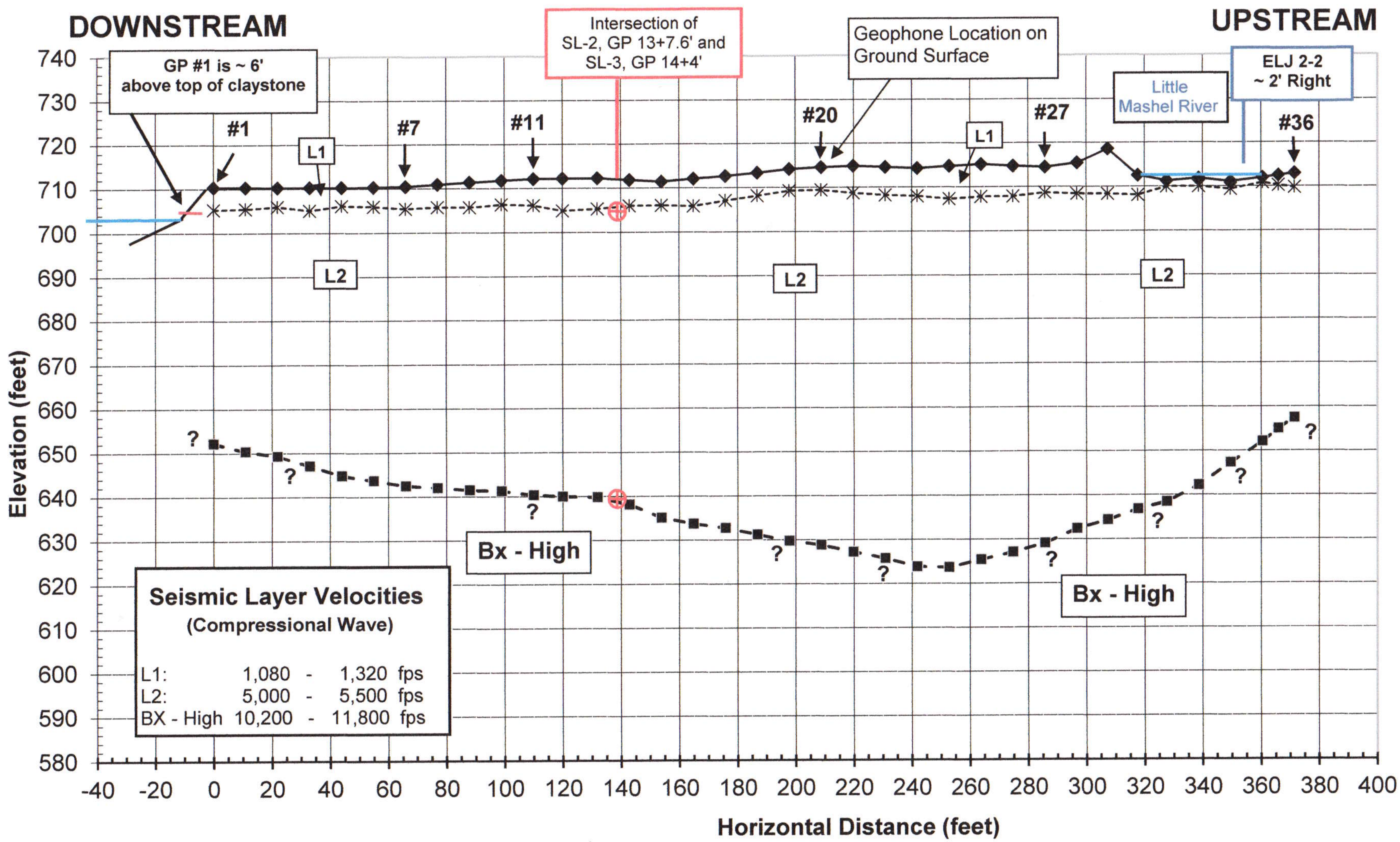
ELJ - 2-1 Seismic Line SL-5
~ 2 feet right of Sta. 443'

Depth	Layer	Interpreted Material
0' to .2'	L1	Loose alluvium overburden
.2' to 1.5'?	L2	Mod. Competent Claystone
> 1.5'?	BX-High	Competent Bedrock


DOWNSTREAM
UPSTREAM
Ground surface elevations are based on hand level measurements. Geophone #18 referenced to ground level at about 703 feet based on Google Earth image.
GP #1 to #11 are on top of claystone
Geophone Location on Ground Surface
ELJ 1-5 ~ 3' Left
ELJ 3-2 ~ 11' Left
#1
#10
#17
#27
#36
L1
L1
L2
L2
L2
Elevation (feet)
720
715
710
705
700
695
690
685
680
Seismic Layer Velocities
(Compressional Wave)
L1: 1,180 - 1,350 fps
L2: 5,100 - 6,700 fps
MASHEL RIVER SEISMIC INVESTIGATION
Philip H. Duoos, Geophysical Consultant
for Herrera Environmental Consultants, Inc.
Job. 1185-16
July 22, 2016
Not to Scale
Horizontal Distance (feet)
SEISMIC PROFILE, SL-1
Mashel River, Eatonville, WA
-40
-20
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360



DOWNSTREAM
UPSTREAM
Seismic Layer Velocities
(Compressional Wave)
L1: 1,080 - 1,320 fps
L2: 5,000 - 5,500 fps
BX - High 10,200 - 11,800 fps
Ground surface elevations are based on hand level measurements. Intersection of SL-2 and SL-3 referenced to ground level at about 712 feet based on Google Earth image.
Little Mashel River
Geophone Location on Ground Surface
ELJ 2-2 ~ 2' Right
Intersection of SL-2, GP 13+7.6' and SL-3, GP 14+4'
GP #1 is ~ 6' above top of claystone
#1
#7
#11
#20
#27
#36
L1
L2
Bx - High Layer observed at depth with elevations ranging from 622 to 652 feet.
MASHEL RIVER SEISMIC INVESTIGATION
Philip H. Duoos, Geophysical Consultant
for Herrera Environmental Consultants, Inc.
Job. 1185-16
July 22, 2016
Not to Scale
Distance (feet)
SEISMIC PROFILE, SL-2
Mashel River, Eatonville, WA
Elevation (feet)
730
725
720
715
710
705
700
695
690
-40
-20
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400



Not to Scale

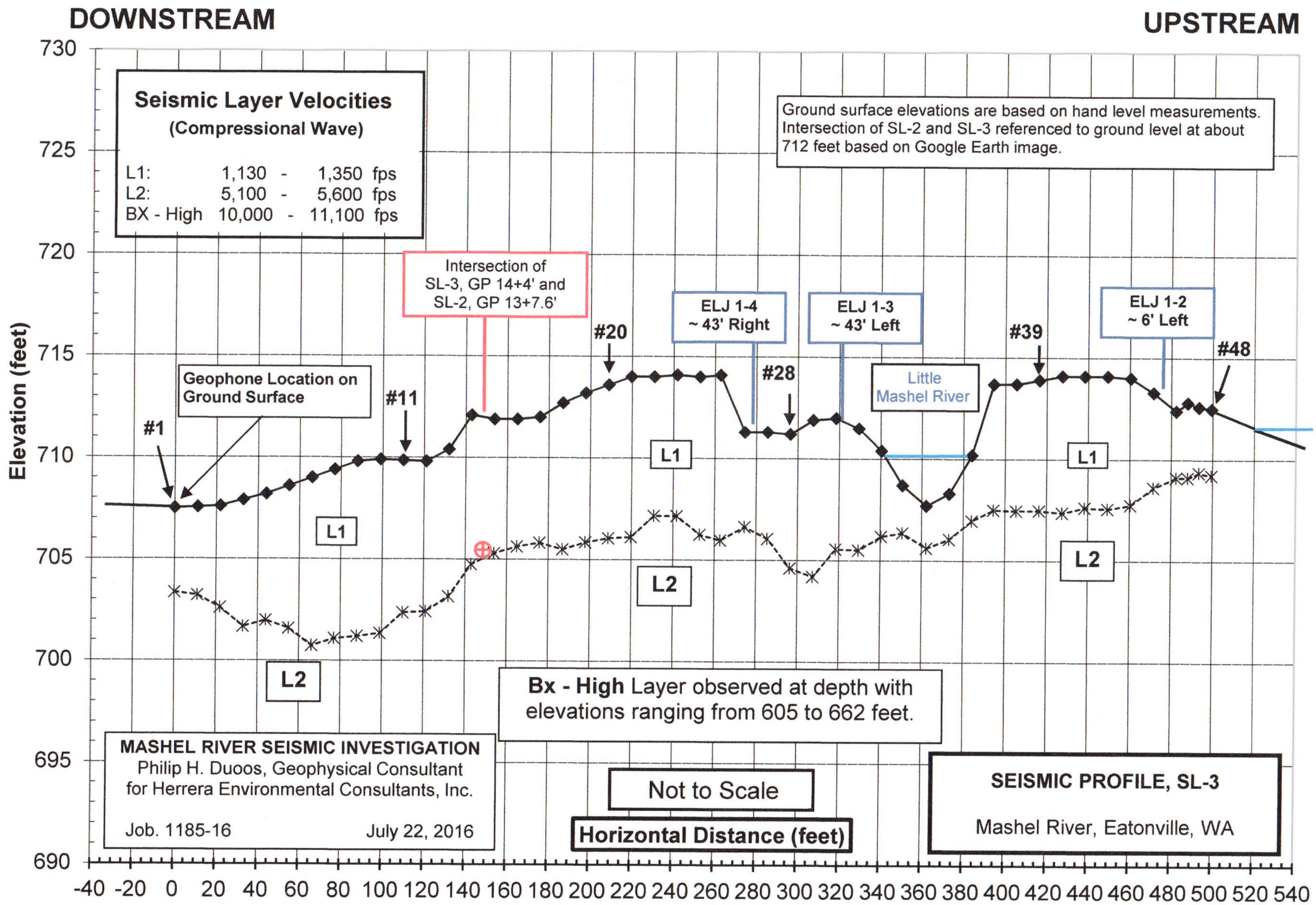
Ground surface elevations are based on hand level measurements. Intersection of SL-2 and SL-3 referenced to ground level at about 712 feet based on Google Earth image.

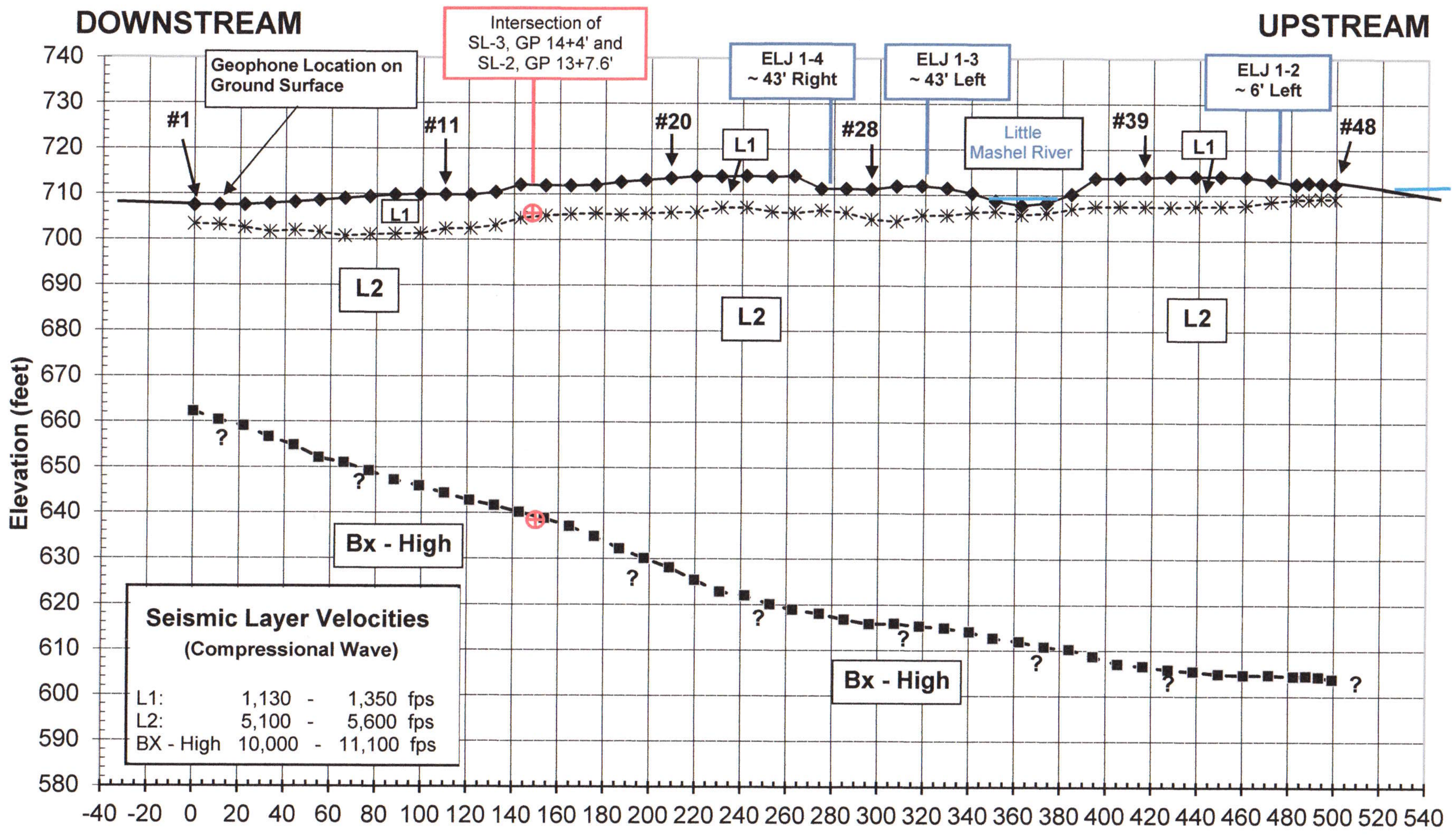
MASHEL RIVER SEISMIC INVESTIGATION
Philip H. Duoos, Geophysical Consultant
for Herrera Environmental Consultants, Inc.

Job. 1185-16 July 22, 2016

SEISMIC PROFILE, SL-2 (deep)

Mashel River, Eatonville, WA


DOWNSTREAM
UPSTREAM
Seismic Layer Velocities
(Compressional Wave)
L1: 1,130 - 1,350 fps
L2: 5,100 - 5,600 fps
BX - High 10,000 - 11,100 fps
Ground surface elevations are based on hand level measurements. Intersection of SL-2 and SL-3 referenced to ground level at about 712 feet based on Google Earth image.
Intersection of SL-3, GP 14+4' and SL-2, GP 13+7.6'
ELJ 1-4 ~ 43' Right
ELJ 1-3 ~ 43' Left
ELJ 1-2 ~ 6' Left
Little Mashel River
Geophone Location on Ground Surface
#1
#11
#20
#28
#39
#48
L1
L2
Bx - High Layer observed at depth with elevations ranging from 605 to 662 feet.
MASHEL RIVER SEISMIC INVESTIGATION
Philip H. Duoos, Geophysical Consultant
for Herrera Environmental Consultants, Inc.
Job. 1185-16
July 22, 2016
Not to Scale
Horizontal Distance (feet)
SEISMIC PROFILE, SL-3
Mashel River, Eatonville, WA
Elevation (feet)
730
725
720
715
710
705
700
695
690
-40 -20 0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540



Not to Scale

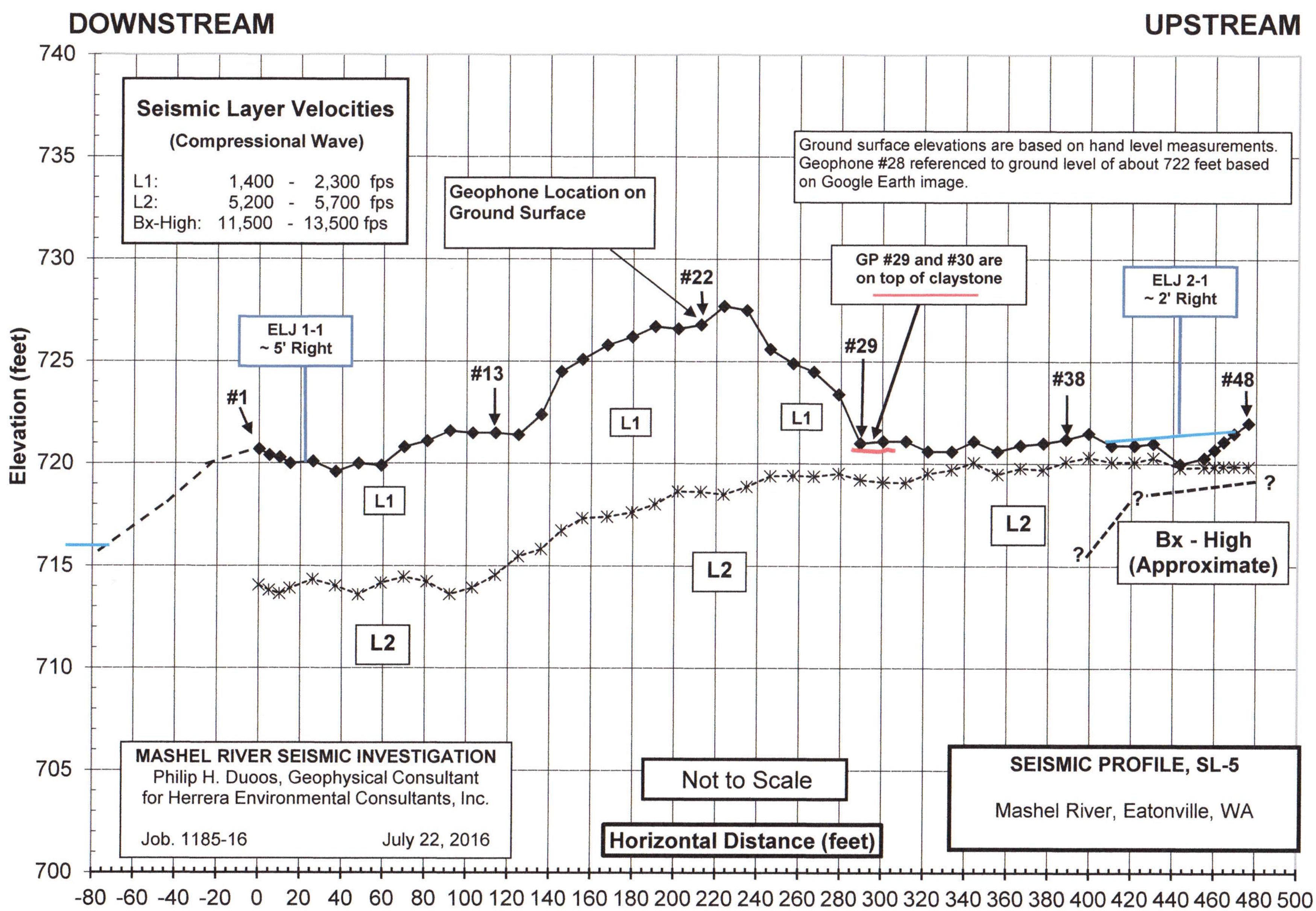
MASHEL RIVER SEISMIC INVESTIGATION
Philip H. Duoos, Geophysical Consultant
for Herrera Environmental Consultants, Inc.

Job. 1185-16 July 22, 2016

Ground surface elevations are based on hand level measurements. Intersection of SL-2 and SL-3 referenced to ground level at about 712 feet based on Google Earth image.

SEISMIC PROFILE, SL-3 (deep)

Mashel River, Eatonville, WA


DOWNSTREAM
UPSTREAM
Seismic Layer Velocities
(Compressional Wave)
L1: 1,400 - 2,300 fps
L2: 5,200 - 5,700 fps
Bx-High: 11,500 - 13,500 fps
Geophone Location on Ground Surface
Ground surface elevations are based on hand level measurements. Geophone #28 referenced to ground level of about 722 feet based on Google Earth image.
GP #29 and #30 are on top of claystone
ELJ 1-1
~ 5' Right
ELJ 2-1
~ 2' Right
#1
#13
#22
#29
#38
#48
L1
L2
Bx - High
(Approximate)
?
Elevation (feet)
740
735
730
725
720
715
710
705
700
MASHEL RIVER SEISMIC INVESTIGATION
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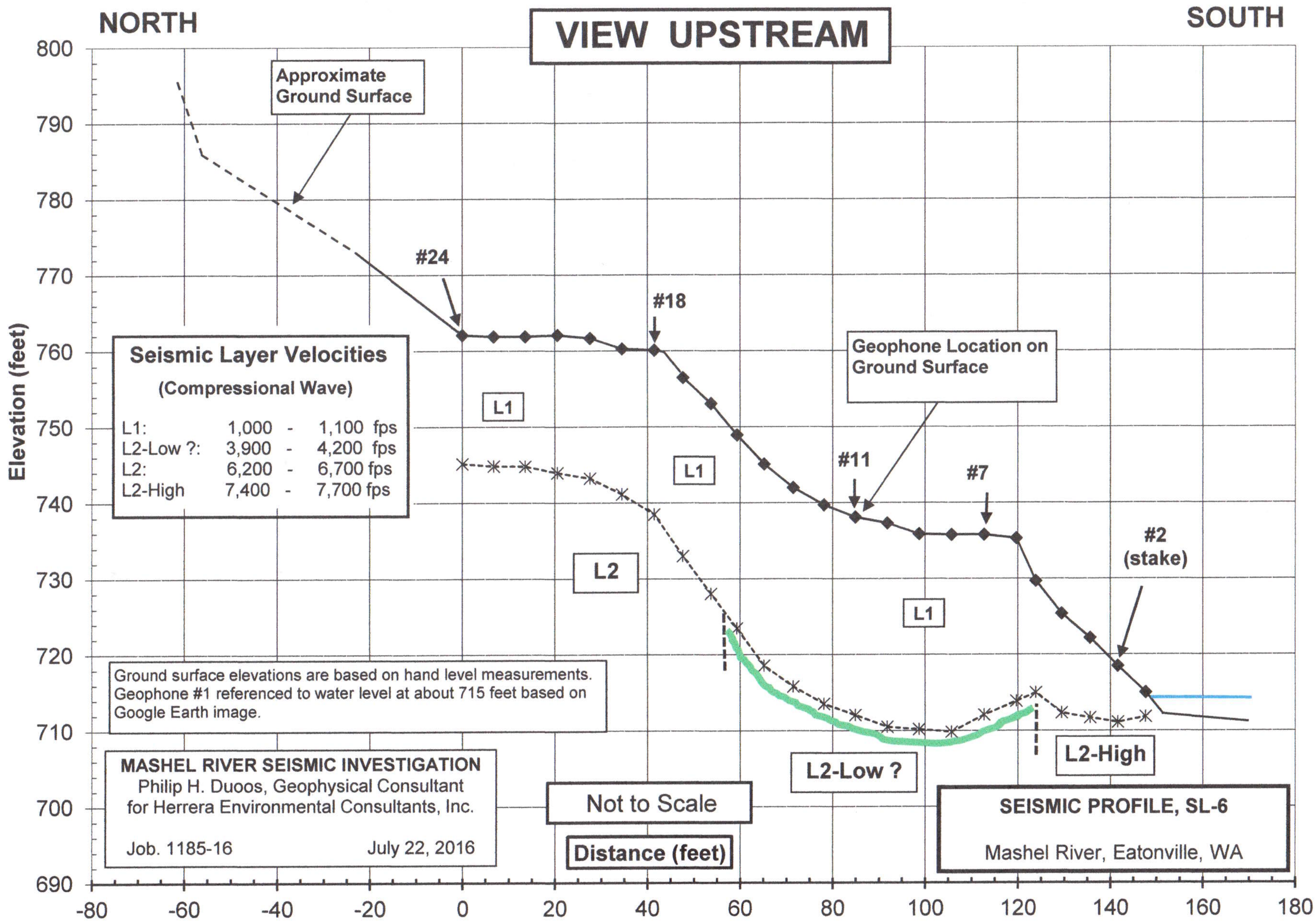
July 22, 2016
Not to Scale
Horizontal Distance (feet)
SEISMIC PROFILE, SL-5
Mashel River, Eatonville, WA
-80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500


NORTH
VIEW UPSTREAM
SOUTH
Approximate Ground Surface
#24
#18
#11
#7
#2 (stake)
Geophone Location on Ground Surface
Seismic Layer Velocities
(Compressional Wave)
L1: 1,000 - 1,100 fps
L2-Low ?: 3,900 - 4,200 fps
L2: 6,200 - 6,700 fps
L2-High 7,400 - 7,700 fps
L1
L1
L1
L2
L2-Low ?
L2-High
Ground surface elevations are based on hand level measurements. Geophone #1 referenced to water level at about 715 feet based on Google Earth image.
MASHEL RIVER SEISMIC INVESTIGATION
Philip H. Duoos, Geophysical Consultant
for Herrera Environmental Consultants, Inc.
Job. 1185-16
July 22, 2016
Not to Scale
Distance (feet)
SEISMIC PROFILE, SL-6
Mashel River, Eatonville, WA
Elevation (feet)
800
790
780
770
760
750
740
730
720
710
700
690
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180