

# FRONTIER GEOSCIENCES INC.

## MULTI-CHANNEL ANALYSIS OF SURFACE WAVES SURVEY REPORT MOTION HAZARD MAPPING PROJECT FORT ST. JOHN AREA, BC

Submitted to:  
**Geoscience BC**  
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Project: FGI-1513

## Table of Contents

1. Introduction	1
2. Multi-Channel Analysis of Surface Waves (MASW)	2
2.1 Survey Equipment	2
2.2 Survey Procedure	2
2.3 Interpretive Method	2
3. Geophysical Results	3
3.1 General	3
3.2 Discussion	3
4. Limitations	5
5. References	6

## Illustrations

	Location
Figure 1	Sikanni Chief Survey Location Plan
Figure 2	Terrace Above Sikanni Chief River Site Plan
Figure 3	Interpreted MASW Section MASW2-1 (Terrace Above Sikanni Chief River)
Figure 4	Example Data MASW2-1 (Terrace Above Sikanni Chief River)
Figure 5	Sikanni River Campground Site Plan
Figure 6	Interpreted MASW Section MASW2-2 (Sikanni River Campground)
Figure 7	Example Data MASW2-2 (Sikanni River Campground)
Figure 8	Pink Mountain Survey Location Plan
Figure 9	Beatton River Crossing Site Plan
Figure 10	Interpreted MASW Section MASW2-3 (Beatton River Crossing)
Figure 11	Example Data MASW2-3 (Beatton River Crossing)
Figure 12	Buffalo Inn Site Plan
Figure 13	Interpreted MASW Section MASW2-4 (Buffalo Inn)
Figure 14	Example Data MASW2-4 (Buffalo Inn)
Figure 15	Ostero Gravel Pit Survey Location Plan
Figure 16	Ostero Gravel Pit Site Plan
Figure 17	Interpreted MASW Section MASW2-5 (Ostero Gravel Pit)
Figure 18	Example Data MASW2-5 (Ostero Gravel Pit)
Figure 19	Parkland Tower Survey Location Plan
Figure 20	Parkland Tower Site Plan
Figure 21	Interpreted MASW Section MASW2-6 (Parkland Tower)
Figure 22	Example Data MASW2-6 (Parkland Tower)

### 1. Introduction

During the period of September 16 to September 18, 2017, Frontier Geosciences Inc. carried out a multi-channel analysis of surface waves (MASW) investigation for Geoscience BC in the Fort St. John, BC area. Two of the sites were located within the Sikanni Chief area, a site plan showing the locations of the Sikanni Chief lines is presented at a 1:25,000 scale in Figure 1 of the Appendix. Two of the sites were located within the Pink Mountain area, a site plan showing the locations of the Pink Mountain lines is presented at a 1:50,000 scale in Figure 6 of the Appendix. A single traverse was located at the Osterio Gravel Pit, with the line location shown at 1:20,000 scale in Figure 11 of the Appendix. The final survey traverse was located near Parkland Tower in the Kiskatinaw River Area, a site plan showing the location of the survey line is shown at 1:20,000 scale in Figure 14 in the Appendix.

The purpose of the geophysical survey was to determine shear wave velocity information of the subsurface materials, at each of six individual site locations. A total of 704 metres of MASW data was collected along six separate seismic lines. This survey is an augmentation of previous geophysical investigation carried out by Frontier Geosciences Inc. in March and April of 2017.

## **2. Multi-Channel Analysis of Surface Waves (MASW)**

### **2.1 Survey Equipment**

The MASW investigation was carried out using two Geometrics, Geode, 24 channel, signal enhancement seismographs and Oyo Geo-Space, 10 Hz geophones. Geophone intervals along the multicored seismic cable was maintained at 2.5 metres in order to ensure high resolution data on subsurface layering. For this survey the active source mode was utilised, with a sledgehammer striking a steel plate, providing the seismic signal energy.

### **2.2 Survey Procedure**

Field procedure entailed setting out two 24 channel geophone cables in a straight line and implanting the geophones. The line was traversed with the sledgehammer source, moving progressively down the array of geophones. The seismic source was operated at each individual shotpoint and 48 channels of data were recorded digitally with the seismograph. The record lengths were planned to be sufficiently long to capture the full surface wave train. For quality assurance, field inspection of raw data after each shot was carried out, with additional shots recorded if first arrivals were unclear. Data recorded during field surveying operations was generally of good to excellent quality.

### **2.3 Interpretive Method**

Interpretation of the MASW data involves a wavefield transformation of the seismogram record. This converts the seismogram from a multichannel shot gather to a dispersion curve that shows the phase velocity of the signal as a function of frequency. The fundamental event is picked on the dispersion curve and this data is inputted into the Geopsy modelling program for inversion. The resulting model reveals the shear wave layer velocity structure, and is plotted at the centre of picked geophone array. The individual models produced are then gridded together to produce a shear wave velocity depth section along the survey lines. Throughout the survey, notes were recorded regarding seismic line positions in relation to topographic and geological features. Relative elevations along the seismic lines were recorded by chain and inclinometer.

### **3. Geophysical Results**

#### **3.1 General**

The interpreted results of the MASW lines are illustrated in profile in Figures 3, 5, 8, 10, 13, and 16, at a scale of 1:500, in the Appendix. Corresponding individual site plans for each location are displayed in Figures 2, 4, 7, 9, 12 and 15. The shear wave velocity data is displayed as colour contours on these profiles with warm colours indicating higher values and cool colours indicating lower values.

#### **3.2 Discussion**

MASW line SL2-1 is located northwest of Sikanni Chief, near the Progress Energy b-87-J multiwell pad, and runs from southeast to northwest parallel to Hwy 97. The interpreted MASW results for the line, displayed in Figure 3 of the Appendix, show increasing shear wave velocities with depth, ranging from approximately 225 m/s at the surface to a maximum approximately 800 m/s at 50 metres depth. Over the section, shear wave velocities average 345 m/s. Velocities change quite gradually for the upper 40 metres before a more rapid increase occurs in the lower 10 metres. The gradual change indicates a more homogeneous lithology with an increase in compaction, overlying a compositional change at approximately 40 metres depth.

Figure 5 displays the interpreted MASW section for line SL2-2. SL2-2 is located at the Sikanni River Campground and RV Park, on the western bank of the Sikanni Chief River. The results of the MASW line illustrate a thick surficial layer with velocities averaging approximately 180 m/s. With an average thicknesses of 6.5 metres, this layer is consistent with nearby drillhole intersections of dry sand with gravel. Underlying this low velocity surficial layer shear wave velocities increase from 200 m/s at 6.5 m depth to 300 m/s at approximately 40 metres. The southeastern portion of the line, from 0NW to approximately 35NW averages 265 m/s at elevation 765m, this decreases to 235 m/s from 35NW to 70NW, and decreases further to an average of 215 m/s at 765 m elevation for the northwestern extent of the line. The lower 10 m of the section shows a relatively faster change to a higher shear wave velocity of 750 m/s. This higher velocity, at the limit of depth penetration may indicate the onset of sedimentary rock.

Line SL2-3 interpreted MASW section is displayed in Figure 8 in the Appendix. The survey line is located near the Beaton River Crossing, along the access road to Progress Energy a-98-A/94-G-2 Wellsite. Velocity contours are generally flat-lying, indicating lateral uniformity along the survey length and increase in velocity with depth. The shear wave velocities range from approximately 175 m/s at the surface to over 800 m/s at depth. At a depth of approximately 32 m, the velocities increase to approximately 400 m/s. The lower 20 m of the section shows a slightly more rapid increase in shear wave velocity.

Figure 10 displays the interpreted MASW section for line SL2-4. Line SL2-4 is located near the Buffalo Inn, and runs parallel to Hwy 97. The results of the MASW line illustrate increasing shear wave velocities with depth, ranging from a minimum of approximately 150 m/s at the surface to the 600 m/s contour at approximately 10 metres depth. Velocities in this zone are consistent with firm to stiff silt and clay or compact sand and gravel. Below 10 m depth, velocities continue to increase from 600 m/s to a maximum of approximately 900 m/s at depth. These velocities likely correspond to the onset of weathered sedimentary bedrock.

MASW line SL2-5 is located near the Ostero Gravel Pit, and runs from west to east on the north side of Spruce St. W. The interpreted MASW results for the line, displayed in Figure 12 of the Appendix, show generally increasing shear wave velocities with depth, with a minor velocity inversion at approximately 5m depth in the centre part of the profile. This inversion may be due to a geological thin layer change. Velocities range from approximately 250 m/s at the surface to a maximum approximately 750 m/s at 50 metres depth. Over the section, shear wave velocities average 500 m/s. Velocities change at a relatively uniform rate with depth. The gradual change suggests a more homogeneous lithology with an increase in compaction, rather than a distinct compositional change.

Located in the Kiskatinaw River Area, near the Parkland Tower Site, is MASW line SL2-6. Figure 16 shows the interpreted profile for this line, which displays shear wave velocity contours that continuously increase with depth. There is also a velocity decrease laterally near surface with higher velocities interpreted at the southern end of the line and lower surficial shear waves interpreted at the northern end of the line. Shear wave velocities in the range of approximately 380 m/s to 500 m/s correspond to silty clay, clay, and silty fine sand, as intersected in nearby boreholes. Higher shear wave velocities, over 800 m/s are encountered at approximately 40 metres depth, indicating the possible onset of sedimentary rock.

#### **4. Limitations**

The multi-channel analysis of surface waves (MASW) method is carried out in the Active or Passive mode with the Active mode generally the most accurate for evaluation of shallow, shear wave velocities. Limitations include reflection and scattering of surface and body waves due to extreme surface topography and in-homogeneous conditions in the subsurface such as boulder concentrations or isolated soil lenses with contrasting properties. The method is generally accepted as an effective means of determining shear wave velocities of geological units.

The information in this report is based upon geophysical measurements and field procedures and our interpretation of the data. The results are interpretive in nature and are considered to be a reasonably accurate representation of existing subsurface conditions within the limitations of the multi-channel analysis of surface waves method.

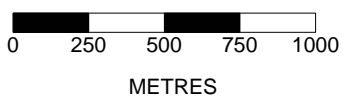
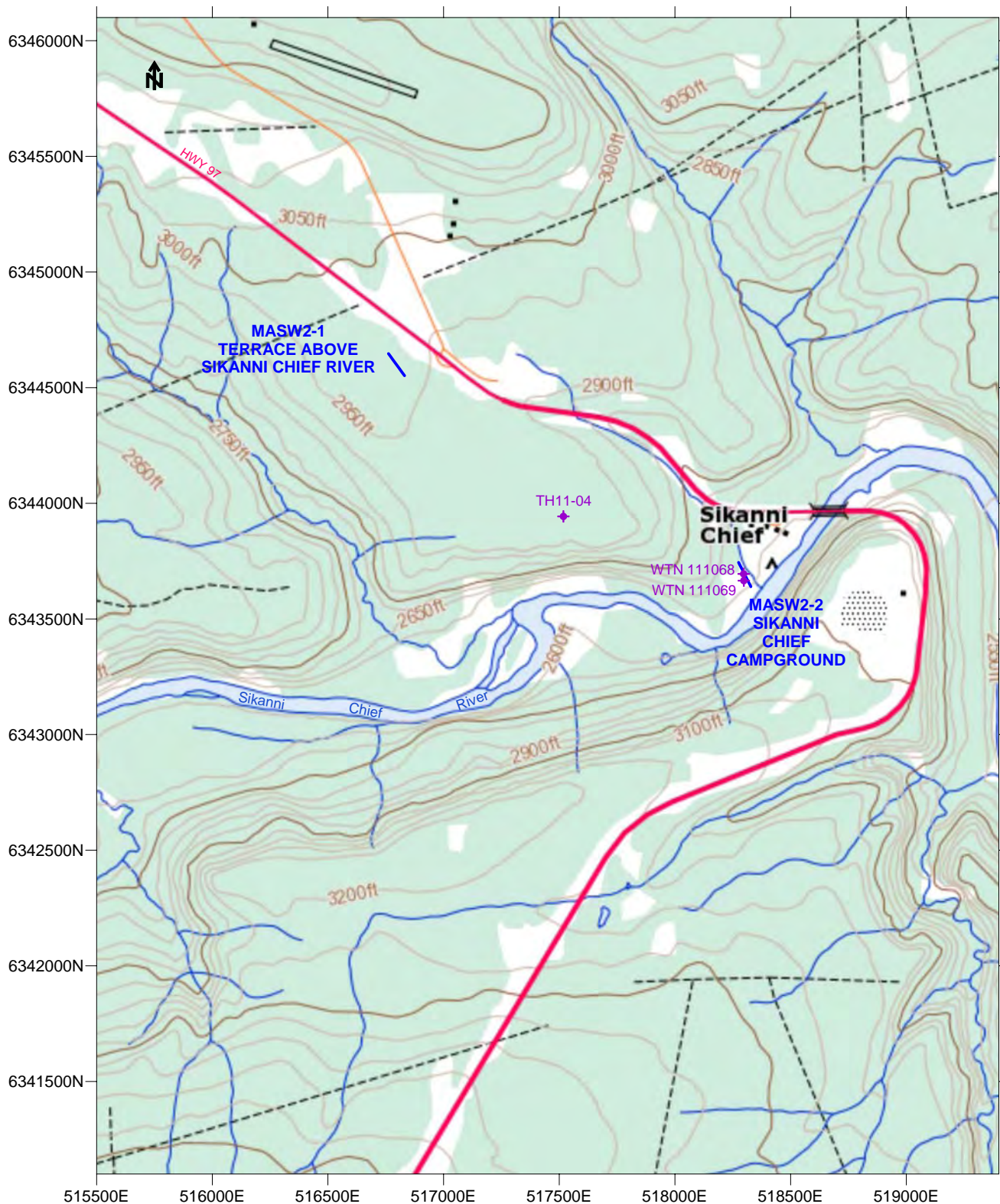
For: Frontier Geosciences Inc.

Beth Galambos, P.Geo.

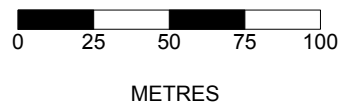
Cliff Candy, P.Geo.

**5. References**

1. *Downhole Seismic Survey Report*, Groundbirch Area, Dawson Creek, B.C.; Submitted to Geoscience BC; Frontier Geosciences Inc.; Project No. FGI-1482; March, 2017
2. *Multi-Channel Analysis of Surface Waves Survey Report*, Motion Hazard Mapping Project, Fort St. John & Dawson Creek, BC.; Submitted to Geoscience BC; Frontier Geosciences Inc.; Project No. FGI-1490; April, 2017

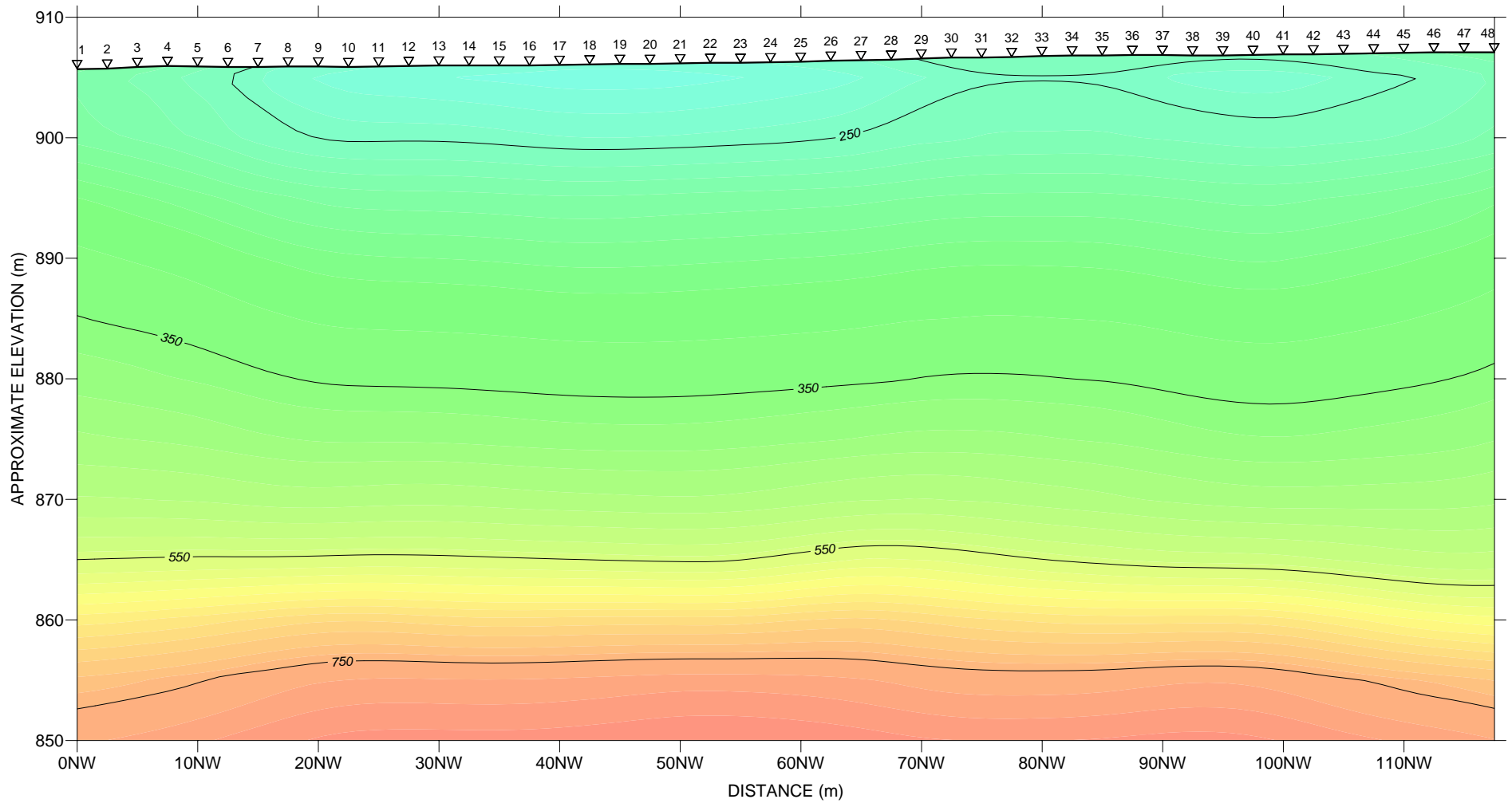


GEOSCIENCE BC SIKANNI CHIEF, BC		
MASW SURVEY		
SIKANNI CHIEF SURVEY LOCATION PLAN		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2017	SCALE 1:25,000	FIG. 1

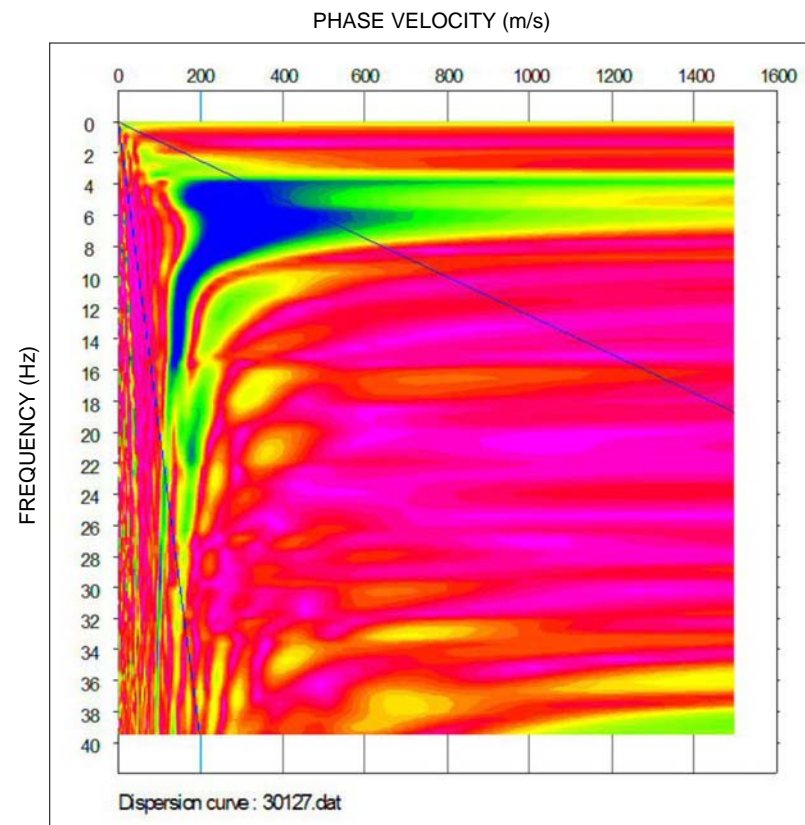
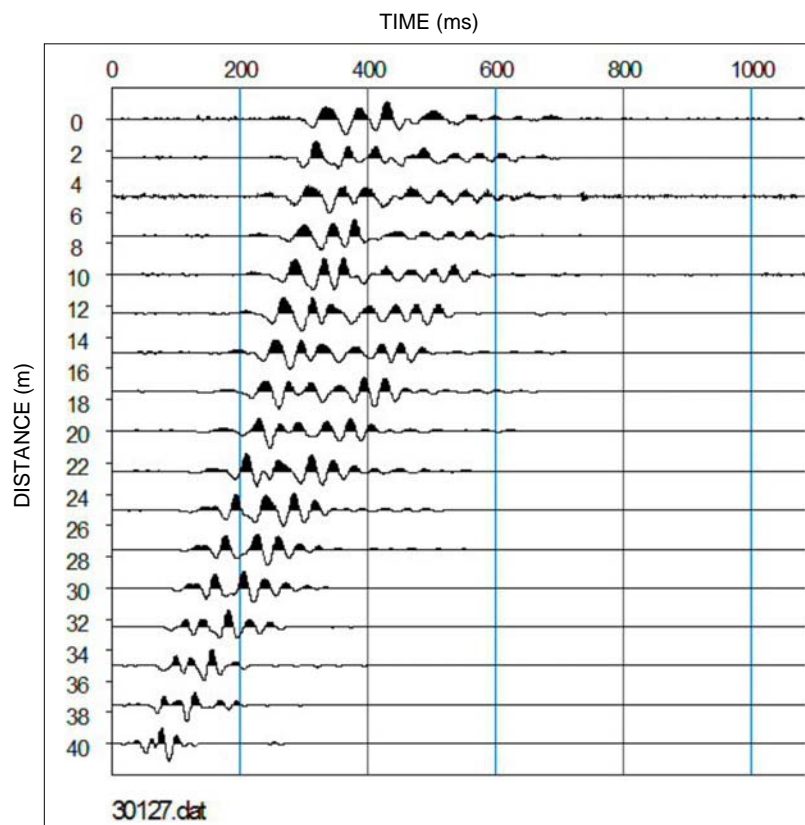


GOOGLE EARTH  
UTM ZONE 10N

GEOSCIENCE BC SIKANNI CHIEF, BC		
MASW SURVEY		
TERRACE ABOVE SIKANNI CHIEF RIVER SITE PLAN		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2017	SCALE 1:2,500	FIG. 2

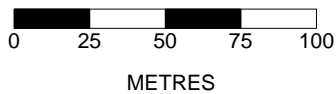
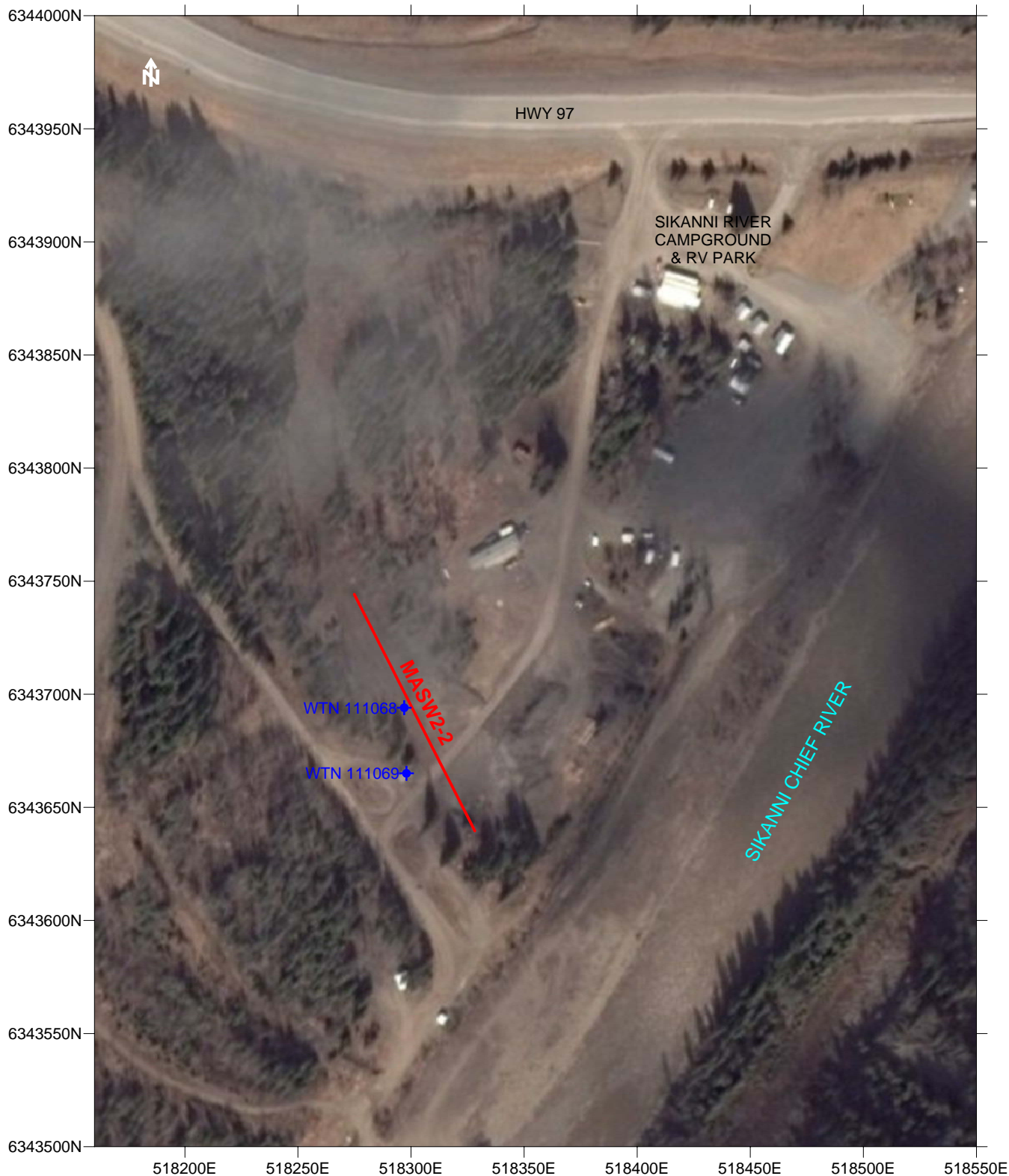


<b>GEOSCIENCE BC</b> SIKANNI CHIEF, BC		
<b>MASW SURVEY</b>		
<b>INTERPRETED MASW SECTION</b> <b>MASW 2-1</b> <b>TERRACE ABOVE SIKANNI CHIEF RIVER</b>		
<b>FRONTIER GEOSCIENCES INC.</b>		
DATE: SEPT. 2017	SCALE 1:500	FIG. 3



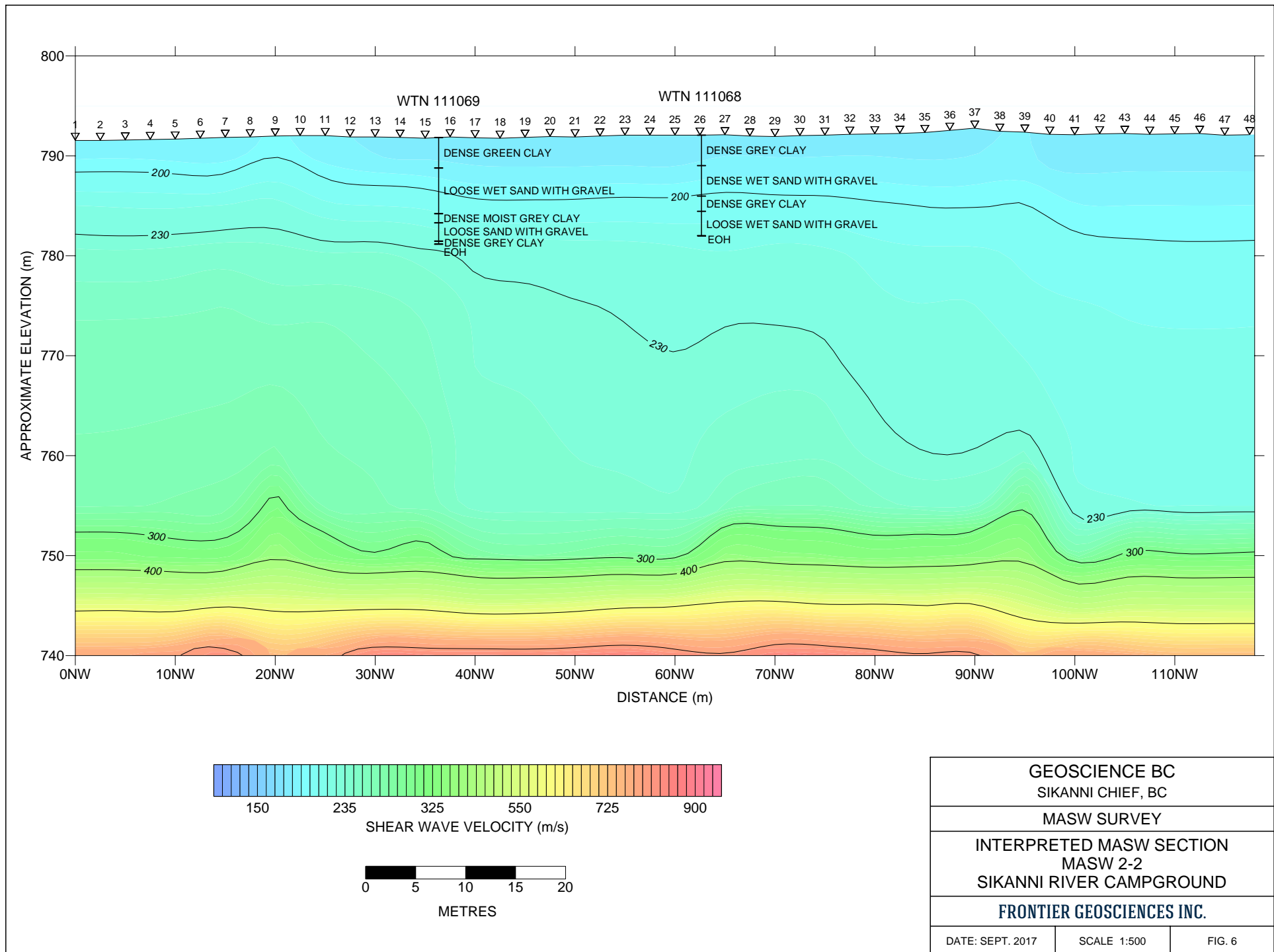
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 SHOT NUMBER: 27  
 SOURCE LOCATION: 43.75m

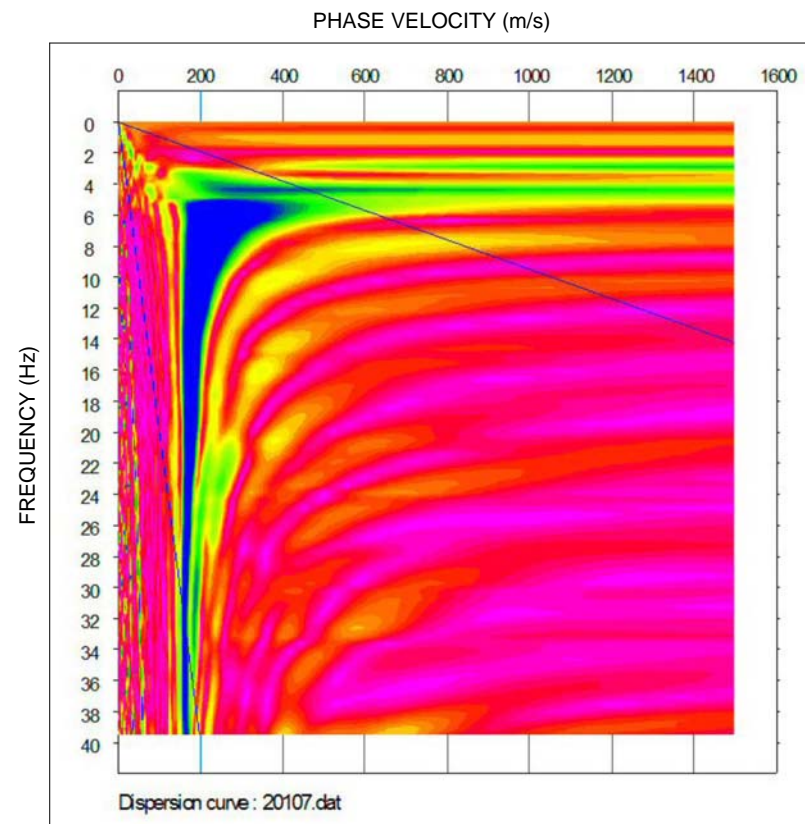
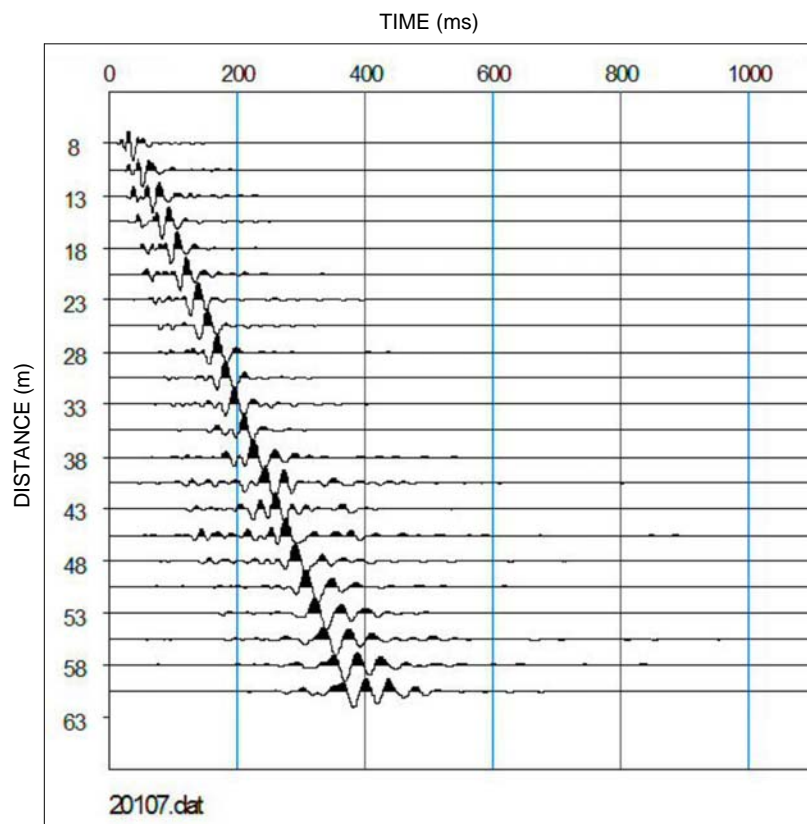
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MASW SURVEY		
EXAMPLE DATA MASW 2-1 TERRACE ABOVE SIKANNI CHIEF RIVER		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2017		FIG. 4



GOOGLE EARTH  
UTM ZONE 10N

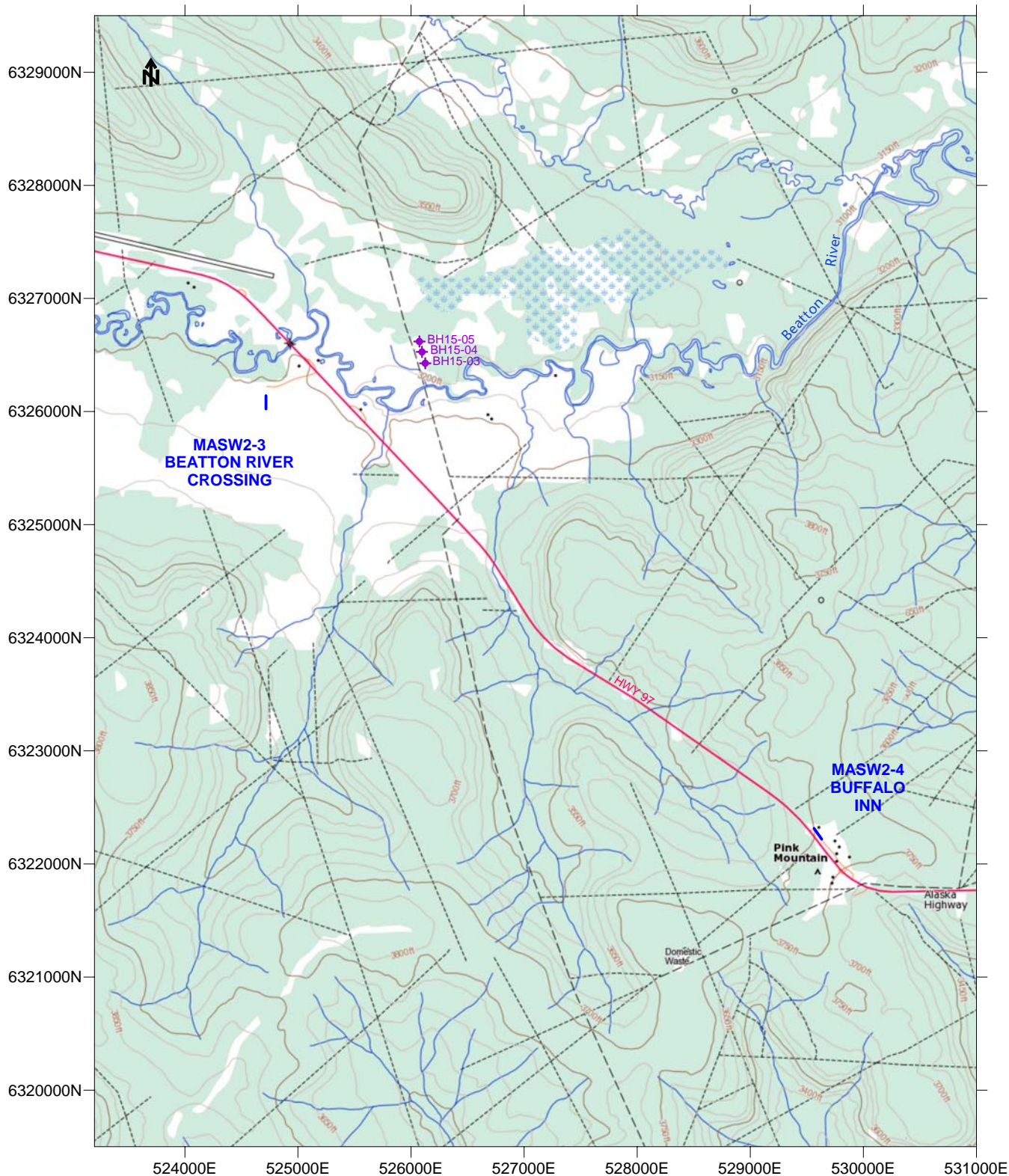
GEOSCIENCE BC SIKANNI CHIEF, BC		
MASW SURVEY		
SIKANNI RIVER CAMPGROUND SITE PLAN		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2017	SCALE 1:2,500	FIG. 5





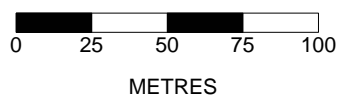
LINE: MASW2-2  
 SHOT NUMBER: 07  
 SOURCE LOCATION: 3.75m

GEOSCIENCE BC SIKANNI CHIEF, BC		
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EXAMPLE DATA MASW 2-2 SIKANNI RIVER CAMPGROUND		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2017		FIG. 7

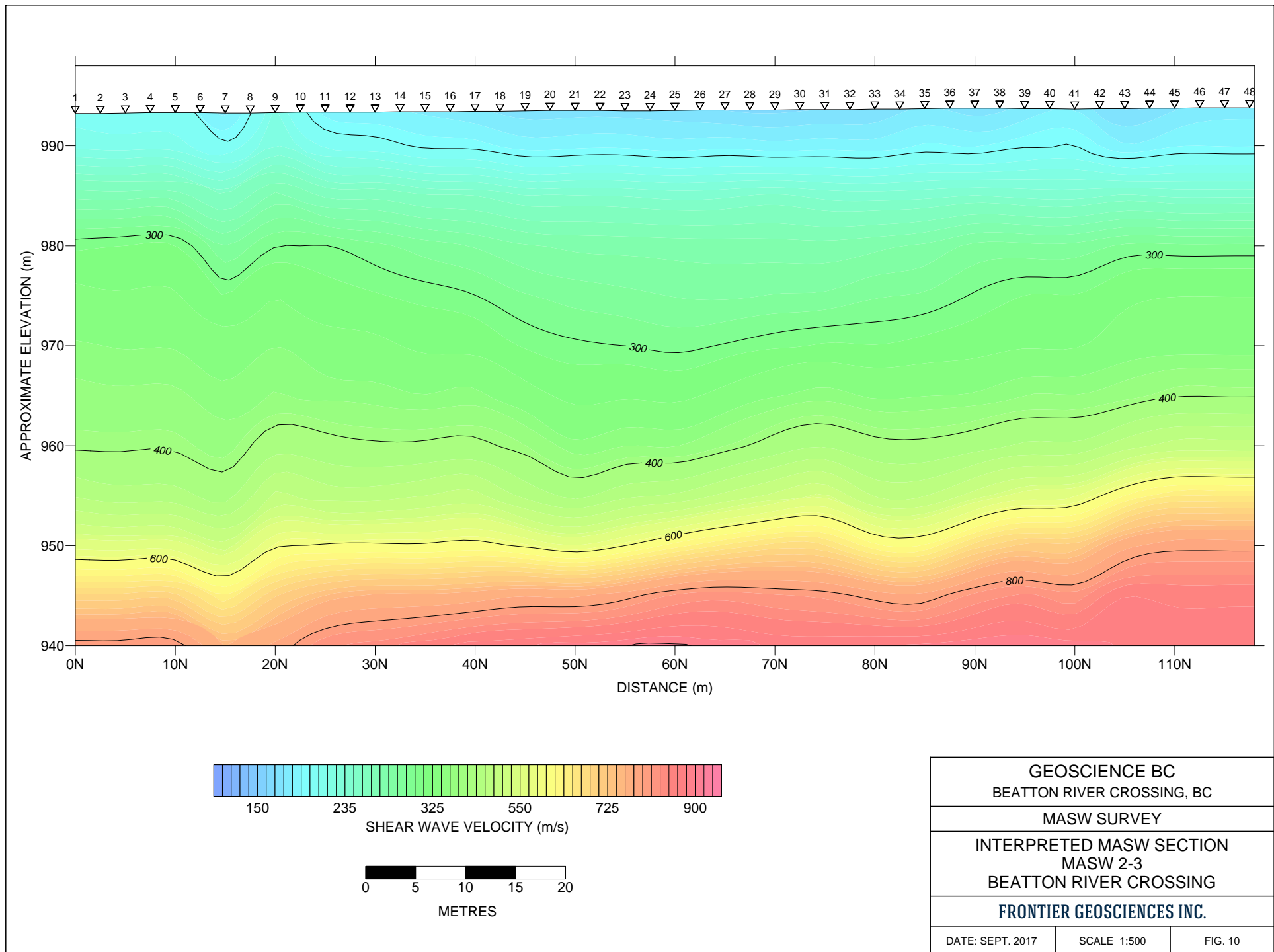


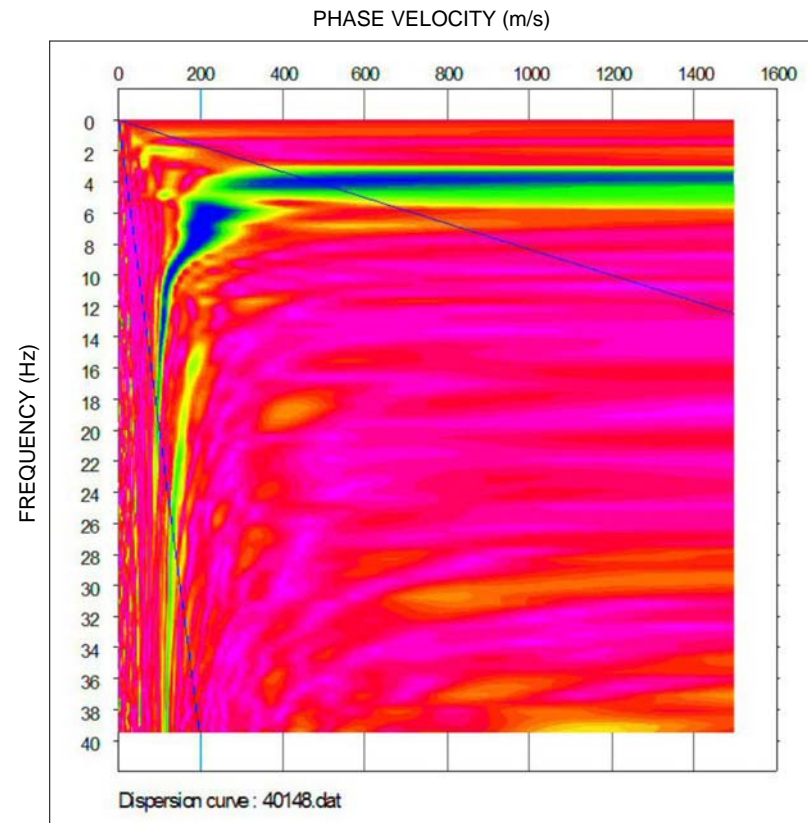
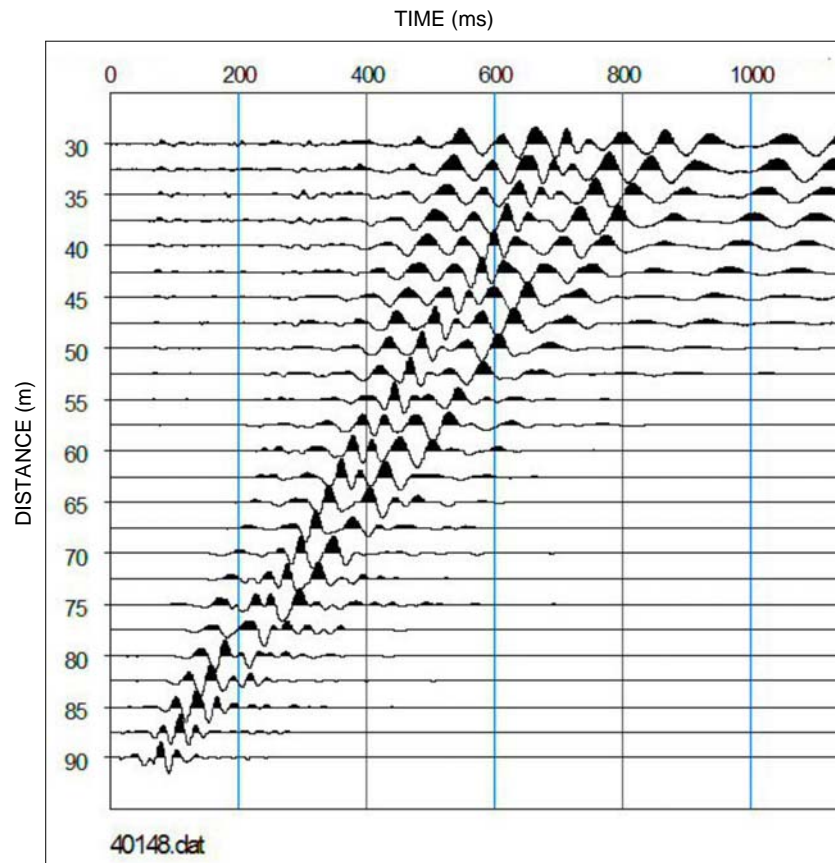
0 500 1000 1500 2000  
METRES

GEOSCIENCE BC PINK MOUNTAIN, BC		
MASW SURVEY		
PINK MOUNTAIN SURVEY LOCATION PLAN		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2017	SCALE 1:50,000	FIG. 8



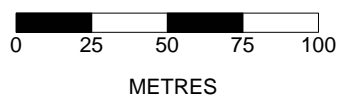
GEOSCIENCE BC		
BEATTON RIVER CROSSING, BC		
MASW SURVEY		
BEATTON RIVER CROSSING SITE PLAN		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2017	SCALE 1:2,500	FIG. 9



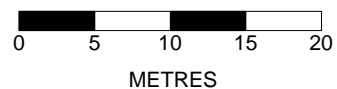
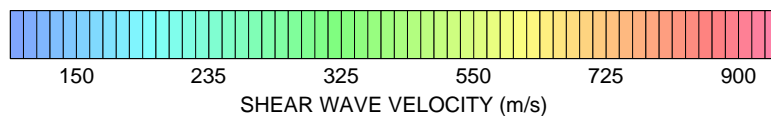
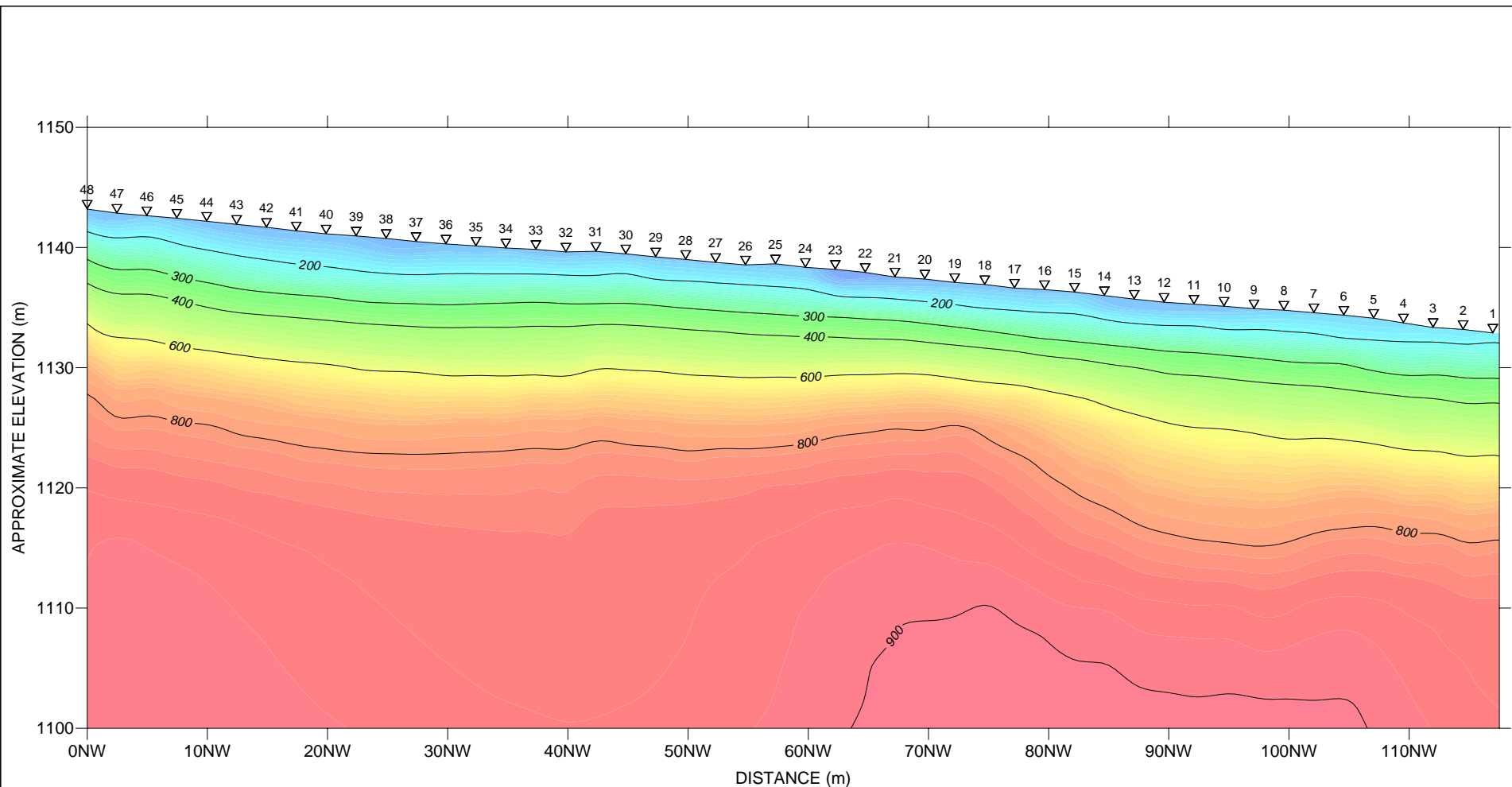


LINE: MASW2-3  
 SHOT NUMBER: 48  
 SOURCE LOCATION: 93.75m

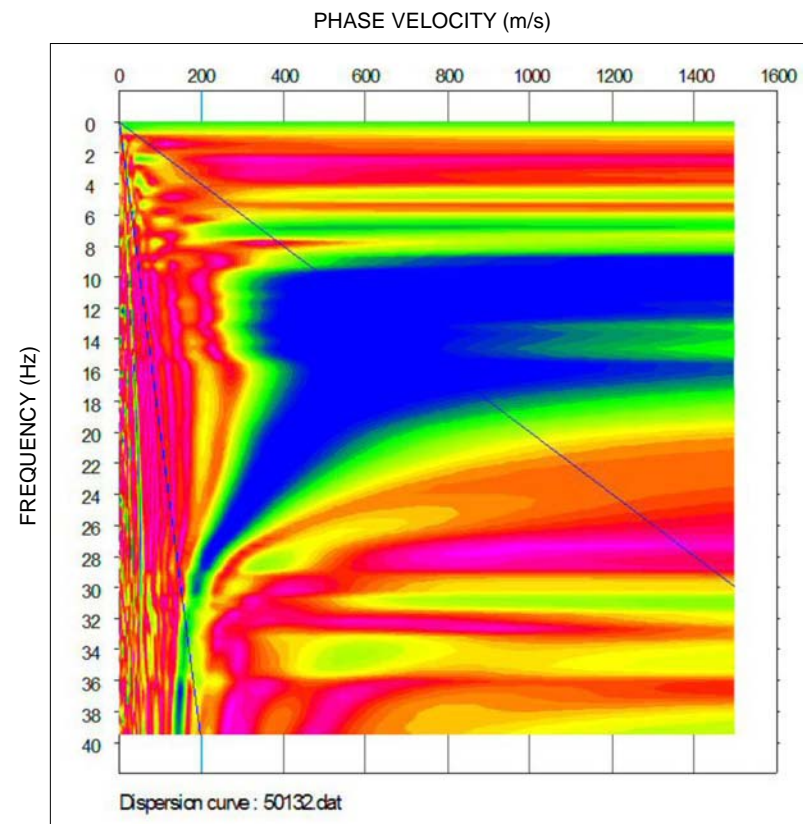
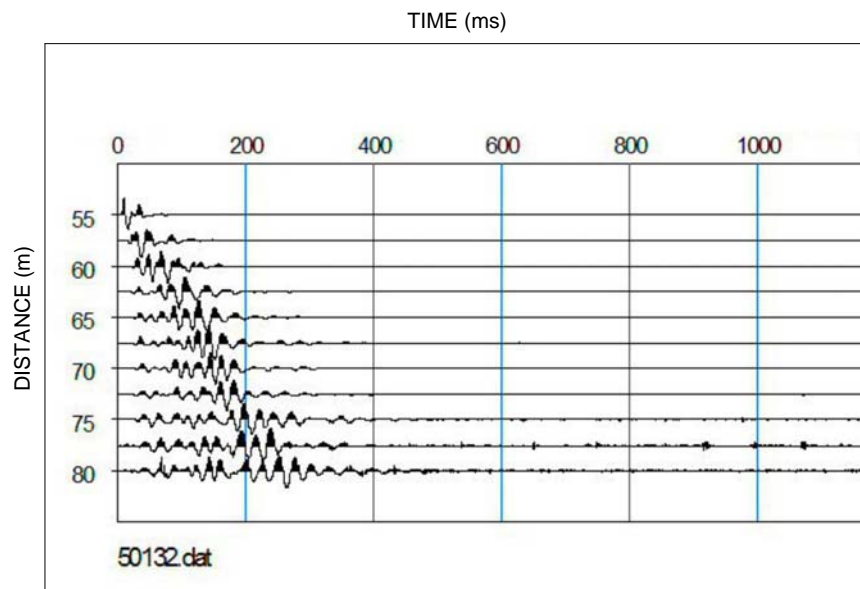
GEOSCIENCE BC BEATTON RIVER CROSSING, BC		
MASW SURVEY		
EXAMPLE DATA MASW 2-3 BEATTON RIVER CROSSING		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2017		FIG. 11



GEOSCIENCE BC PINK MOUNTAIN, BC		
MASW SURVEY		
BUFFALO INN SITE PLAN		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2017	SCALE 1:2,500	FIG. 12

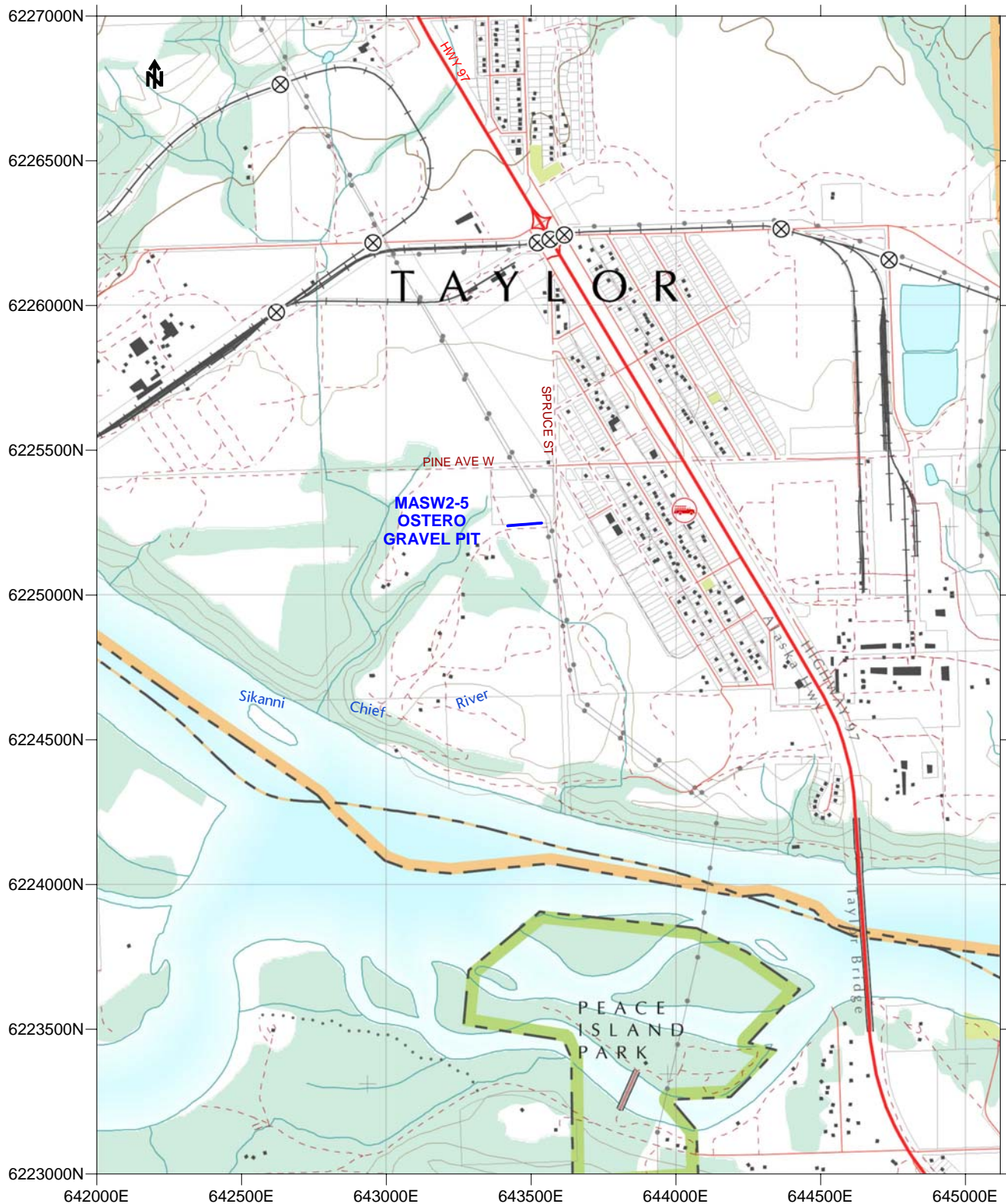


GEOSCIENCE BC PINK MOUNTAIN, BC		
MASW SURVEY		
INTERPRETED MASW SECTION MASW 2-4 BUFFALO INN		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2017	SCALE 1:500	FIG. 13



LINE: MASW2-4  
 SHOT NUMBER: 32  
 SOURCE LOCATION: 78.75m

GEOSCIENCE BC PINK MOUNTAIN, BC		
MASW SURVEY		
EXAMPLE DATA MASW 2-4 BUFFALO INN		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2017		FIG. 14



0 200 400 600 800  
METRES

GEOSCIENCE BC  
TAYLOR, BC

MASW SURVEY

OSTERO GRAVEL PIT  
SURVEY LOCATION PLAN

**FRONTIER GEOSCIENCES INC.**

DATE: SEPT. 2017

SCALE 1:20,000

FIG. 15

6225450N



6225400N

6225350N

6225300N

6225250N

6225200N

6225150N

643200E

643250E

643300E

643350E

643400E

643450E

643500E

643550E

643600E

643650E

643700E

643750E

PINE AVE W

SPRUCE ST W

MASW2-5



METRES

GOOGLE EARTH  
UTM ZONE 10NGEOSCIENCE BC  
TAYLOR, BC

MASW SURVEY

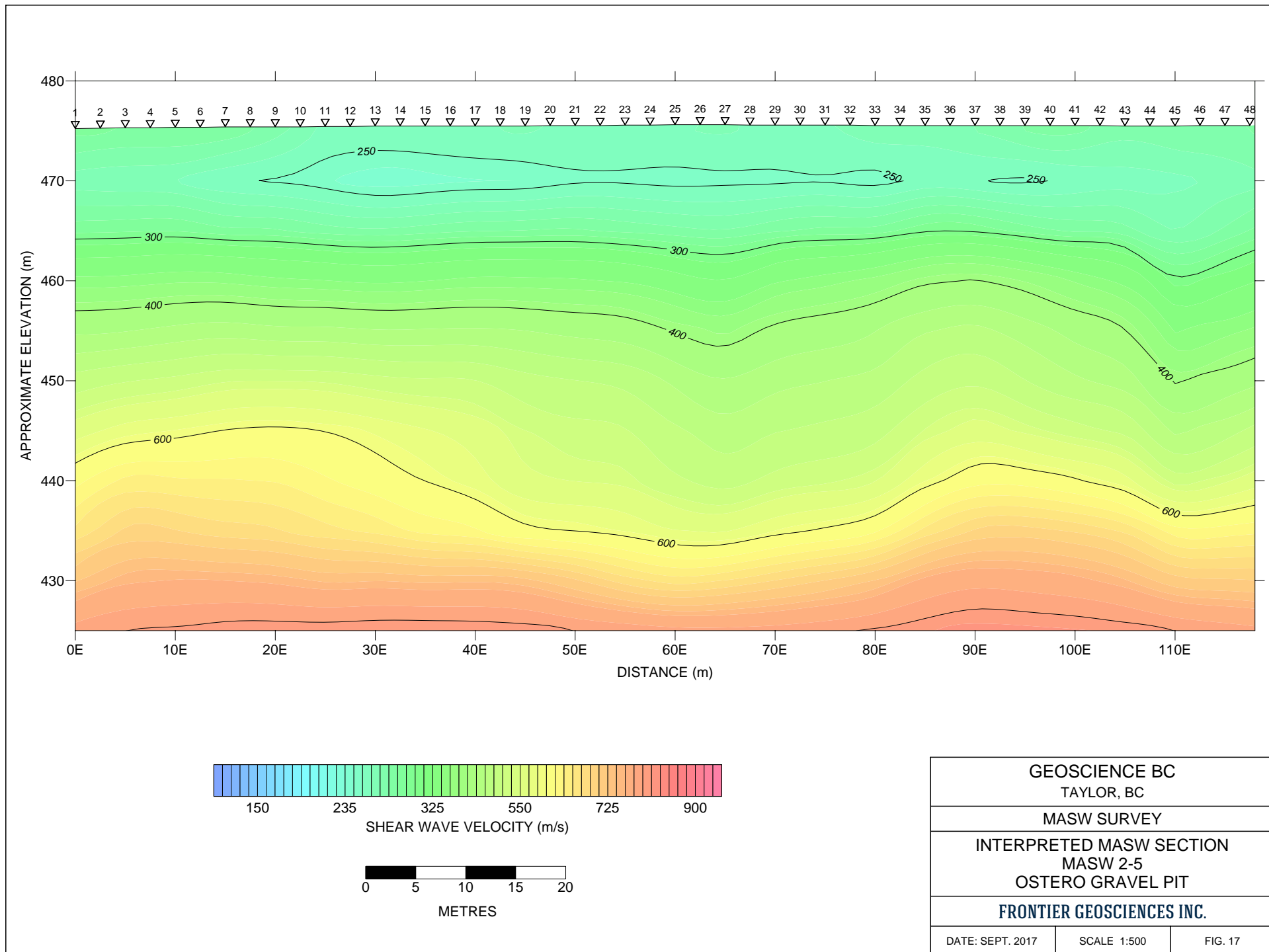
OSTERO GRAVEL PIT  
SITE PLAN

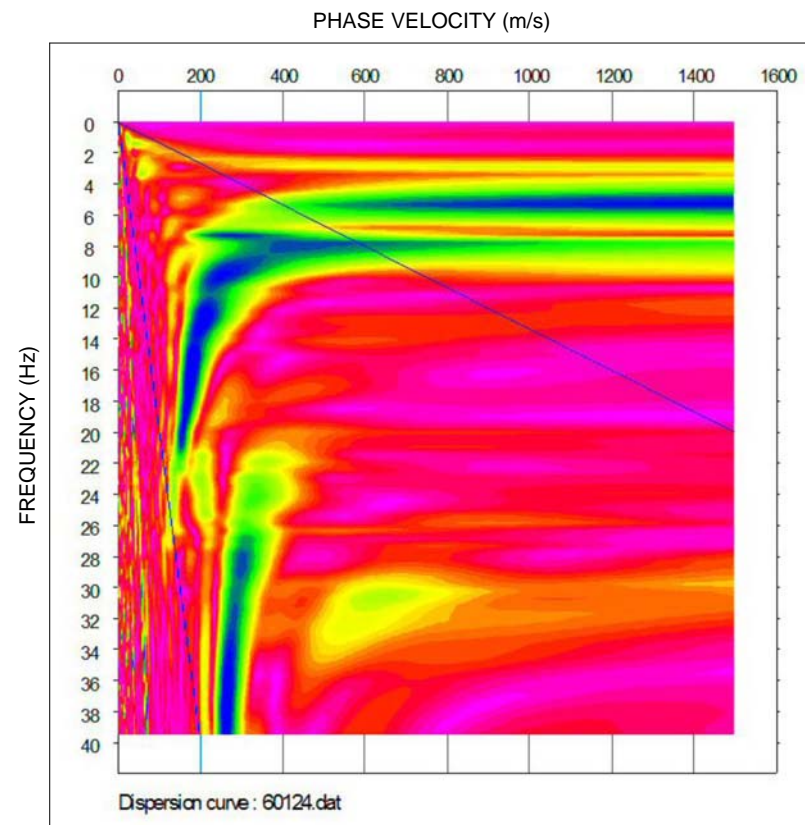
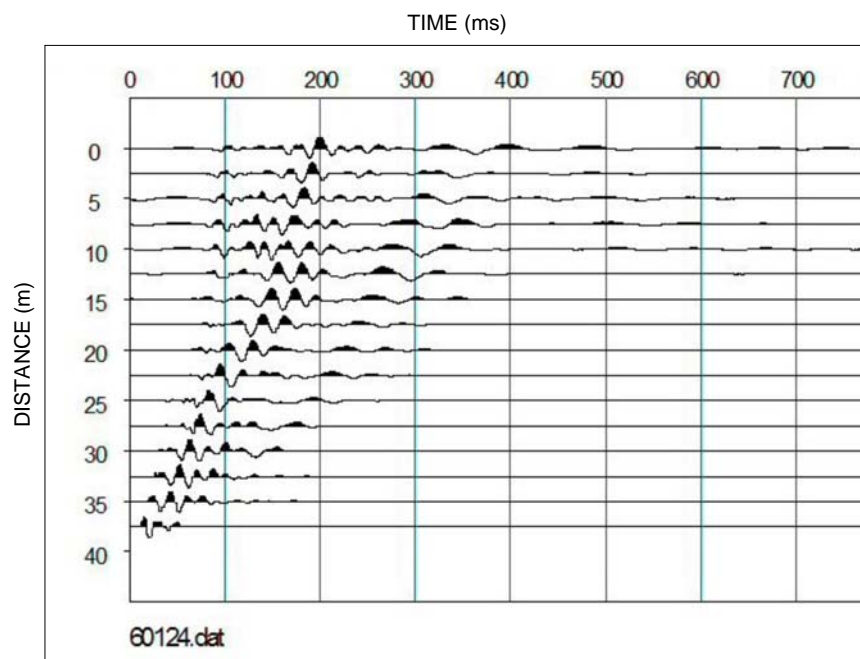
FRONTIER GEOSCIENCES INC.

DATE: SEPT. 2017

SCALE 1:2,500

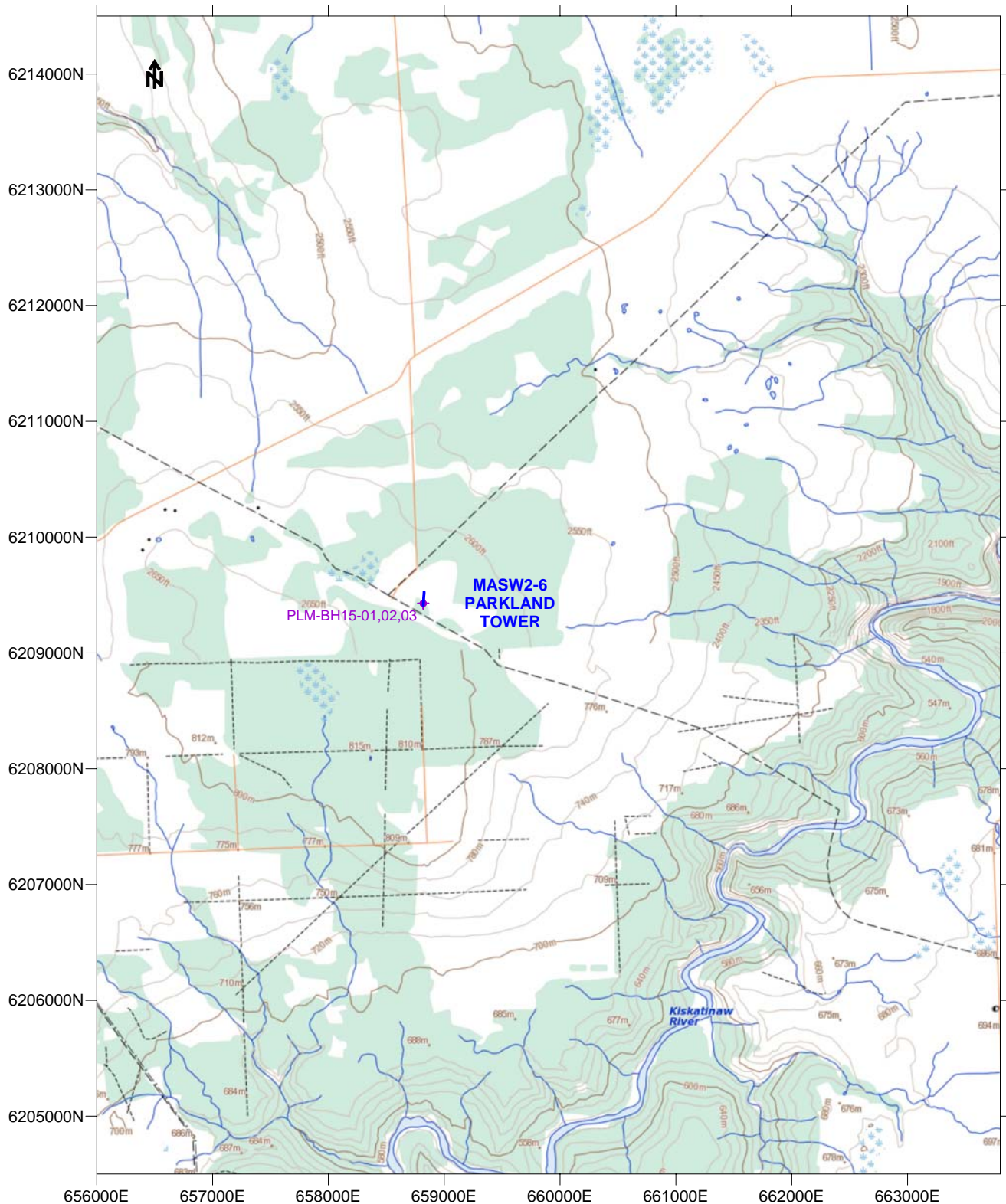
FIG. 16





LINE: MASW2-5  
 SHOT NUMBER: 24  
 SOURCE LOCATION: 38.75m

GEOSCIENCE BC TAYLOR, BC		
MASW SURVEY		
EXAMPLE DATA MASW 2-5 OSTERO GRAVEL PIT		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2017		FIG. 18



0 500 1000 1500 2000  
METRES

**GEOSCIENCE BC**  
KISKATINAW RIVER AREA, BC

**MASW SURVEY**

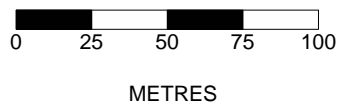
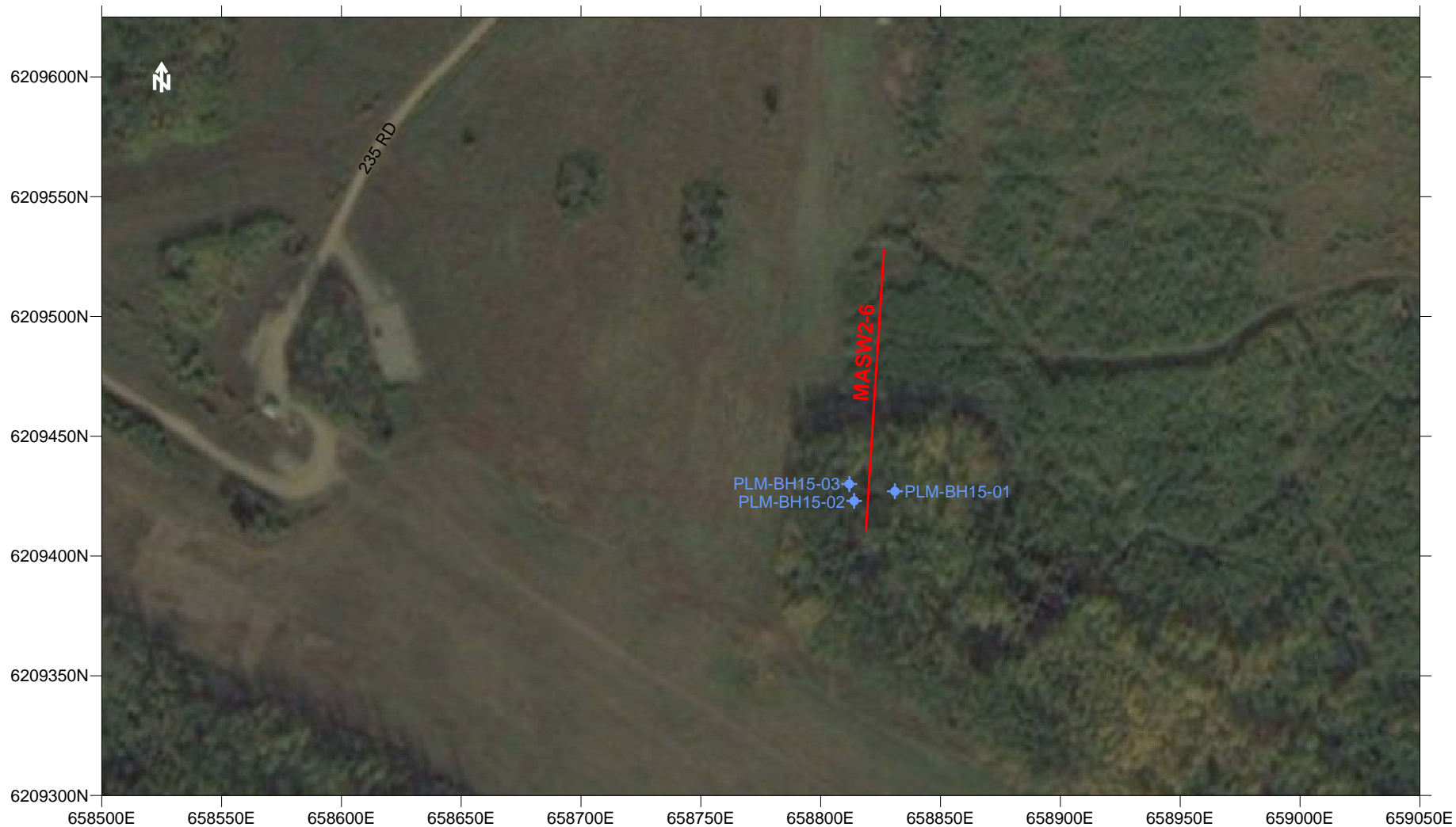
**PARKLAND TOWER  
SURVEY LOCATION PLAN**

**FRONTIER GEOSCIENCES INC.**

DATE: SEPT. 2017

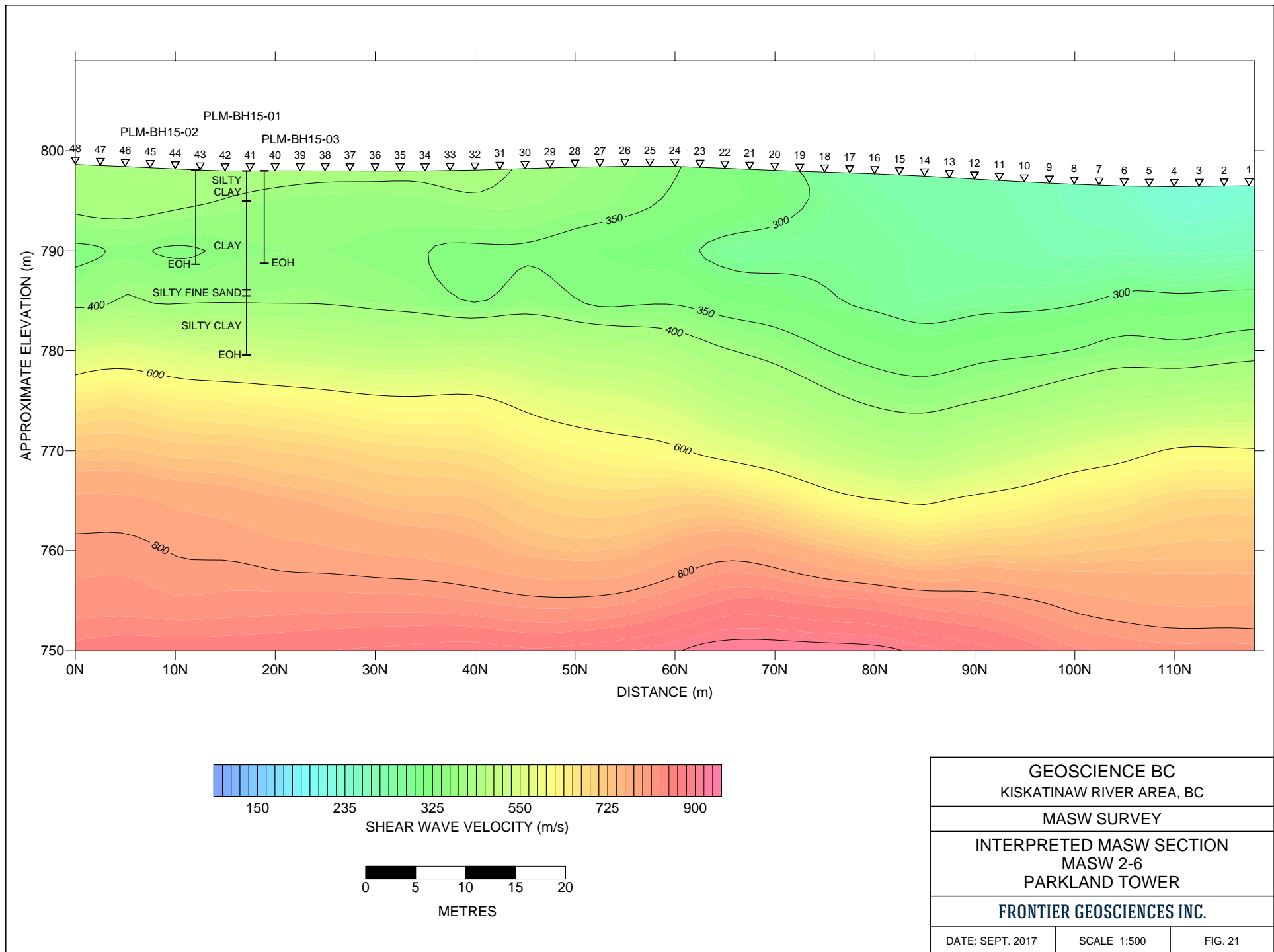
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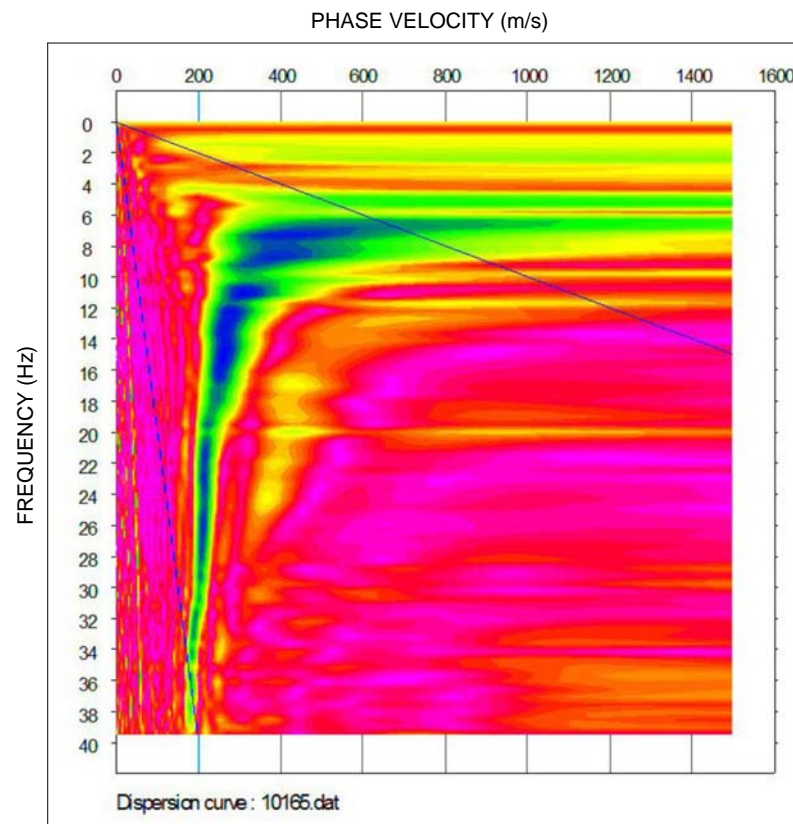
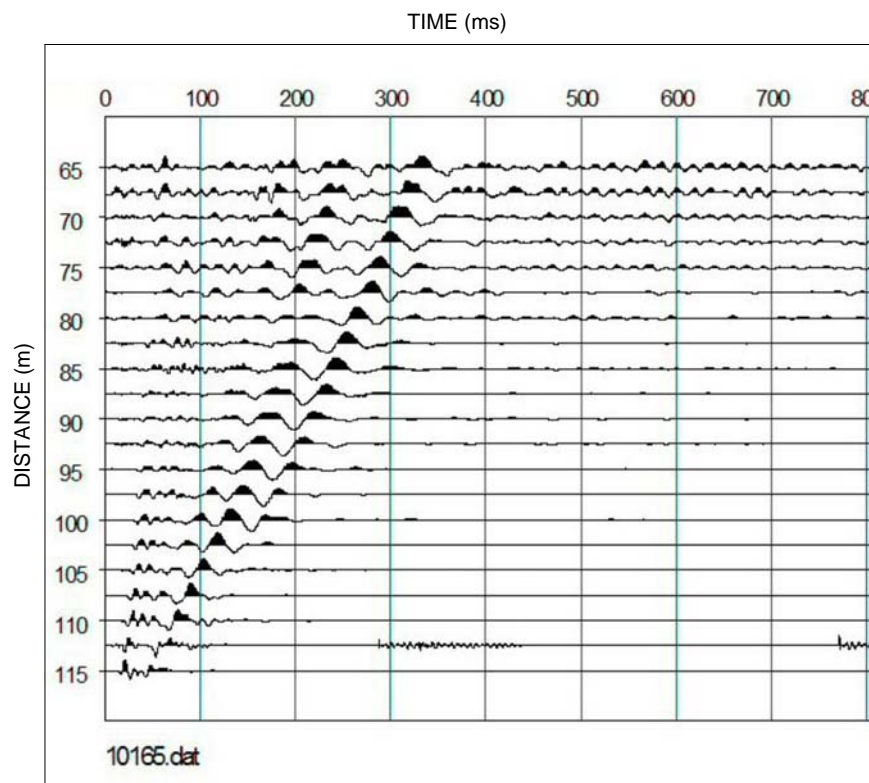
FIG. 19



GOOGLE EARTH  
UTM ZONE 10N

<b>GEOSCIENCE BC</b> KISKATINAW RIVER AREA, BC		
<b>MASW SURVEY</b>		
<b>PARKLAND TOWER</b> <b>SITE PLAN</b>		
<b>FRONTIER GEOSCIENCES INC.</b>		
DATE: SEPT. 2017	SCALE 1:2,500	FIG. 20





LINE: MASW2-6  
 SHOT NUMBER: 65  
 SOURCE LOCATION: 188.75m

GEOSCIENCE BC KISKATINAW RIVER AREA, BC		
MASW SURVEY		
EXAMPLE DATA MASW 2-6 PARKLAND TOWER		
FRONTIER GEOSCIENCES INC.		
DATE: SEPT. 2017		FIG. 22