Introduction of SASW Technique and Its Data Reduction Procedures

Prepared

by

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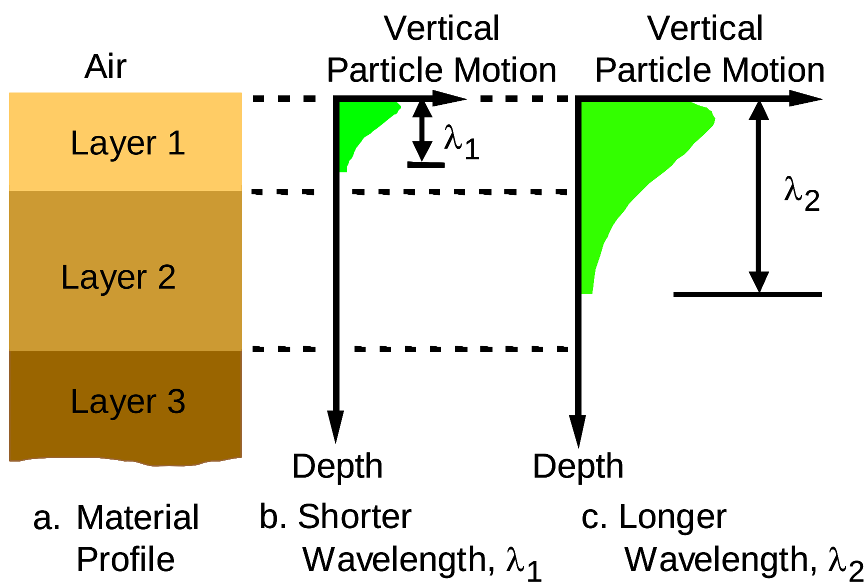


Figure 1 Illustration of Surface Waves with Different Wavelengths Sampling Different Materials in a Layered System which Results in Dispersion in Wave Velocities

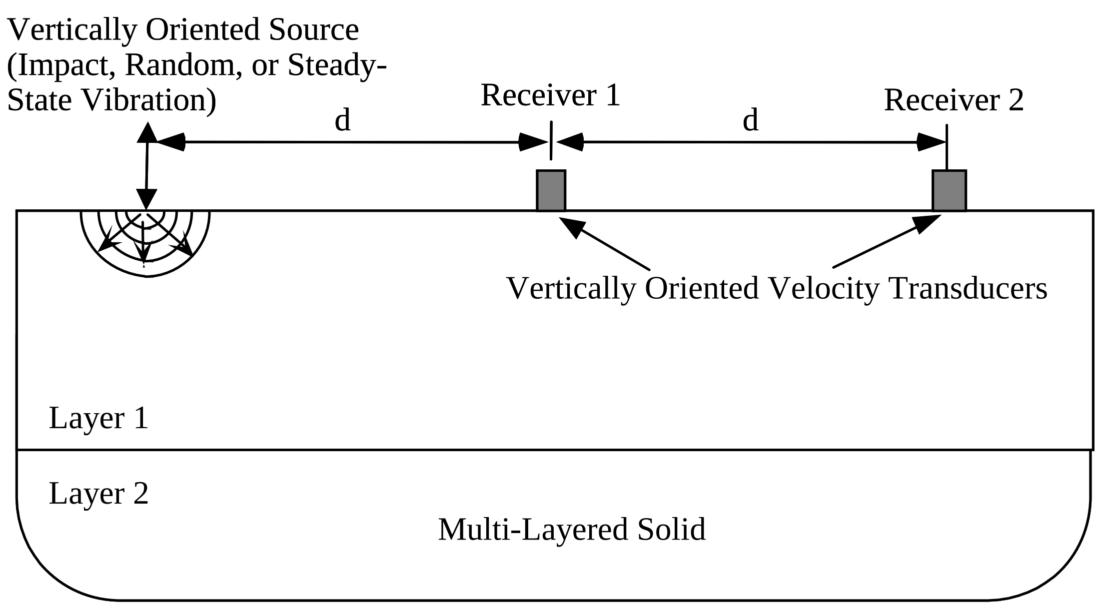


Figure 2 Schematic Diagram of the Generalized Equipment Arrangement Used in Spectral-Analysis-of-Surface-Waves (SASW) Testing

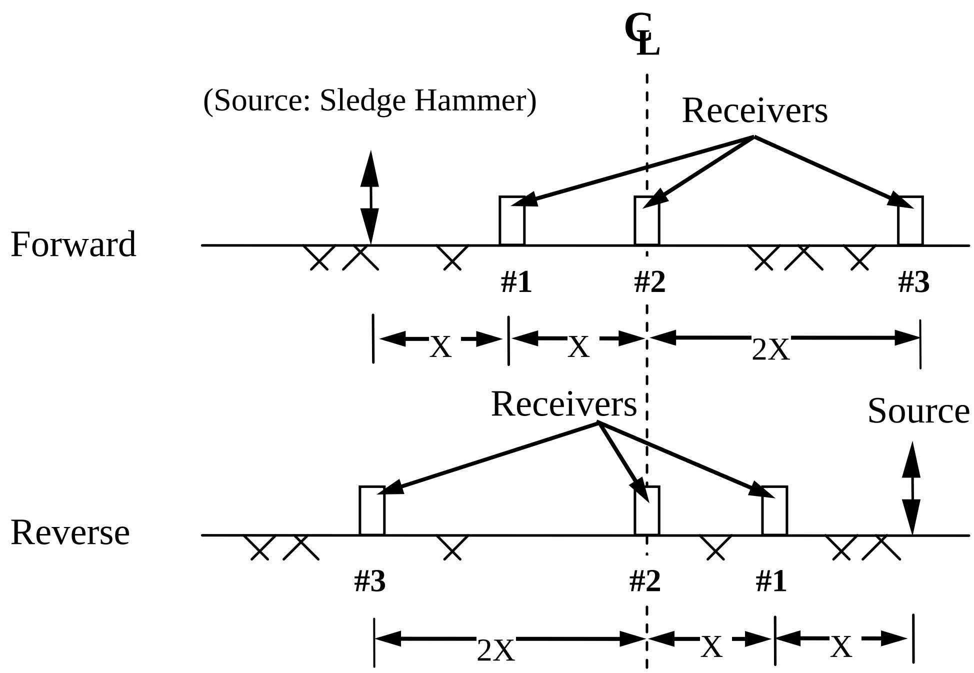


Figure 3 Common-Middle-Receiver Geometry Used in SASW Testing at Hanford Sites

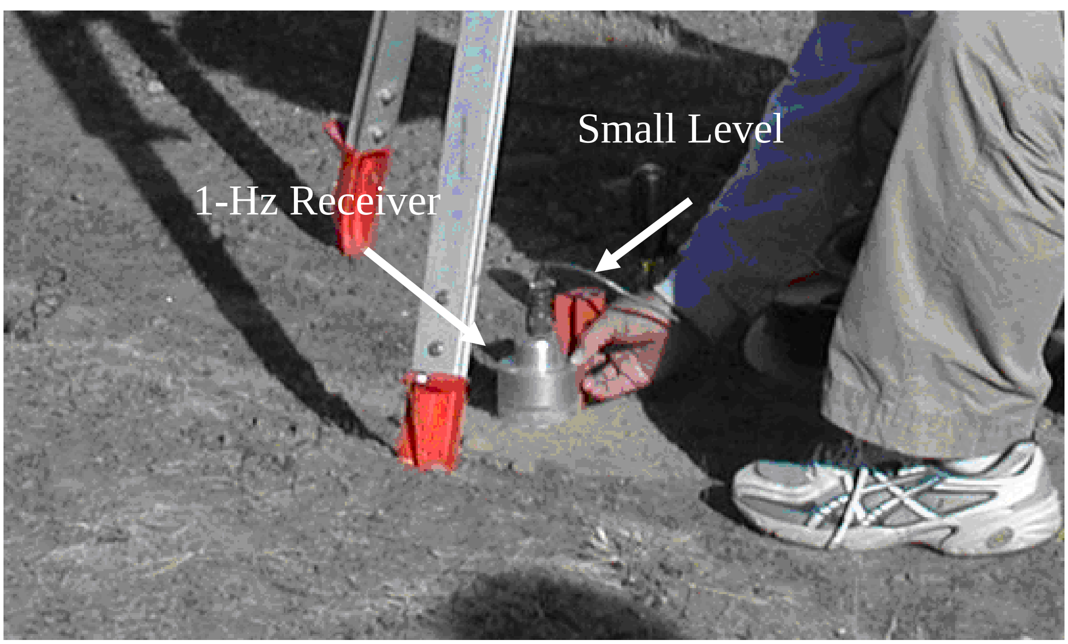


Figure 4 Photograph of 1-Hz Geophone Semi-embedded in the Ground and the Pre-test Check for Plumbness

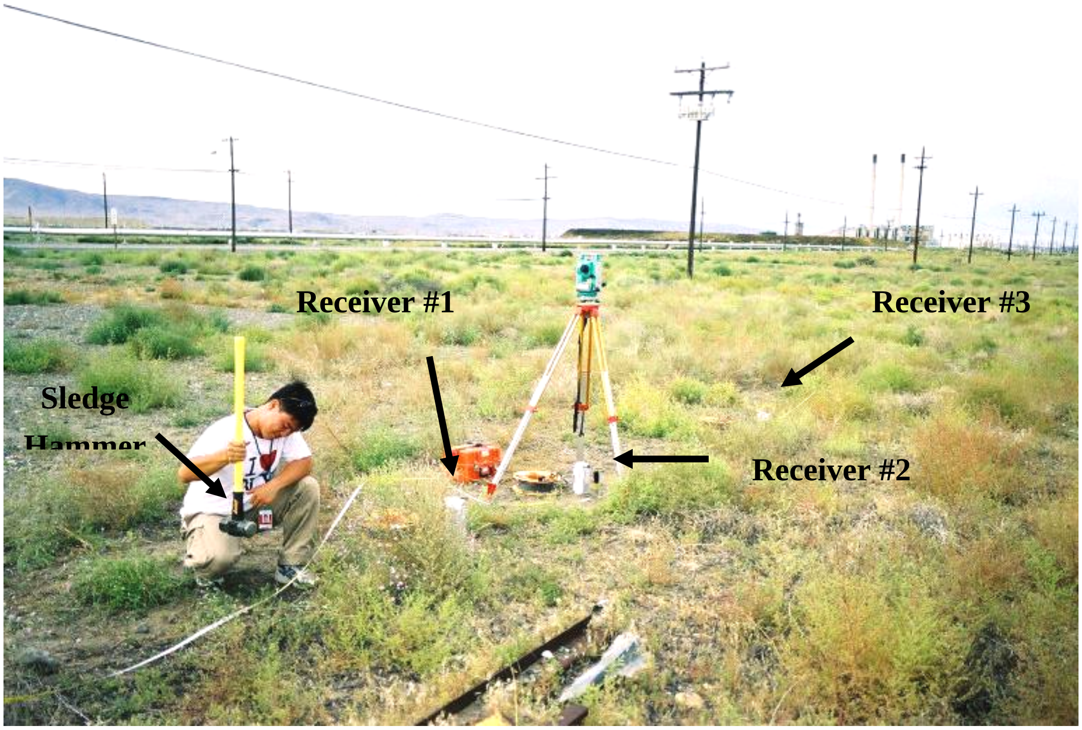


Figure 5 Photograph of Mr. Min Jae Jung Using the Sledge Hammer Source at Hanford Site H9

Figure 6 Photograph of Liquidator Operating in Stepped-Sine Mode at the Hanford Site H10

Figure 7 Photograph of Mr. Brady Cox Operating the Data Recording Equipment

Spectral Calculations

The dynamic signal analyzer was used to measure time-domain records (x(t) and y(t)) from the two receivers at each receiver spacing. These time records were then transformed into the frequency domain (X (f) and Y (f)) and used to calculate the power spectra (G_{XX} and G_{YY}), the cross spectrum (G_{XY}) and the coherence function (γ^2). Expressions for these quantities are:

$$G_{XX} = X^*(f) \bullet X(f) \tag{2}$$

$$G_{YY} = Y^*(f) \bullet Y(f) \tag{3}$$

$$G_{XY} = X^*(f) \bullet Y(f) \tag{4}$$

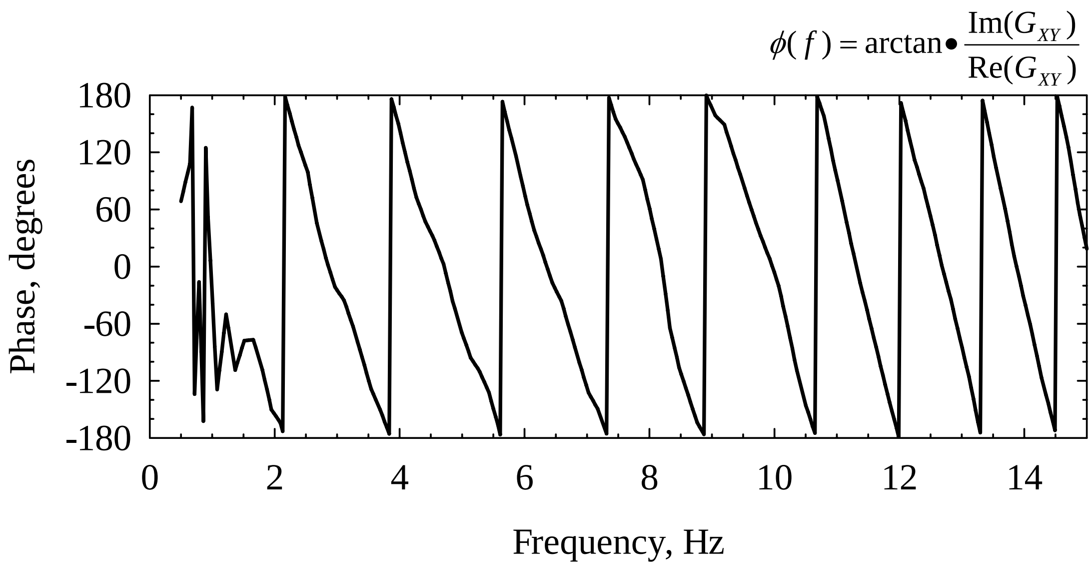
$$\phi(f) = \arctan \bullet \frac{\mathrm{Im}(G_{XY})}{\mathrm{Re}(G_{XY})} \tag{5}$$

$$\gamma^2(f) = \frac{\left|G_{XY}(f)\right|^2}{G_{XX}(f) \bullet G_{YY}(f)} \tag{6}$$

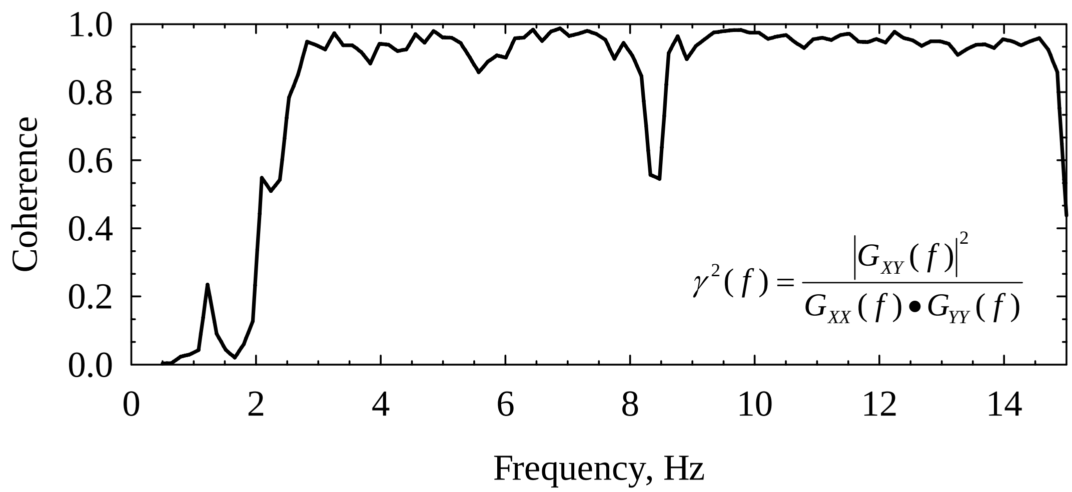
where $G_{XY}(f) = \frac{1}{N}\sum_{i=1}^{N} X^{'}(f) \bullet Y_i(f)$ is the cross power spectrum from coherent signal averaging, (*) represents the complex conjugate of the quantity, Im signifies the imaginary part of the expression, Re signifies the real part of the expression, and $\phi(f)$ is the relative phase between two receivers of the cross power spectrum.

The relative phase of the cross spectrum $\phi(f)$ is the key spectral quantity in SASW testing. The coherence function of averaged measurements is also important as an indicator of the quality of the measurement over the monitored frequency range. Low values of coherence indicate a possible decrease in data quality. The spectral functions were determined one frequency at a time in a stepped-sine fashion. The number of averages and integration time was adjusted in the field to control how long the source remained at each frequency. Typically 3 to 5 averages were used at each frequency in the determination of the spectral functions when Liquidator was used as the source. Five averages were typically used when the impact source (sledge hammer) was employed. The relative phase of the cross spectrum, simply called the phase hereafter, represents the phase difference of the motion at the two receivers. One set of spectral functions was measured for each receiver spacing and testing direction.

As an example, the wrapped phase spectrum and coherence function from one receiver spacing are shown in Figure 11. These data were collected with the 600-ft receiver spacing recorded at Site H1. Construction of individual dispersion curves from each receiver pair and combining them into composite dispersion curves are discussed below.

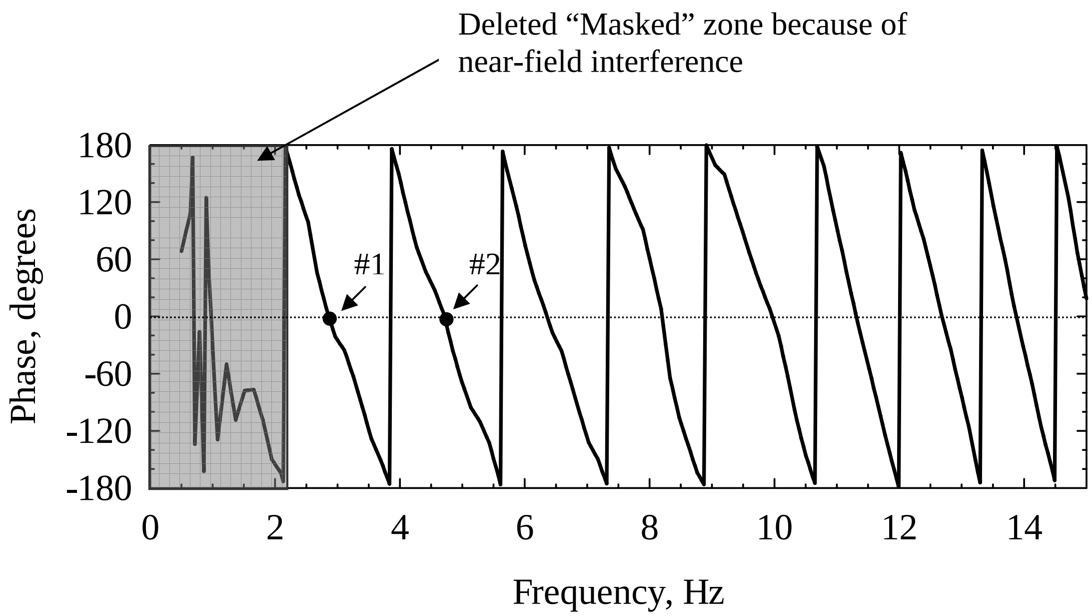


a. Cross Power Spectrum

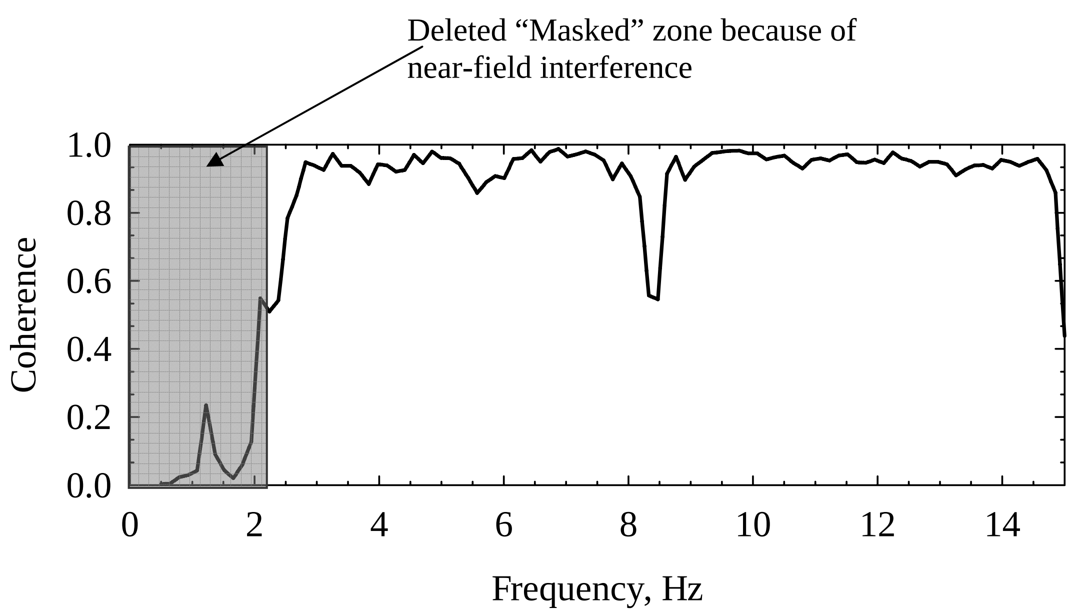


b. Coherence Function

Figure 8 Phase of the Cross Power Spectrum and Coherence Function Measured at Site H1 with a 600-ft Receiver Spacing



a. Cross Power Spectrum



b. Coherence Function

Figure 9 Phase of the Cross Power Spectrum and Coherence Function Measured at Site H1 with 600-ft Receiver Spacing Showing the Masking Applied to the Near-Field Region

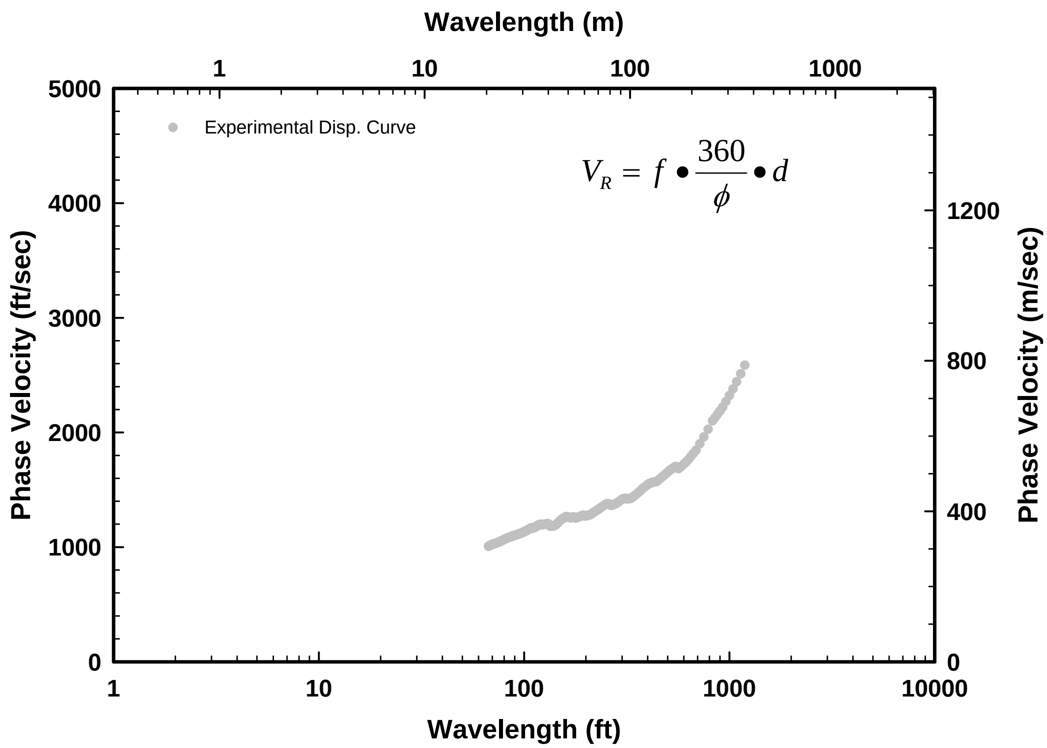


Figure 10 Individual Dispersion Curve Created from the Unwrapped Phase Record in Figure 12a Measured with a 600-ft Receiver Spacing at Site H1

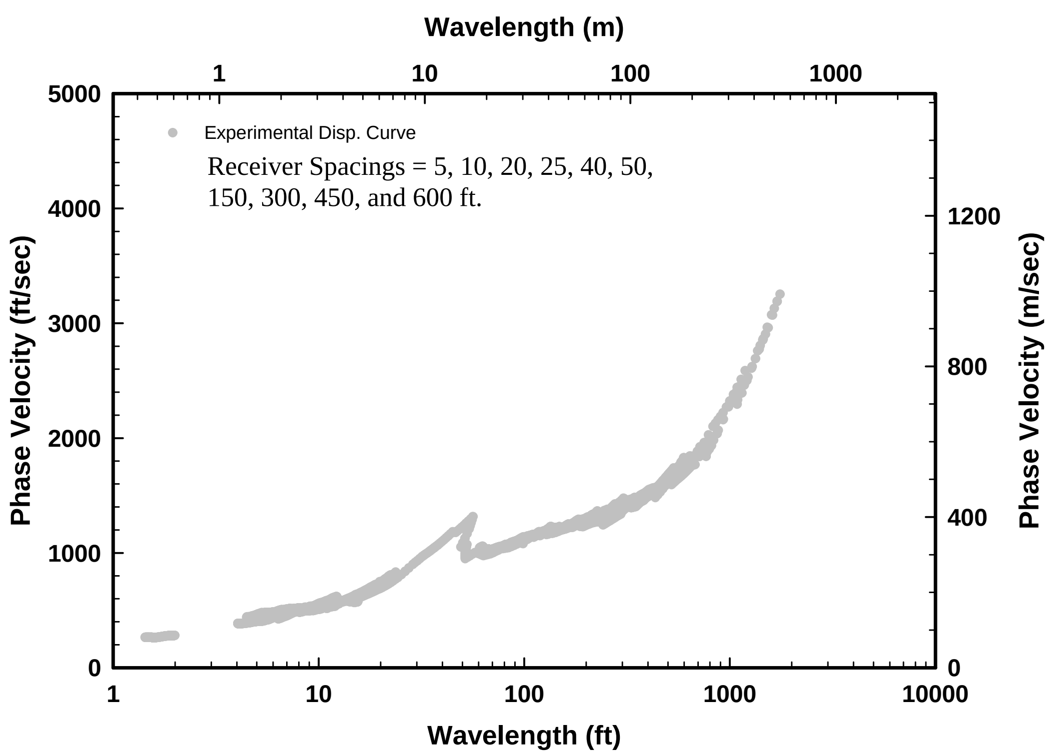
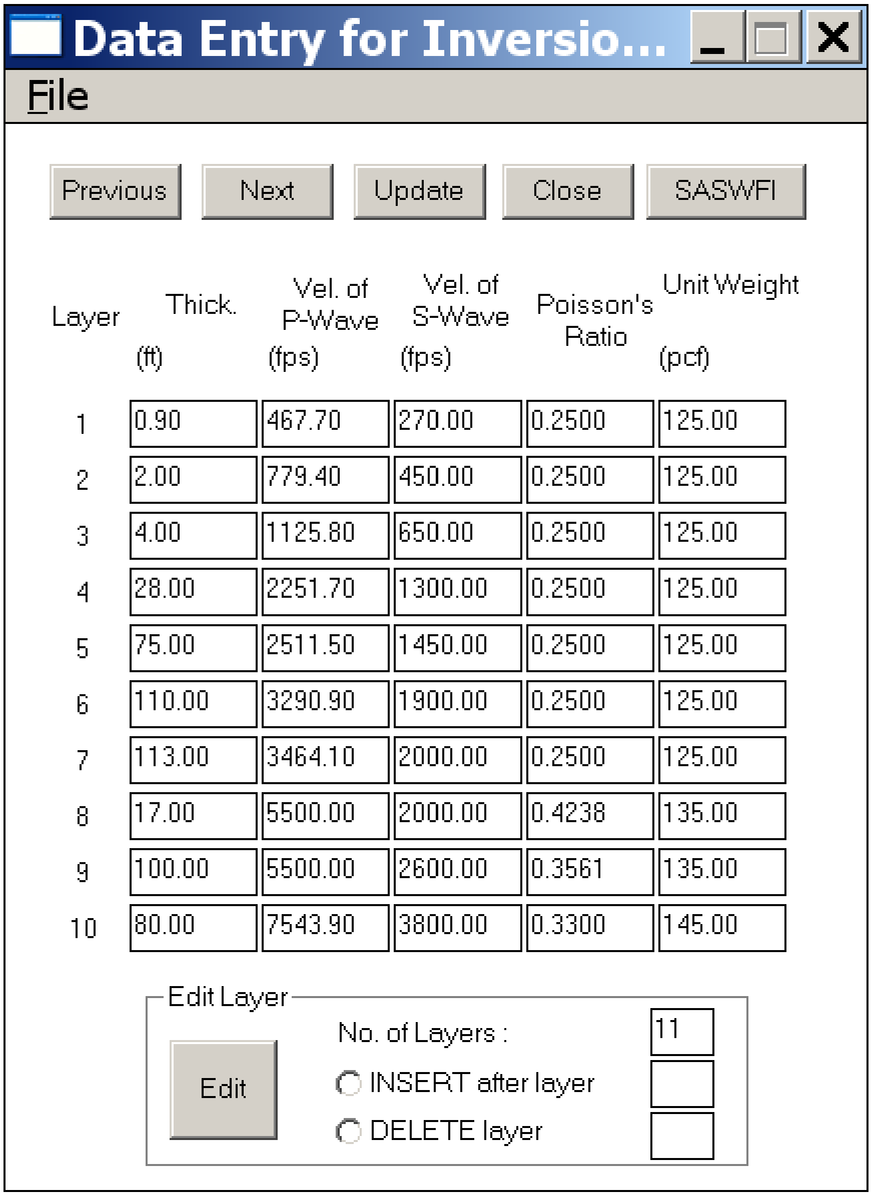


Figure 11 Composite Experimental Dispersion Curve Created from Phase Measurements Performed at all Receiver Spacings at Site H1



Layer	Thick. (ft)	Vel. of P-Wave (fps)	Vel. of S-Wave (fps)	Poisson's Ratio	Unit Weight (pcf)
1	0.90	467.70	270.00	0.2500	125.00
2	2.00	779.40	450.00	0.2500	125.00
3	4.00	1125.80	650.00	0.2500	125.00
4	28.00	2251.70	1300.00	0.2500	125.00
5	75.00	2511.50	1450.00	0.2500	125.00
6	110.00	3290.90	1900.00	0.2500	125.00
7	113.00	3464.10	2000.00	0.2500	125.00
8	17.00	5500.00	2000.00	0.4238	135.00
9	100.00	5500.00	2600.00	0.3561	135.00
10	80.00	7543.90	3800.00	0.3300	145.00

Figure 12 Window of Parameters Used to Generate SASW Theoretical Dispersion Curve

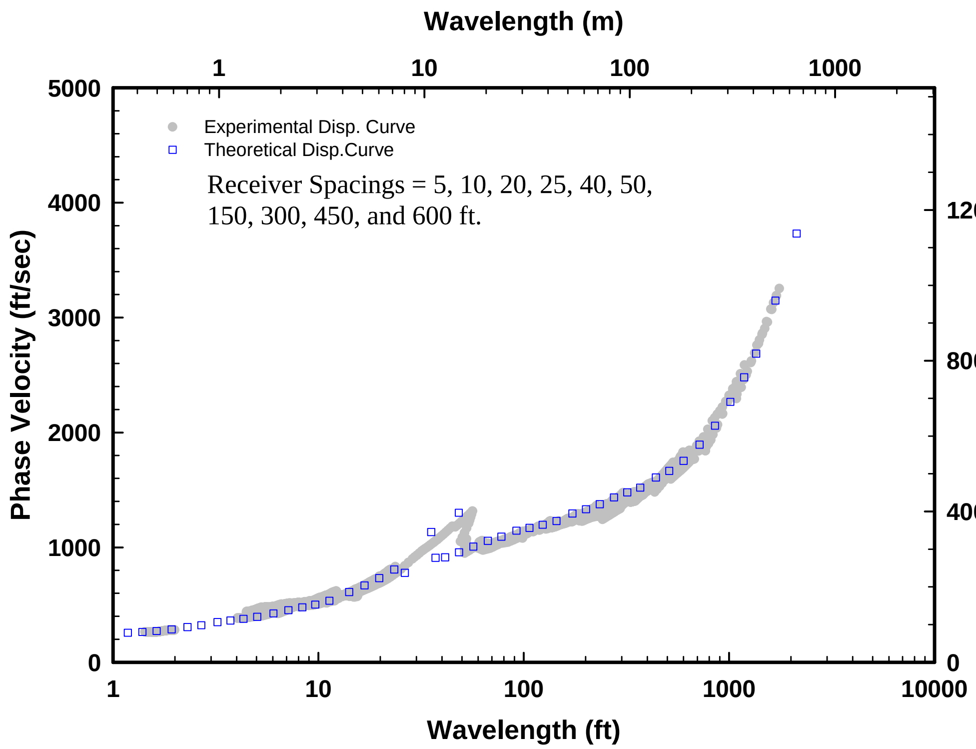


Figure 13 Comparison of the Fit of the Theoretical Dispersion Curve to the Experimental Dispersion Curve at Site H1

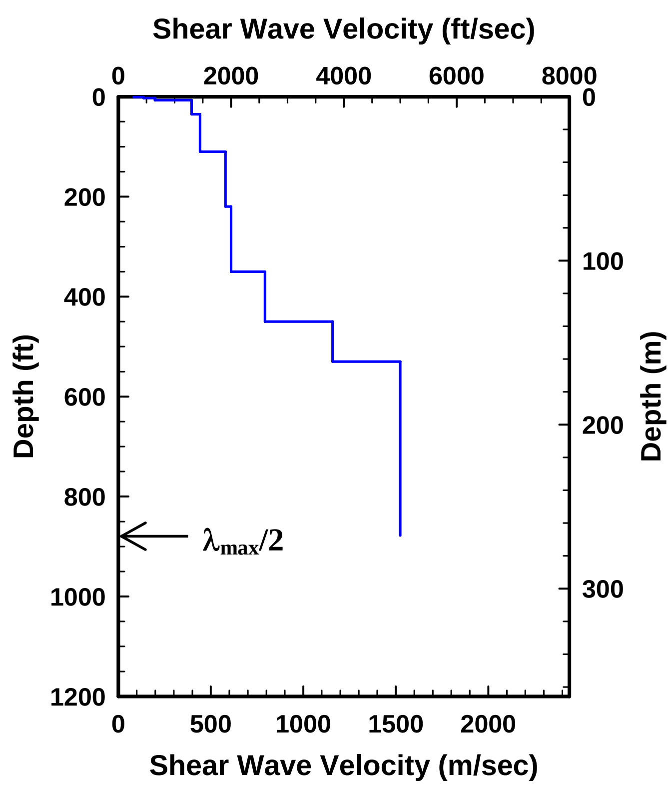


Figure 14 Final Shear Wave Velocity Profile Determined at Site H1