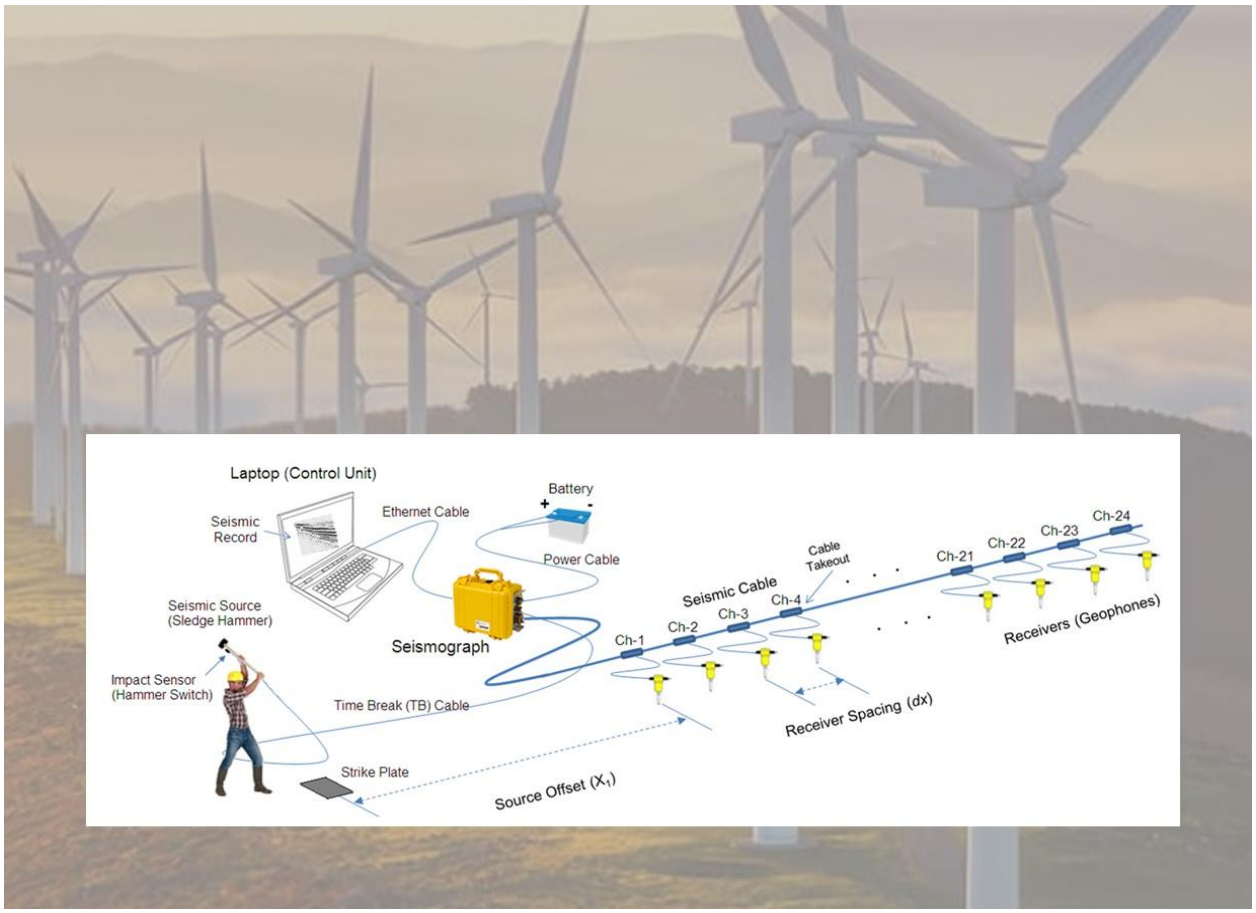
HOW TO RUN AN MASW SURVEY

An Illustration-Based Handbook for

"1D and 2D Shear-Wave Velocity (Vs) Profiling"



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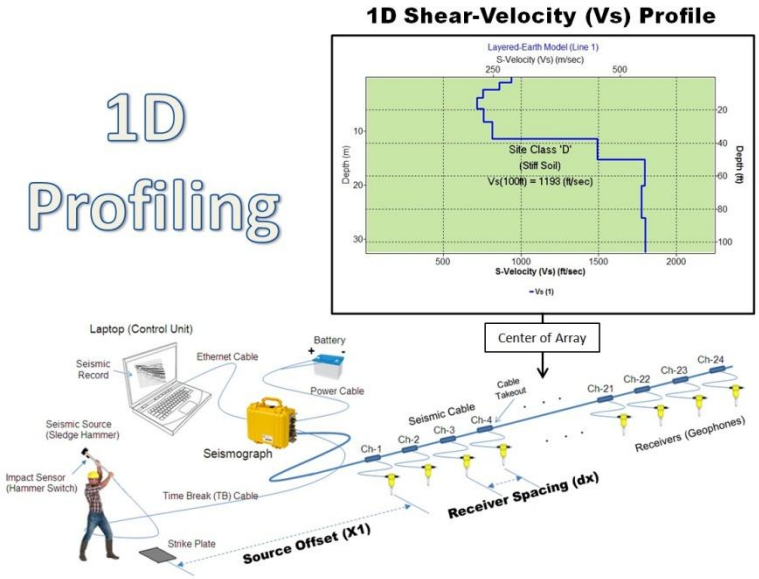
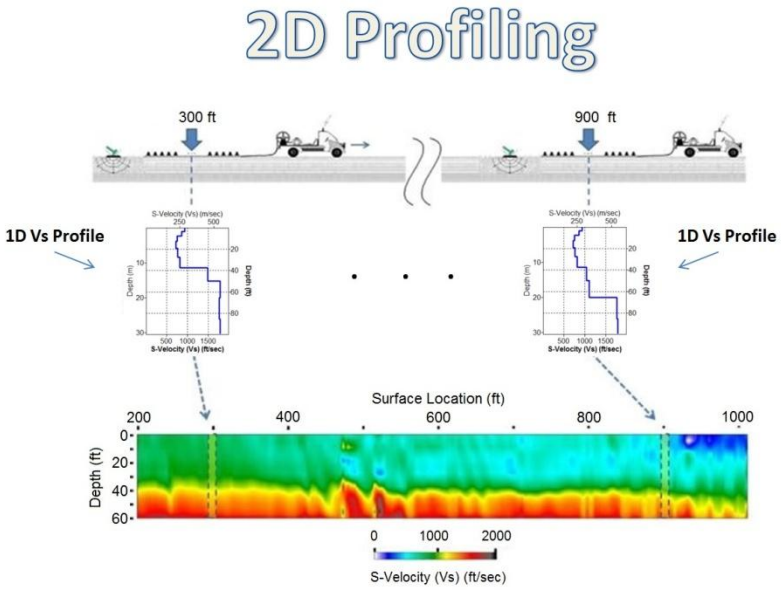
1. How To Run an MASW Survey – 6 Steps

To design and start an MASW survey for shear-wave velocity (Vs) profiling, follow the six (6) steps outlined below. **Common and most recommended selections are indicated in *underlined italic***.

STEP 1: Select Velocity (Vs) Profile To Be Obtained (1D or 2D)

a. ***1D profiling*** (e.g., seismic site characterization or Vs30m investigation)
b. ***2D profiling*** (e.g., soil-bedrock characterization, anomaly detection, etc.)





STEP 2: Select Survey Type (Active, Passive, Active-Passive)

a. ***Active (ACT) Survey***

Surface waves are actively generated by using an impact source like a sledgehammer. This provides most reliable velocity (Vs) results. Maximum depth of investigation (Zmax) is usually less than about 100 ft. Use a sampling interval (dt) of 1 ms and a recording time (T) of 2 seconds: i.e., *dt = 1* ms and *T = 2 sec*.

b. **Passive (PAS) Survey**

No active impact source is used. Instead, the survey completely rely on ambient surface waves passively generated by, for example, traffic. This is used only for deep depth investigation (e.g., > 300 ft). Results are less reliable than those from the ACT survey. Pure passive surveys are rarely used. Instead, whenever it is necessary to utilize passive surface waves, the following active-passive combined (COM) surveys are more commonly used. Use *dt = 4 ms* and *T = 30 sec*.

c. **ACT-PAS combined (COM) survey**

This is identical to ACT survey except for a longer recording time (e.g., T = 30 sec). This can be used for a roadside survey. Multiple hammer impacts can be applied during the long recording (e.g., 10 or more impacts) that will enhance bandwidth of recorded surface waves. Whenever the survey site is nearby a busy street or a major highway, this type of survey is recommended. Use *dt = 4 ms* and *T = 30 sec*.

dt = sampling interval, T = recording time

dt = *1.0 ms*
T = *2 sec*

dt = *4.0 ms*
T = *30 sec*

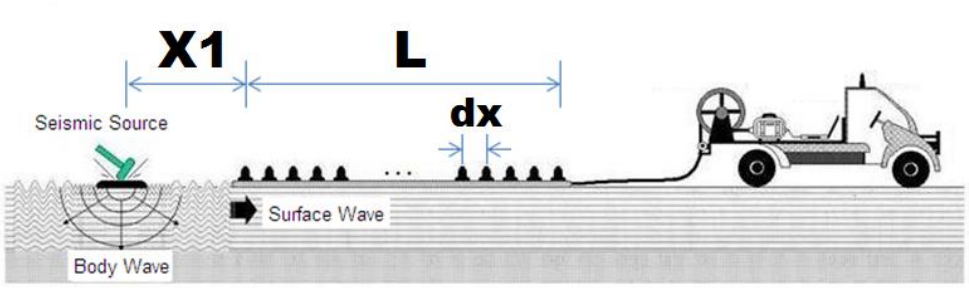
dt = *4.0 ms*
T = *30 sec*

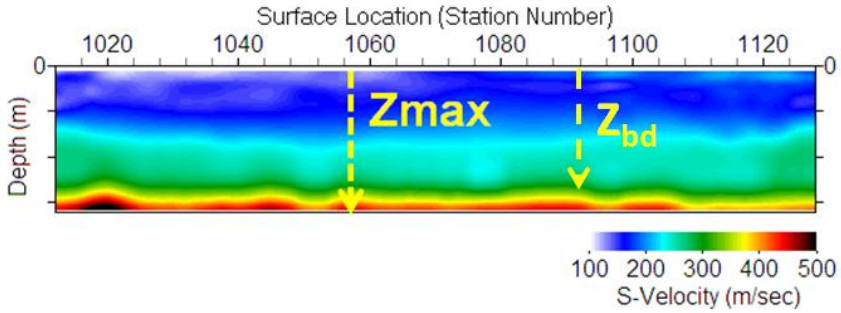
STEP 3: Select Receiver Spacing (dx) Based On Expected Bedrock Depth (Z_{bd})

Top of the bedrock is the maximum depth that surface waves can penetrate in most of engineering seismic surveys. Therefore, the maximum investigation depth (Zmax) is usually set equal to, or slightly deeper than (e.g., by 10%), the bedrock depth (Z_{bd}). The receiver array length (L) must be at least twice longer than Zmax to capture sufficiently long surface waves. The receiver spacing (dx) is then determined approximately as, usually a whole number of, L/Nch (Nch=number of channels used for acquisition). The constant source offset (X1) for 2D surveys is determined as about 25% of L, e.g., 6dx for 24-channel acquisition. The following are most recommended dx and X1 values for different bedrock depths.

a. *dx = 5 ft and X1 = 30 ft* (Z_{bd} < 50 ft)
b. dx = 10 ft and X1 = 60 ft (50 ft < Z_{bd} < 100 ft)
c. dx = 15 ft and X1 = 90 ft (100 ft < Z_{bd} < 200 ft)
d. dx = 20 ft and X1 = 120 ft (200 ft < Z_{bd} < 300 ft)

$$L \approx 2 \times Zmax$$





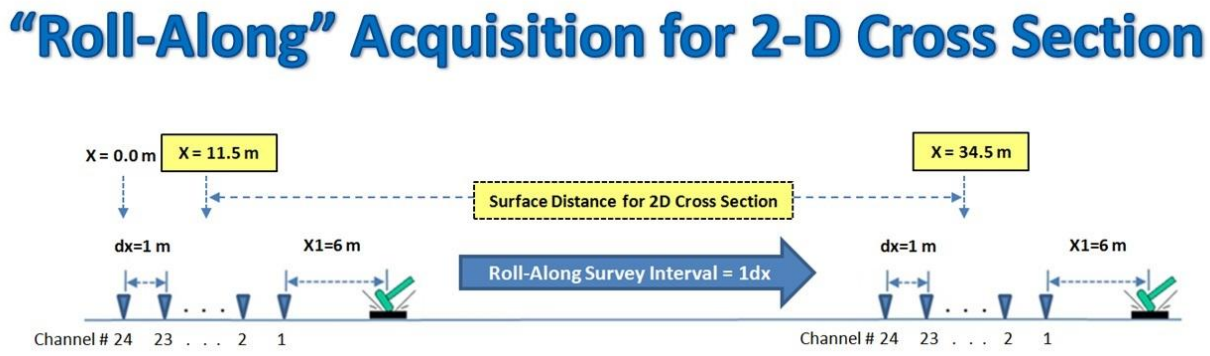
STEP 4: Select Survey Interval (dSR) (for 2D survey with a land streamer*)

For a 2D survey, the same source-receiver (SR) configuration must be used at all measurement locations to maintain a consistency in the surface wave measurements. The SR configuration moves by a fixed amount of distance (e.g., 1dx), which is called a survey interval (dSR), and this mode of acquisition is repeated as many times as needed. This is called a "roll-along" mode of acquisition.

a. ***one receiver spacing (1dx)***
This will provide the highest lateral resolution in the final 2D velocity (Vs) cross section. Whenever bedrock depth (Z_{bd}) and/or overburden materials are expected to change significantly along the survey line, this is the most optimum survey interval.

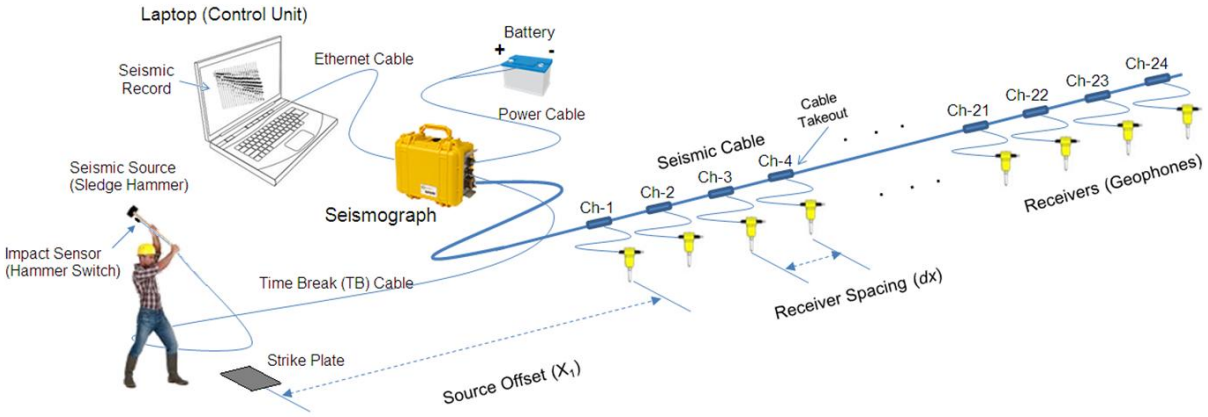
b. multiple dx (e.g., 2dx, 3dx, etc.)
This can be used if the lateral variation of Z_{bd} and overburden materials is expected to be mild.

**If the land streamer is not available and a 2D profiling is still needed, ask for the instructions on the "shoot-through survey with a fixed array."*

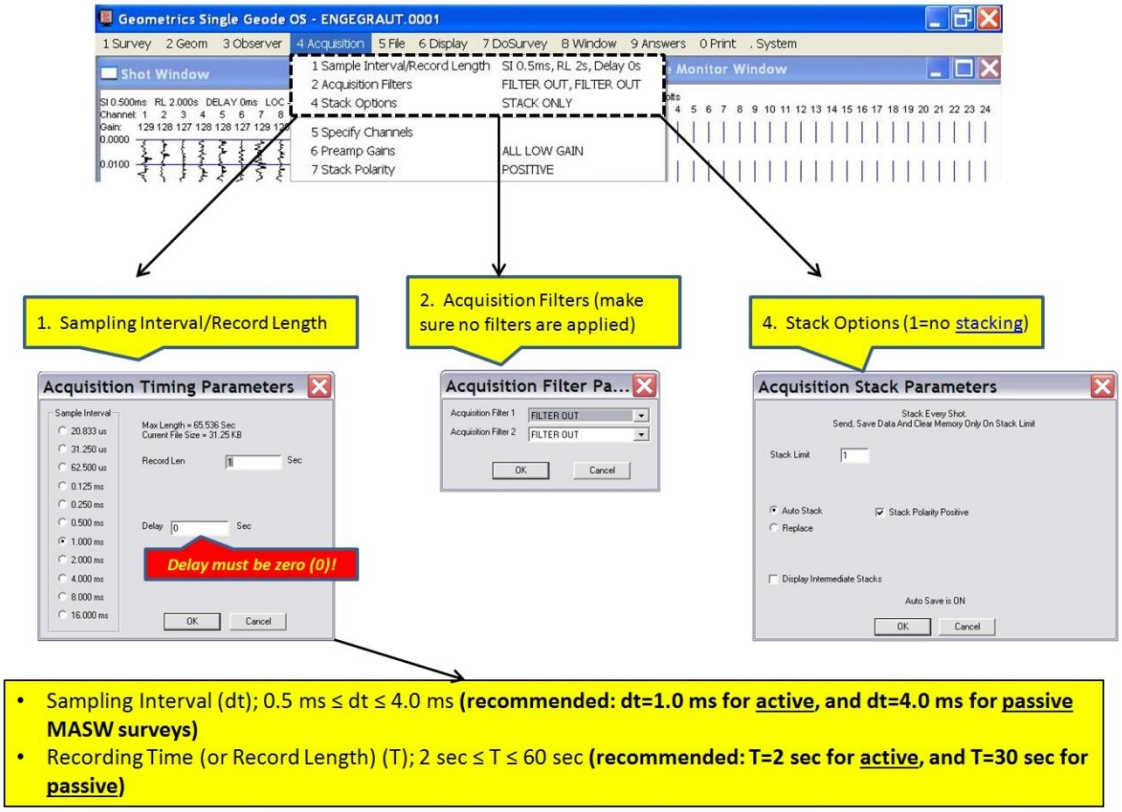


STEP 5: Deploy Equipment and Setup Acquisition Software

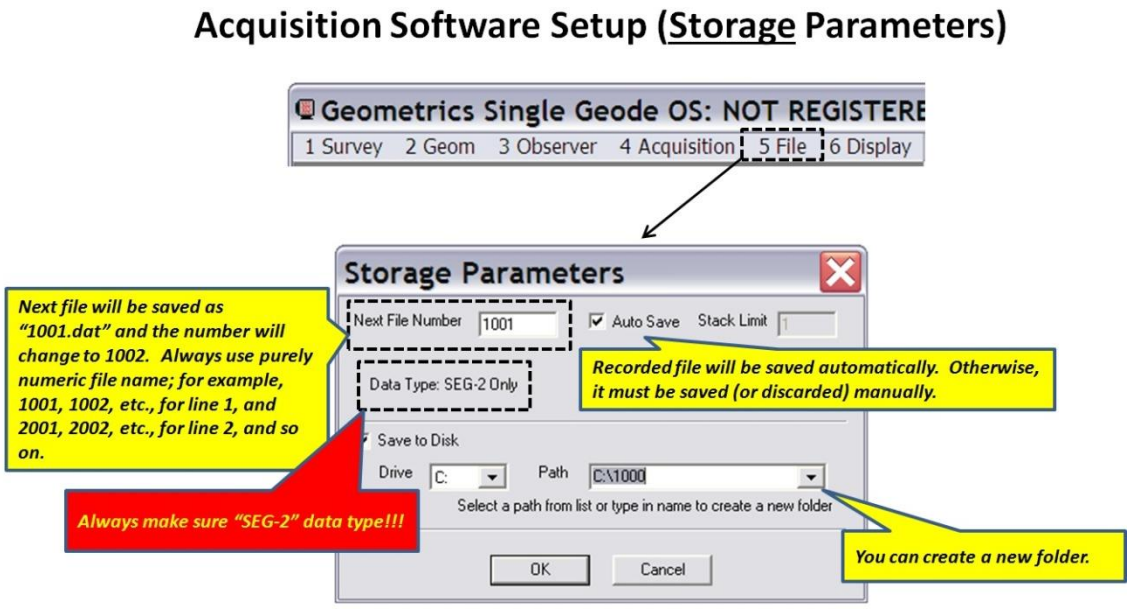
Deploy hardware components by referring to the schematic below that shows common items and connections for MASW surveys. Setup acquisition software for the seismograph. Setting key acquisition parameters are illustrated below.



Acquisition Software Setup (Recording Parameters)

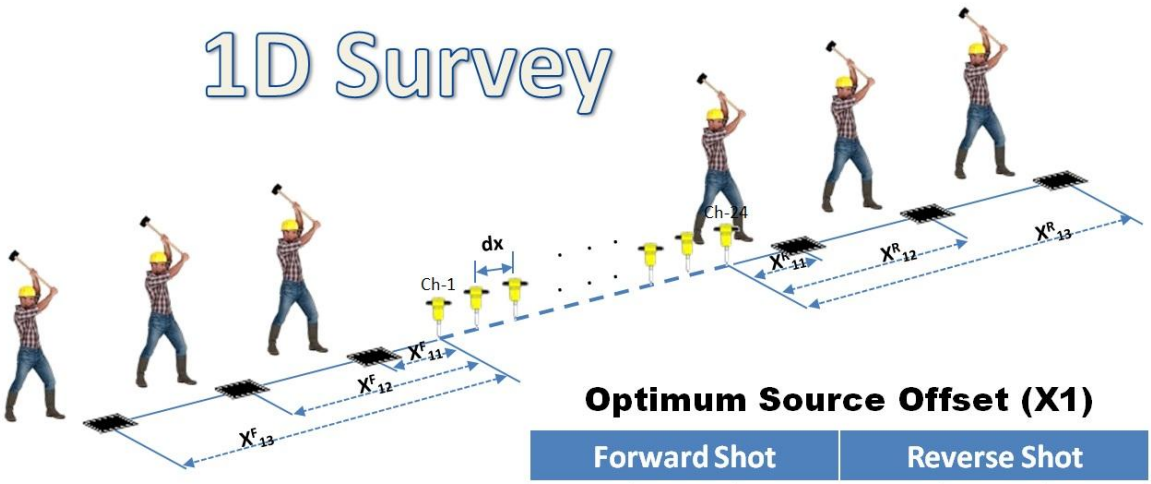


- Sampling Interval (dt); 0.5 ms ≤ dt ≤ 4.0 ms **(recommended: dt=1.0 ms for active, and dt=4.0 ms for passive MASW surveys)**
- Recording Time (or Record Length) (T); 2 sec ≤ T ≤ 60 sec **(recommended: T=2 sec for active, and T=30 sec for passive)**



STEP 6: Start Survey

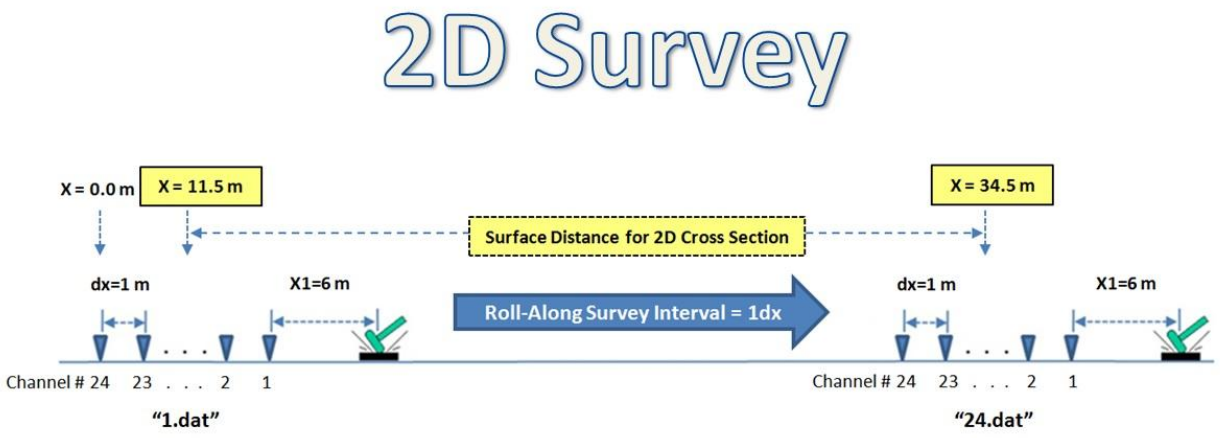
For a 1D survey, collect multiple files (e.g., six) with different source offsets (X1's) from both ends of a stationary receiver array as illustrated below (e.g., ***X11=dx, X12=6dx, and X13=12dx***). Field geometry of each file may be properly set using the acquisition software. Or it can be skipped. However, the information (e.g., source and receiver locations) must be kept in a separate field note. Please refer to the " Field Note (Sample Cases)" for an actual survey case.

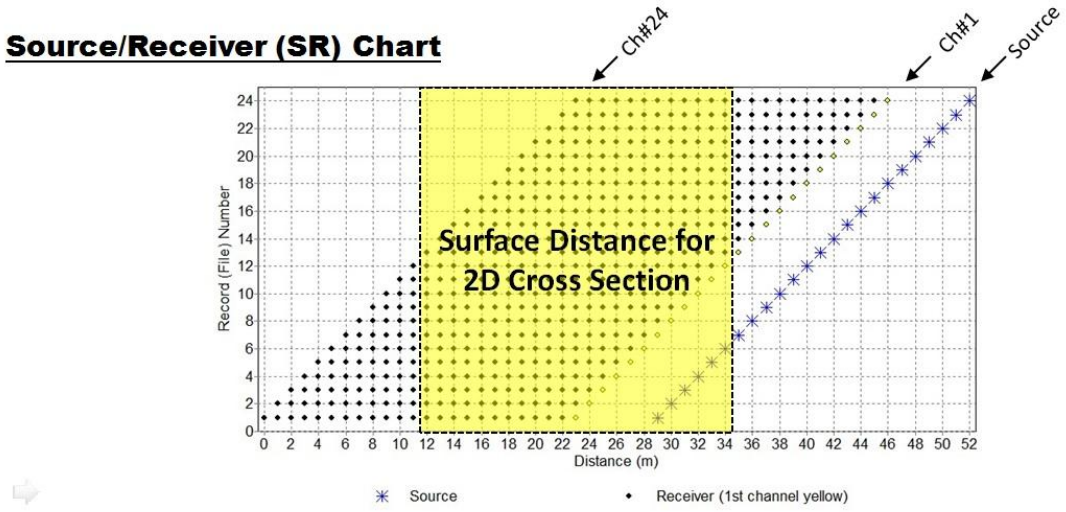


Optimum Source Offset (X1)

Forward Shot			Reverse Shot		
X^F_{13}	X^F_{12}	X^F_{11}	X^R_{11}	X^R_{12}	X^R_{13}
12dx	6dx	1dx	1dx	6dx	12dx

For a 2D survey, an optimum X1 of 6dx is commonly used for a 24-channel acquisition system. After saving a file at one location, the same source/receiver (SR) configuration is moved to the next location by a fixed survey distance (e.g., dSR=1dx). This "roll-along" acquisition mode is repeated as many times as needed to cover a required distance. The start and end points in the final 2D velocity (Vs) cross section to be obtained afterward will be the mid points of the receiver arrays at the first and last survey locations as illustrated below. This must be accounted for when placing the receiver arrays at the beginning and end of the survey. Field geometry of each file may be properly set using the acquisition software. Or it can be skipped. However, the information (e.g., source and receiver locations) must be kept in a separate field note. Please refer to the "Field Note (Sample Cases)" for an actual survey case.





2. Field Note (Template)

This is a template of field note for an MASW survey (1D or 2D). We recommend making a hard copy of this and use during the field survey. The most basic information to be filled is listed in red. Other items are optional.

MASW Field Note

Required fields are listed in red.

Project # (or name): _____

Date: _____/_____/_____ Time: _____ Observer: _____

SURVEY PURPOSE

Seismic Site Characterization (Vs30m): ☐ 2D Velocity (Vs) Cross Section: ☐

Other _____

SURVEY TYPE: Active (ACT): ☐ Passive (PAS): ☐ Active-Passive Combined (COM): ☐

SITE: Location: _____ Weather (Temp °F): _____

Special Note: _____

_____

INSTRUMENT

Seismograph: 24-CH ☐, 48-CH ☐, Other: _____-CH Note: _____

Source: _____ Receivers (Hz): _____ Stacking: _____

Sampling Interval (ms): _____ Recording Time (sec): _____ Note: _____

Special Notes: _____

_____

FIELD GEOMETRY

Distance Unit: feet ☐, meters ☐

Receiver Spacing: _____ Source Offset: _____ Survey/Shot Interval (for 2D): _____

Survey Mode: land streamer: ☐ fixed-spread ☐ Other _____

Special Note: _____

GENERAL COMMENTS:

_____

No.	File Name (*.dat)	Surface Coordinate (feet ☐, meters ☐)			Note
		Source	1st Receiver	Last Receiver	
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

No.	File Name (*.dat)	Surface Coordinate (feet ☐, meters ☐)			Note
		Source	1st Receiver	Last Receiver	
11					
12					
13					
14					
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17					
18					
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No.	File Name (*.dat)	Surface Coordinate (feet ☐, meters ☐)			Note
		Source	1st Receiver	Last Receiver	
51					
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56					
57					
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90					

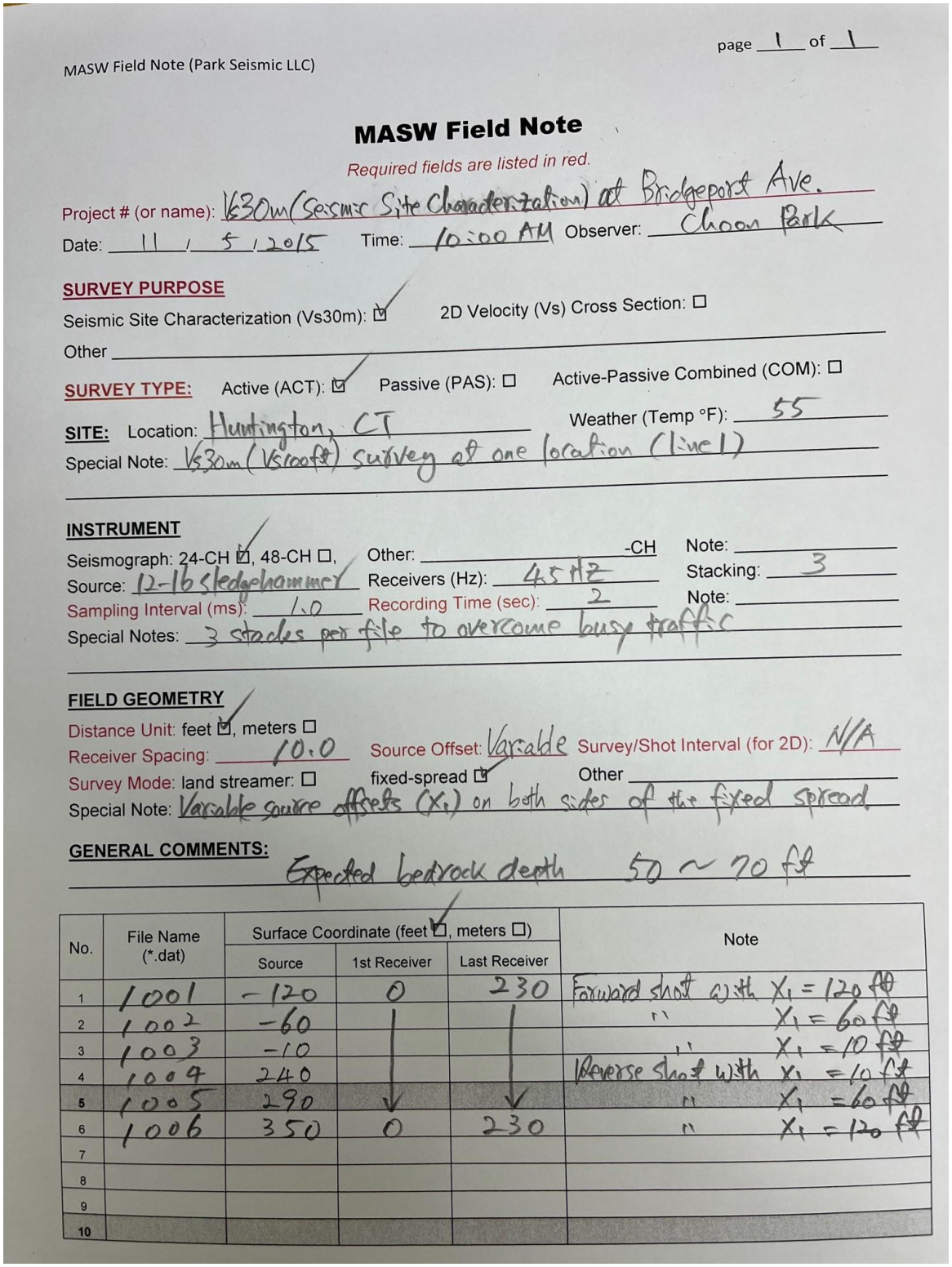
3. Field Note (Sample Cases for 1D and 2D surveys)

These are sample field notes kept during actual MASW surveys (1D and 2D). They will illustrate what type of information to be filled in the field note.

Sample MASW Field Note (1D Vs Profiling)

[Seismic Site Characterization (Vs30m) Survey*]

**Corresponding field geometry is displayed in a source/receiver (SR) chart on next page.*



MASW Field Note (Park Seismic LLC)

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MASW Field Note

Required fields are listed in red.

Project # (or name): Vs30m (Seismic Site Characterization) at Bridgeport Ave.

Date: 11 / 5 / 2015 Time: 10:00 AM Observer: Choon Park

SURVEY PURPOSE

Seismic Site Characterization (Vs30m): ☑ 2D Velocity (Vs) Cross Section: ☐

Other

SURVEY TYPE: Active (ACT): ☑ Passive (PAS): ☐ Active-Passive Combined (COM): ☐

SITE: Location: Huntington, CT Weather (Temp °F): 55

Special Note: Vs30m (Vs100ft) survey at one location (Line 1)

INSTRUMENT

Seismograph: 24-CH ☑, 48-CH ☐, Other: -CH Note:

Source: 12-lb sledgehammer Receivers (Hz): 45 Hz Stacking: 3

Sampling Interval (ms): 1.0 Recording Time (sec): 2 Note:

Special Notes: 3 stacks per file to overcome busy traffic

FIELD GEOMETRY

Distance Unit: feet ☑, meters ☐

Receiver Spacing: 10.0 Source Offset: Variable Survey/Shot Interval (for 2D): N/A

Survey Mode: land streamer: ☐ fixed-spread ☑ Other

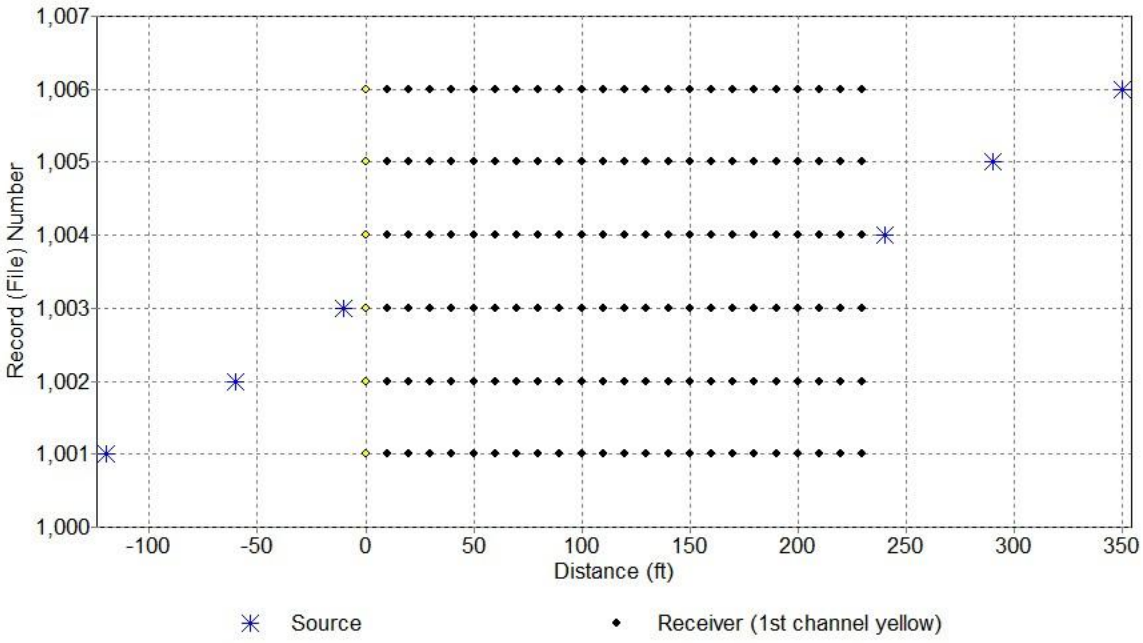
Special Note: Variable source offsets (X_1) on both sides of the fixed spread.

GENERAL COMMENTS: Expected bedrock depth 50 ~ 70 ft

No.	File Name (*.dat)	Surface Coordinate (feet ☑, meters ☐)			Note
		Source	1st Receiver	Last Receiver	
1	1001	-120	0	230	Forward shot with X_1 = 120 ft
2	1002	-60	↓	↓	" X_1 = 60 ft
3	1003	-10	↓	↓	" X_1 = 10 ft
4	1004	240	↓	↓	Reverse shot with X_1 = 10 ft
5	1005	290	↓	↓	" X_1 = 60 ft
6	1006	350	0	230	" X_1 = 120 ft
7					
8					
9					
10					

Source/Receiver (SR) Chart (1D Vs Profiling)

("Graphical Display of Field Geometry Specified in the Previous Sample Field Note")



Sample MASW Field Note* (2D Vs Cross Section)

(Bedrock Characterization Survey**)

**Only one of two pages is displayed here.*
***Corresponding field geometry is displayed in a source/receiver (SR) chart on next page.*

MASW Field Note (Park Seismic LLC) page 1 of 2

MASW Field Note

Required fields are listed in red.

Project # (or name): Bedrock Characterization at Huntington St

Date: 10 / 1 / 2018 Time: 1:00 pm Observer: Choon Park

SURVEY PURPOSE

Seismic Site Characterization (Vs30m): ☐ 2D Velocity (Vs) Cross Section: ☑

Other One line of survey ("Line 1")

SURVEY TYPE: Active (ACT): ☑ Passive (PAS): ☐ Active-Passive Combined (COM): ☐

SITE: Location: Shelton, CT Weather (Temp °F): ~70

Special Note:

INSTRUMENT

Seismograph: 24-CH ☑, 48-CH ☐, Other: -CH Note:

Source: 12-lb Sledgehammer Receivers (Hz): 4.5 Stacking: 3

Sampling Interval (ms): 1.0 Recording Time (sec): 2 Note:

Special Notes: Applied 3 stacks to overcome traffic noise

FIELD GEOMETRY

Distance Unit: feet ☑, meters ☐

Receiver Spacing: 5.0 Source Offset: 30.0 Survey/Shot Interval (for 2D): 5.0

Survey Mode: land streamer: ☑ fixed-spread ☐ Other

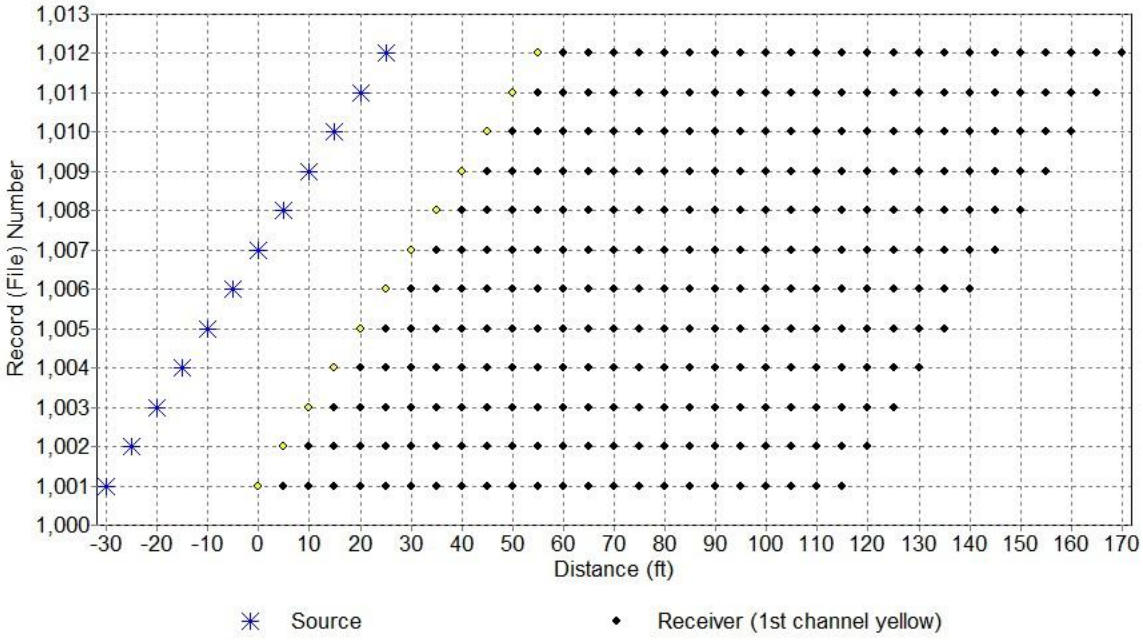
Special Note:

GENERAL COMMENTS: Expected bedrock depth 20 ~ 30 ft

No.	File Name (*.dat)	Surface Coordinate (feet ☑, meters ☐)			Note
		Source	1st Receiver	Last Receiver	
1	1001	-30	0	115	Survey started at ~1:30PM
2	1002	-25	5	120	
3	1003	-20	10	125	
4	1004	-15	15	130	
5	1005	-10	20	135	
6	1006	-5	25	140	
7	1007	0	30	145	
8	1008	5	35	150	
9	1009	10	40	155	
10	1010	15	45	160	continued on next page

Source/Receiver (SR) Chart (2D Vs Cross Section)

("Graphical Display of Field Geometry Specified in the Previous Sample Field Note")



4. Frequently Asked Questions (FAQ)

SURVEY

How can I best prepare for the first MASW survey?

Prepare a separate large-capacity 12-V battery (e.g., a car battery) and charge it fully overnight before the survey day. It is not recommended connecting the power cable of a seismograph directly to the battery inside a car because of the safety reason. Sometime, this can cause electric noise in the system if the car engine is running.

How accurately should I place geophone and source in their locations?

It is always recommended placing them as much accurately as possible. However, under some unavoidable conditions (e.g., obstacles along the line), they can be placed on the ground within a certain margin, e.g., ±5% error. For example, a geophone can be planted within a few inches (e.g., ±3 inches) from the accurate location when using a 5-ft receiver spacing. The receiver array can slightly bend or deviate from the perfect linear pattern (e.g., deviate transversely ±2% of the entire length).

Some receivers are located on pavement or rock and cannot be planted.

If they are only a few (e.g., 1-3), simply place them sideways on the surface and keep notes in the field note. If they are many (e.g., ≥ 12), it is recommended replacing the spikes with metal plates so that they can be placed on the surface upright. In this way, they will record surface waves without any loss of quality.

During a 2D survey, I have to skip a certain portion of the line due to obstacles (e.g., road, building, etc.). What should I do?

That's completely acceptable. Keep notes accordingly in the field note.

How can I know if a file is saved or not?

It is usually notified in a status bar at the bottom of the acquisition control software.

How can I know if the system is currently under recording or finished recording or ever triggered?

It is usually notified in a status bar at the bottom of the acquisition control software. It can also be notified by sound. In this case, different stages of recording (e.g., recording triggered, recording under progress, recording finished, etc.) are notified by different sounds. This option is usually available from the "System" menu.

What should I do when a file is saved mistakenly?

You have two options. You can keep it and make a note accordingly in the field note. Or, manually delete it by going into the corresponding folder and reset the next file number to be saved by going into the corresponding option in the acquisition control software.

Can I change recording parameters (e.g., sampling interval, recording time, etc.) during a survey?

Strongly discouraged. If this happens because of unavoidable reasons, please make a note in the field note.

Can I change geometry (e.g., receiver spacing, source offset, survey interval, etc.) during a survey?

Strongly discouraged. If this happens because of unavoidable reasons, please make a note in the field note.

HARDWARE

How can I know if some channels are bad or not?

A bad channel is detected usually from noise monitor, which displays electric currents from all channels in real time. A good channels is displayed with wiggle patterns, while a bad channel will show a straight line without any variation of current.

I find some channels are bad. Will this be acceptable?

If a few channels (e.g., 1-3 channels from a 24-channel acquisition) are bad for unavoidable reasons, it will not affect adversely on the data analysis later as far as recorded surface waves maintain strong amplitudes (i.e., high S/N), which is usually the case.

I find some channels are bad. How do I know what causes it and how can I fix them?

If it is due to a bad geophone, it will become normal when the bad geophone is replaced with a good one. Otherwise, it can be a bad takeout connection inside the cable or a bad pin in the cable head connector.

The system would not trigger.

The trigger sensor (i.e., hammer switch) usually has a preferred orientation. For example, it may have a black dot that has to be placed against the hammer handle on the opposite side of the hitting direction.

The system triggers spontaneously.

The trigger sensor is a simple contact-closure switch. So, if there is a short circuit inside the trigger cable or connector, this may happen. A low battery power can also cause this for certain type of seismographs.

Trigger (or hammer) sensor is bad.

A trigger sensor is a simple contact-closure switch. So, you can manually attach one wire in the trigger cable on the metal strike plate and another wire on the hammer head. Or, you can use a manual trigger by pressing a keyboard (e.g., by pressing 't') right before an impact is made. The MASW data analysis does not need accurate trigger information.

Can I mix different geophones, like 4.5-Hz phones and 14 Hz phones, in the same receiver array?

Very strongly discouraged.

How heavy sledgehammer should I use?

It can be between 10 lb and 20 lb. The lighter ones (e.g., 10 lb - 15 lb) can be used for relatively shallow survey (e.g., < 50 ft), while the heavier ones can be used for deeper surveys (e.g., 50 ft - 100 ft).

What type of strike plate should I use?

A conventional metal plate (e.g., an aluminum plate) can be used. However, nowadays a strike plate made out of non-metallic softer material (e.g., a polyethylene plate) is preferred because it can impart more energy in low frequencies, which is critical in increasing the investigation depth.

Acquired data shows only partial channels (e.g., 16 channels), not full 24 channels. Or a "timeout error" message is displayed in the acquisition control software.

It is due to low batter power.