

**MUSAR Training Foundation**

**TRENCH RESCUE  
SHORING OPERATIONS GUIDE**



**Trench Rescue Operations Level**

**2<sup>nd</sup> Edition- September 2020  
2<sup>nd</sup> Printing**

# SHORING NOTES

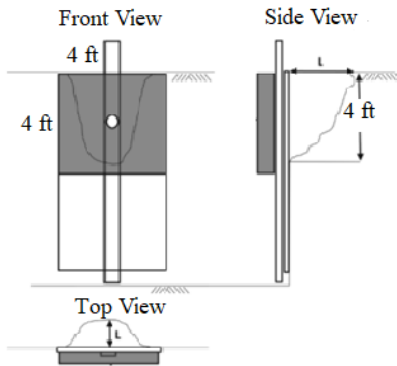
These shoring systems contained herein provide a minimum factor of safety of 2 to 1. These rescue shoring systems and charts are conditional upon the following soil and shoring system conditions:

1. Water level that is below the bottom of the trench
2. The bottom of the excavation is not "boiling"
3. The soil is not oversaturated and/or flowing
4. Surcharged loads (spoil piles and equipment) that are within the Simple L area must be added to the Total L in accordance with the Surcharge chart.
5. Tight sheeting selected from the shoring panel chart
6. Struts must be placed within 10 degrees of level and 10 degrees of perpendicular (horizontal) to the trench walls except when shoring angled walls.
7. Use swivel bases on both ends of Paratech struts secured with (2) 16d nails in each foot
8. Do not use for trench widths greater than indicated in the chart
9. 80% of panel in contact with trench wall and or backfill this does not apply to panels that utilize back shoring or buttresses
10. Do not place any vertical loads on struts or wales (do not hang items from them, stand on them, climb them or cross shore to them)
11. Horizontal shoring distances should exceed the depth of the trench.
12. This shoring chart is not designed for soil that will not stand up long enough to install shoring
13. Struts must be within 1 foot minimum and 2 feet maximum (below) the trench lip and within 1 foot minimum and 2 feet maximum (above) the trench floor.
14. Maximum vertical strut spacing is 4 feet.
15. Horizontal strut spacing is 4 feet.
16. After placement, warning signs to be aware of:
  - a. Cracking and popping of the wood panels after installation is a sign of increasing loads
  - b. The strong back will break before the panel breaks
  - c. If a strong back begins to break, evacuate the trench.  
From outside of the trench add a strut at the break location and monitor the panels closely for signs of increasing load (increasing deflection) or instability
  - d. The interface between the strut feet and strong back must be monitored for excessive crushing of the wood
  - e. If the panel deflection exceeds 1" between struts  
evacuate the trench and add an intermediate strut. Monitor panels to assure the deflection has stopped before reentering.
  - f. Monitor the lip of the trench for widening or growing cracks and fissures.

# ESTIMATING LATERAL SOIL FORCES

LATERAL FORCE- For rescue situations (trench collapse) with trench walls that can be shored with panels and struts an accurate estimation of the lateral force on the shoring by using the following (T-L) method.

ESTIMATING LATERAL EARTH PRESSURE: The maximum lateral force on a 4ft x 4ft section of a shoring panel is a function of the distance from the original (pre-collapse) face of trench to the back of the farthest failure or to the farthest tension crack. That distance, measured in feet, is called the Simple L.



## Definitions

**Simple L (SL):** The distance (length) measured in feet from the original trench wall perpendicular to the furthest point of soil failure or signs of failure (cracks/fissures).

**Surcharged L (ScL):** Surcharged loads (spoil piles/equipment), that are within the area that is between the original trench faces and the furthest point of soil failure (SL). Measured in feet perpendicular to the trench wall.

**Total L (L):** The Simple L (SL) plus the Surcharge L (ScL) if one exists.

A tape measure is used to find the distance (SL) from the original trench face (wall) to the farthest point of soil failure and to measure the amount of surcharge (ScL) within the affected area. Common failures include:



Open Lip Failure



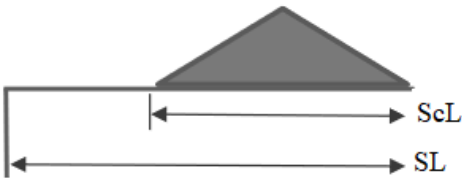
Closed Lip Failure



Fissure

## SURCHARGE CALCULATIONS FOR EARTH PRESSURES

**SURCHARGED LOADS-** Surcharged loads at a trench site usually include the spoil pile and/or construction equipment and materials. Construction equipment and materials can include but are not limited to excavators, dump trucks, trench boxes, pipes, and gravel.



**SPOIL PILE-** Measure the amount of spoil (ScL) that is within the Simple L (SL). Round the measurement up to the next foot to determine the ScL.

**EQUIPMENT-** Measure the amount of equipment (ScL) that is within the simple L (SL). Round the measurement up to the next foot to determine the (ScL).

## SURCHARGE CHART

<b>SURCHARGE (ScL)- Feet within Simple L (SL)</b>				
<b>SPOIL</b>	<b>Add to SL</b>		<b>EQUIP.</b>	<b>Add to SL</b>
1	1		1	1
2	1		2	2
3	1		3	3
4	2		4	5
5	3		5	8
6	4		6	11
7	5		7	N/A
8	7		8	N/A
9	9		9	N/A
10	10		10	N/A

**Note: Total L (L)=Simple L (SL) plus Surcharge L (ScL)**  
**Charts are valid for Total L of 20 or less**

## DEPTH CONVERSION CHART

<b>DEPTH TO SIMPLE L (SL) CONVERSION GUIDE</b>		
<b>Trench Depth</b>		<b>SL Equivalent</b>
4- 8 feet		SL- 6
9 feet		SL-7
10 feet		SL-7
11 feet		SL- 8
12 feet		SL-9
13 feet		SL-10
14 feet		SL-10
15 feet		SL-11
16 feet		SL-12
17 feet		SL-12
18 feet		SL-13
19 feet		SL-14
20 feet		SL-14

**Note: Total L (L)=Simple L (SL) plus Surcharge L (ScL)**

In the unlikely event of a rescue in a trench that has not had a soil failure you need to measure the depth of the trench (measured in feet and rounded up) and use this chart to convert the depth to a Simple L.

## OPERATIONS LEVEL

# TRENCH RESCUE SHORING SYSTEMS

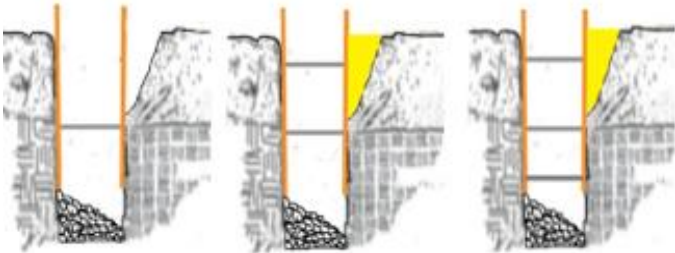
### NON-ENTRY SHORING

This shoring system may be used to provide stabilization of trench wall to depths of 8ft. Non-entry shoring at the Operations Level, includes panels, wales, and back-fill techniques. For straight run trenches deeper than 8 feet see (Deep Trench Shoring)

Rescue Shoring must provide:

- 1) Primary Shoring- rapidly protect the victim
- 2) Secondary Shoring- create a Safe Zone for rescuers

### 1) Primary Shoring

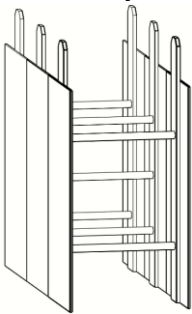


Positioning strut

Backfill strut

Compliance strut

### 2) Secondary Shoring



Panels and Struts



Panels, Struts and Wales

## TABULATED DATA

The tabulated data used in the guide is engineered and is designed specifically, for collapsed trench walls and rescue conditions.

Engineered tab data is based on worst case soil (T-L soil). The shoring charts provided can be used at all rescue incidents and in all soil conditions.

### PARATECH STRUT CHART

(Vertical Spacing with Maximum 4' Horizontal Spacing)

Total "L"	GRAY STRUTS		GOLD STRUTS			
	Width <8'	Width 8'-10'	Width ≤10'	Width 12'	Width 14'	Width 16'
L-1	4'	4'	4'	4'	4'	4'
L-2	4'	4'	4'	4'	4'	4'
L-3	4'	4'	4'	4'	4'	4'
L-4	4'	4'	4'	4'	4'	4'
L-5	4'	4'	4'	4'	4'	4'
L-6	4'	4'	4'	4'	4'	3'
L-7	4'	4'	4'	4'	4'	3'
L-8	4'	4'	4'	4'	4'	3'
L-9	4'	4'	4'	4'	4'	2'
L-10	4'	3'	4'	4'	4'	2'
L-11	4'	3'	4'	4'	3'	N/A
L-12	4'	3'	4'	4'	3'	N/A
L-13	4'	3'	4'	3'	3'	N/A
L-14	4'	3'	4'	3'	3'	N/A
L-15	4'	2'	4'	3'	3'	N/A
L-16	4'	2'	4'	3'	3'	N/A
L-17	4'	2'	4'	3'	2'	N/A
L-18	4'	2'	4'	3'	2'	N/A
L-19	4'	2'	4'	3'	2'	N/A
L-20	4'	N/A	4'	2'	2'	N/A

Chart data based on strut capacities provided by Paratech at 2:1 factor of safety and converted for spacings depending on Total L

## AIRSHORE STRUT CHART

(Vertical Spacing with Maximum 4' Horizontal Spacing)

Total "L"	WITH 1 PIN		WITH 2 PINS		
	Width 8 ft	Width 12 ft	Width 4ft	Width 8ft	Width 12ft
L-1	4'	4'	4'	4'	4'
L-2	4'	4'	4'	4'	4'
L-3	4'	4'	4'	4'	4'
L-4	4'	4'	4'	4'	4'
L-5	4'	4'	4'	4'	4'
L-6	4'	4'	4'	4'	4'
L-7	4'	4'	4'	4'	4'
L-8	4'	4'	4'	4'	4'
L-9	4'	4'	4'	4'	4'
L-10	4'	4'	4'	4'	4'
L-11	4'	4'	4'	4'	4'
L-12	4'	4'	4'	4'	4'
L-13	4'	3'	4'	4'	4'
L-14	4'	3'	4'	4'	4'
L-15	4'	3'	4'	4'	4'
L-16	4'	3'	4'	4'	4'
L-17	4'	3'	4'	4'	4'
L-18	3'	3'	4'	4'	4'
L-19	3'	3'	4'	4'	3'
L-20	3'	2'	4'	4'	3'

Chart data based on strut capacities provided by Airshore at 2:1 factor of safety and converted for spacings depending on Total L



## WALE CHARTS

### WALE CHART

4' Maximum Vertical Spacing

#### DISTRIBUTED LOAD CHART

Wale Type	8" Span	12' Span
6"x6"	Maximum Total L-2	Maximum Total L-1
8"x8"	Maximum Total L-5	Maximum Total L-2
7"x7" LVL	Maximum Total L-12	Maximum Total L-4
Paratech	Maximum Total L-10	Maximum Total L-1

NOTES:

\*Span is the distance between the struts supporting the wales

\*Gaps between the wales and panels at the panel edges and both ends of the wales must be filled with spacers and/or wedges

\*2' vertical Spacing will increase the capacity (Total L Value) of each wale by 150% (Total L x 1.5)

\*6"x6" and 8"x8" timber capacities are based on #1 Douglas Fir/SPF

\*7"x7" LVL capacity is based on bending strength of 3,100

### CANTILEVER WALE CHART

4' Maximum Vertical Spacing

#### MAXIMUM TOTAL L for DISTRIBUTED LOADS

Wale Type	Cantilever Length				
	3'	4'	5'	6'	8'
6"x6"	L-3	L-2	L-1	L-1	N/A
8"x8"	L-8	L-4	L-3	L-2	L-1
7"x7" LVL	L-16	L-9	L-5	L-4	L-2
Paratech	L-10	L-5	L-3	L-2	L-1

NOTES:

\*Length is the distance between the end of the cantilever and the nearest strut.

\* The end of the cantilever wale must be kept between 12"-18" from the outside corner of the trench to prevent overlapping wales

\*Gaps between the wales and panels at the panel edges and both ends of the wales must be filled with spacers and/or wedges

\*2' vertical Spacing will increase the capacity (Total L Value) of each wale by 150% (Total L x 1.5)

\*6"x6" and 8"x8" timber capacities are based on #1 Douglas Fir/SPF

\* 7"x7" LVL capacity is based on bending strength of 3,100 psi

## TRENCH RESCUE PANEL CHART

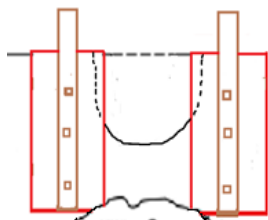
COMPOSITE CONSTRUCTION	MAXIMUM TOTAL "L"	NON-COMPOSITE CONSTRUCTION	MAXIMUM TOTAL "L"
2x12 LVL/FinForm	L-20	2x12 LVL/FinForm	L-5
2x12 Wood/Finform	L-11	2x12 Wood/Finform	L-3
2x12 Wood/CDX	L-8	2x12 Wood/CDX	L-1

**NOTES:**

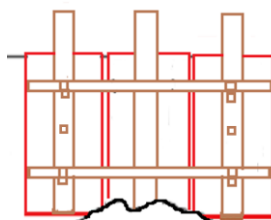
- Composite construction requires the application of heavy-duty exterior construction grade adhesive that has an ultimate strength of at least 4,000 psi between the strong-back and sheeting. Surface areas must be sanded prior to the application of adhesive
- Non-composite construction includes attaching strong-backs to sheeting with Nails, Bolts and Screws. Simply positioning strong-backs against the sheeting is also considered non-composite.
- Capacities can be increased with the non-composite application of additional strong-backs. (a) 2x12 sawn lumber add 1L (b) 2x12 LVL add 3L (c) 6x6 sawn lumber add 6L (d) 8x8 sawn lumber add 16L (e) 7x7 LVL add 20L
- Plywood (FinForm and CDX) is 3/4"
- "Wood" (strong-back) values are based on #1 Douglas Fir
- LVL strong-back values are based on FB-3,100 psi Laminated Veneer Lumber

## ENTRY SHORING DESIGN

This guide does not consider entry shoring as a best practice and does not recommend “entry” shoring equipment (i.e.-wood struts, screw jacks and pneumatic struts requiring pins and collars) for trenches deeper than 8’.



1. Shore both sides of void



2. Use wales to span void

### WOOD STRUT CHART

(3’ Maximum Vertical Spacing)

Strut Wood Type	Trench Width up to 8’
Doug Fir	Maximum L-8
Spruce/Pine/Fir	Maximum L-8
<b>Notes:</b>	
*Maximum L is based on 4”x4” wood struts and Ellis Screw jacks	

### WALE/WOOD STRUT CHART

8’ maximum span/ 4’ maximum vertical wale spacing

Strut Wood Type	Trench Width					
	3’	4’	5’	6’	7’	8’
Doug Fir	Max L-9	Max L-9	Max L-9	Max L-8	Max L-6	Max L-4
Spruce/Pine/Fir	Max L-7	Max L-7	Max L-7	Max L-7	Max L-6	Max L-4
<b>Notes:</b>						
*Based on 4”x4” wood struts, Ellis Screw jacks and 7”x7” LVL wales (3,100 psi bending strength)						
*Span is the distance between the struts supporting the wales						
*Gaps between the wales and panels at the panel edges and both ends of the wales must be filled with spacers and/or wedges.						

# GLOSSARY OF TERMS

**Axial Load-** A tension or compression load which passes through the center of a structural member (like a column, beam, truss member, diagonal brace or hanger rod).

**Beam-** A horizontal structural member, subject to compression, tension, and shear, usually found in any one of three different configurations: cantilever, continuous, and simple.

**Back-fill-** Reinforcement behind the panel and/or wale where a void in the trench wall exists.

**Buttress-** A wall reinforcement or brace built on the outside of a structure.

**Cantilever Beam (Wale)-** A beam that has two or more supports but extends beyond one end support and ends in clear space

**Collapse-** The failure of any portion of a trench or excavation wall.

Common collapse patterns include:

- **Lip Shear-** A lip shear is a common failure when the soil is layered. The void pattern (size, shape and angle) is dependent on how the layered soil is stacked. Strong soil on the top will usually result in a topple type collapse and may include the sliding of the weaker soil below it. Weak soil on top of strong soil will usually result in a sliding type of collapse.
- **Rotational Failure-** A failure that rotates downward in a circular fashion along the shear failure surface and into the bottom of the trench. Rotational soil failure first occurs at the bottom of the trench which can sometimes be seen as bulging on the trench wall.
- **Soft Pocket-** Soft pockets may be encountered in areas containing varying soil types. While the trench walls might consist of mostly stable soils, areas of sandy soil can be exposed at depths. These soft, sandy areas are weak spots that will cave in, creating voids beneath more stable soils. Eventually, those voids lead to larger trench wall collapse.
- **Wedge Failure-** A wedge failure begins with fissures along the surface of the ground. The fracture continues in an angular direction toward the face. A large section of the trench wall will collapse by sliding down the shear failure surface and into the trench. Wedge failures are common at the inside corners of intersecting trenches.

- **Slough In-** Sloughing occurs when a trench wall becomes so dry that it creates a weak area. Wind blowing into an open trench is a common cause of sloughing. This weak area cannot support the weight of the soil above and will eventually cause the trench to collapse. Sloughing may cause the bottom 1/3 of the trench wall to “belly” or bulge out until a collapse occurs. The void near the bottom of the wall sometimes leaves an overhanging section of trench wall.
- **Wall Shear-**A wall shear (shear wall) collapse begins with fissures at the trench lip. Wall shears are usually seen in cohesive soil conditions. The cohesive soil stays together as the fissure breaks deeper into the trench.

**Collapse Zone-** The expected ground area that a falling wall will cover when it collapses. For safety, assumed to be 1.5 times the trench wall height.

**Complete Shoring-** Shoring is complete when all panels, wales (as needed) and struts are in place and are compliant with trench rescue shoring tabulated data (charts). Strut activation forces on all are between 1-1.25 kips, back fill is in place and a minimum of two 16d nails secure the ends (bases) of every strut. Supplemental shoring each time 2 feet of trench wall is exposed during the soil debris removal process has been completed.

**Compression-**Force that tends to push the mass of a material together.

**Concentrated Load-** A load applied at one point or within a limited area of a shoring system.

**Deflection-**The movement of a structural element under a load.

**Distributed Load-** A load applied over the length of a shoring system or element.

**End Wall-** The walls that are perpendicular to the direction of the digging (excavation process). End walls can become a serious hazard whenever they are vertical or near-vertical (not cut back to a safe angle) and 1) the wall is showing signs of active soil (sloughing, raveling, fissures, bulging or partial collapse) or 2) the end wall is wide (usually wider than four feet) and 3) the trench is more than eight feet deep.

**Entry Shoring-** Shoring that requires rescuers to enter the trench (typically on ladders) in order to install, lock mechanical collars and/or place struts in compression.

**Face-** (see wall)

**Excavation-** Any man-made cavity or depression in the earth's surface (including its walls, floor and lip) formed by earth removal. For rescue purposes an excavation is wider than it is deep.

**Hydraulic Shoring-** The use of hydraulic struts in conjunction with shoring materials to support trench walls. Hydraulic struts have movable parts that are operated by the action of hydraulic fluid. Hydraulic struts can be installed without entering the trench (non-entry). Hydraulic struts can create large activation forces which can cause additional collapse in weak soils.

**Intersecting Trench-** A trench which meets or crosses another trench. Usually take an L-shape, T-shape or X-shape.



**Kip-** One thousand pounds of force. Kilo-pound

**Lip-** The area, both horizontal and vertical, at the top edge of the trench wall (face).

**Non-Entry Shoring-** Shoring that does not require rescuers to enter the trench during shoring operations. Installation, locking mechanical collars and/or placing struts in compression are completed from protected areas above the trench lip.

**Panel-** A trench rescue panel consists of a sheet of plywood and an attached strongback

**Pneumatic Shoring-** The use of pneumatic struts in conjunction with shoring materials to support trench walls. Pneumatic struts have movable parts that are operated by the action of air pressure and are mechanically locked with a collar. Some pneumatic struts can be installed without entering the trench (non-entry) while other pneumatic strut designs require rescuers to enter to trench in order to lock collars.

**Primary Shoring-** The rapid installation of a shoring system that is designed to protect the trapped victim from secondary collapse. Primary shoring typically includes a shored area 4 feet wide (trench rescue panel set) that is in line with the victim's head and chest and covers the trench wall from the lip to the floor or to the collapse debris pile on the floor.

**Screw Jack-** A trench shore or jack with threaded parts. The threading allows the jack to be lengthened or shortened and can place the strut into compression.

**Secondary Collapse-** A collapse which follows the initial collapse. Can be caused by application of additional loads (aftershocks, wind snow, etc. rescue equipment, rescuers, etc.), settling of collapsed structures, drying of the soil.

**Secondary Shoring-** A safe zone in a trench created by shoring the area of exposed trench walls around the trapped victim. Typically, at least 12 feet wide covering all exposed walls within the collapse zone.

**Sheeting-** Generally speaking, wood planks and wood panels that support trench walls when held in place by shoring.

**Shoring-** The general term used for lengths of timber, screw jacks, hydraulic and pneumatic struts and other devices that can be used to hold sheeting against trench walls. Individual supports are called shores, cross-braces, or struts.

**Simply Supported Beam (Wale)-** Simply Supported Beam- A beam vertically supported at both ends but free to rotate at the supports.

**Spoil Pile-** A pile of excavated soil next to the trench or excavation.

**Spot Shoring-** Struts placed from wall to wall without the use of panels.

**Straight Run Trench-** A trench which does not cross or meet another trench.

**Strongback-** Lumber (sawn or engineered), typically 2"x12" or 2"x10", attached length wise to a sheet of plywood.

**Strut-** A compression element used in support of panels, wales and trench walls.

**Supplemental Shoring-** Includes operations that involve the use of sheeting and shoring and/or isolation devices when greater than 0.6 m (2 ft) of exposed trench wall exists below the bottom of the trench rescue panel.

**Surcharge Load-** Any weight above the ground in the proximity of the trench that increases instability or the likelihood of secondary collapse.

**Trench-** A narrow excavation which is deeper than it is wide, with a maximum width of fifteen (15) feet, measured at the floor.

\*Intersecting Trench- A trench where multiple cuts or legs converge at a single point.

\*Non-intersecting Trench- A trench cut in a single straight or nearly straight line with no converging or crossing legs or cuts,

\* Shallow trench- A trench that is 8 feet or less in depth.

\* Deep Trench- A trench that is deeper than 8 feet.

**Wale-** Horizontal beam used in shoring systems placed parallel to the excavation face whose sides bear against the vertical members

of the shoring system (called inside wales) or trench walls (called outside wales). Outside wales can contribute to additional soil failure and is not a recommended practice.

**Wall-** A trench wall (face) is the vertical or inclined earth surface formed as a result of excavation work.



## Conclusion and Credits

The shoring design and installation methodology presented in this section is intended solely for emergency trench rescue operations as a measure of managing risk versus reward. It is intended as a temporary measure to be used only by trained trench rescue personnel to mitigate and manage risk during rescue operations. The shoring designs and installation methodology presented in this section are NOT intended to provide safety shoring for any other application and is not offered as an OSHA (construction)compliant shoring guide. Emergency trench rescue shoring should be properly abandoned and should not be used for any purpose by anyone after of the trench rescue operations.

This guide is not intended to be a student manual for those learning to shore trenches. The design and installation methodology is intended for use by certified and qualified Trench Rescues.

The information, practices, and tabulated data in this guide have been engineered, designed, and reviewed by the following Subject Matter Experts.

**Oliver-Denzil S. Taylor**- PhD, P.E. Senior geotechnical engineer, US Army Engineer Research and Development Center, USACE-USAR Task Force

**S. Marie LaBaw**-PhD, P.E.- Professional Engineer, Montgomery County (MD), Structures Specialist (MD-TF1)

**George (Donnie) Barrier** P.E.- Geotechnical Forensic Engineer, Barrier Foundation Engineering Services, PC, Structures Specialist (NC-TF3)

**Janos Gergely** P.E. (PhD)- Associate Professor, Department of Civil and Environmental Engineering, UNC, Structures Specialist (NC-TF3)

**Craig Dashner** P.E.- Manager OHM Associates, Structures Specialist (MI-TF1)

**Ron Zawlocki**- Rescue Team Manager (MI-TF1), Lead Rescue Instructor (MUSAR Training Foundation), Battalion Chief (retired) City of Pontiac (MI) Fire Dept.

## SHORING SIZE UP

### Assess the Trench Lip

- Stable (may use ground pads)
- Unstable or collapsed (use lip bridges)

### Assess the Collapse Potential

- Undercut/overhanging section
- Fissures
- Bulging
- Surcharged loads
- Sloughing/Raveling

### Assess the Voids

- Location (open lip or closed lip)
- Height (top to bottom)
- Width (side to side)
- Length (trench wall to farthest failure)

### Assess Patient Condition

- Rescue
- Recovery
- Undetermined

### Measure the Trench

- Depth
- Width
- Wall Angle
- Determine the Total "L"

## TABULATED DATA

Use the Total L calculations and charts to determine shoring materials and equipment

- Panels
- Struts
- Wales

## SHORING BENCHMARKS

- Hazards Controlled
- Lip Safety
- Primary Shoring
- Secondary Shoring
- Complete Shoring

