

Response of Petro Pipelines to Longwall Subsidence

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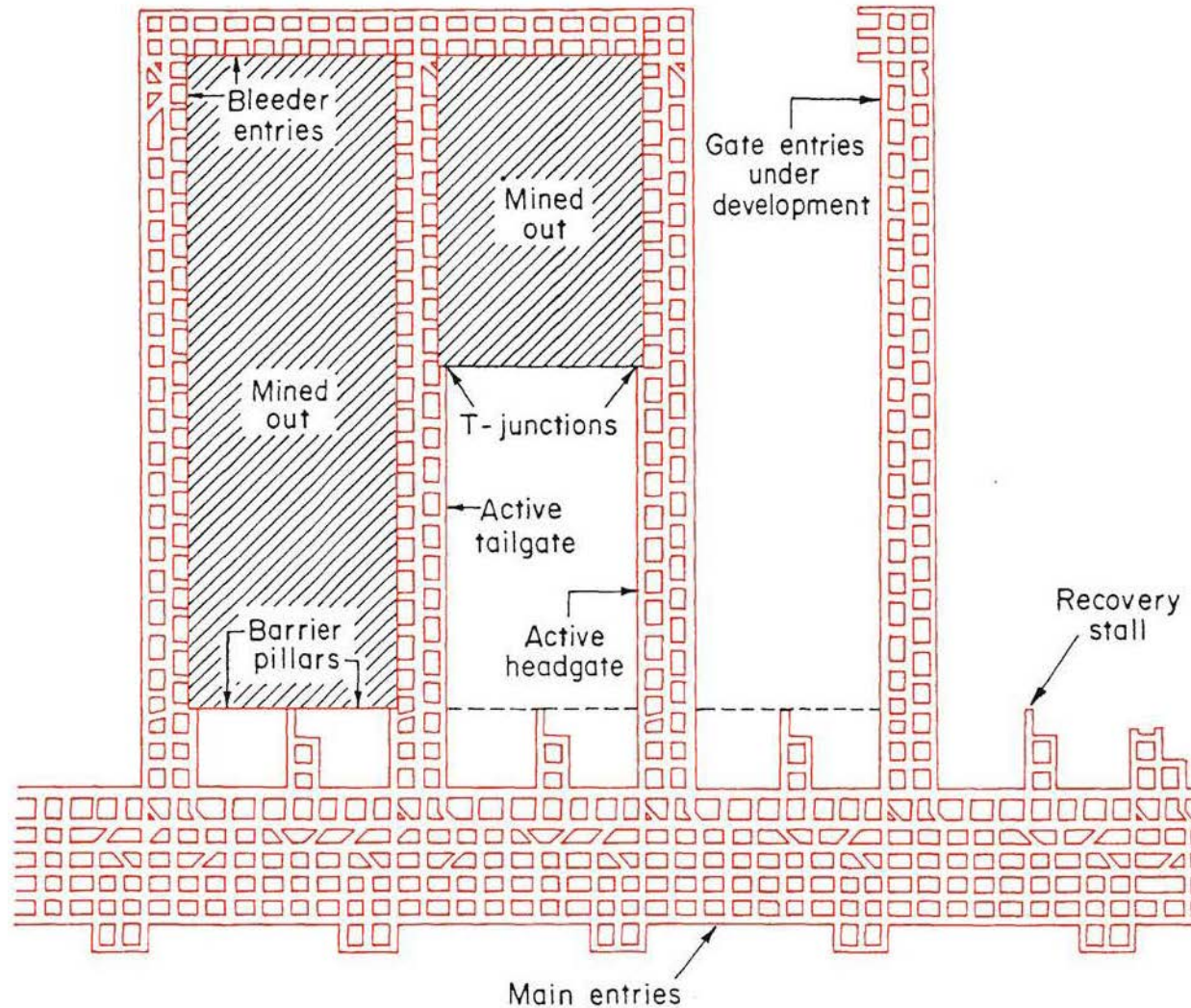
INTRODUCTION

OUTLINE

- ▶ Longwall Mining
- ▶ Subsidence Movements
- ▶ Subsidence Response
- ▶ Subsidence Damage
- ▶ Subsidence Damage Mitigation

LONGWALL MINING

MINING METHODS - LONGWALL MINING

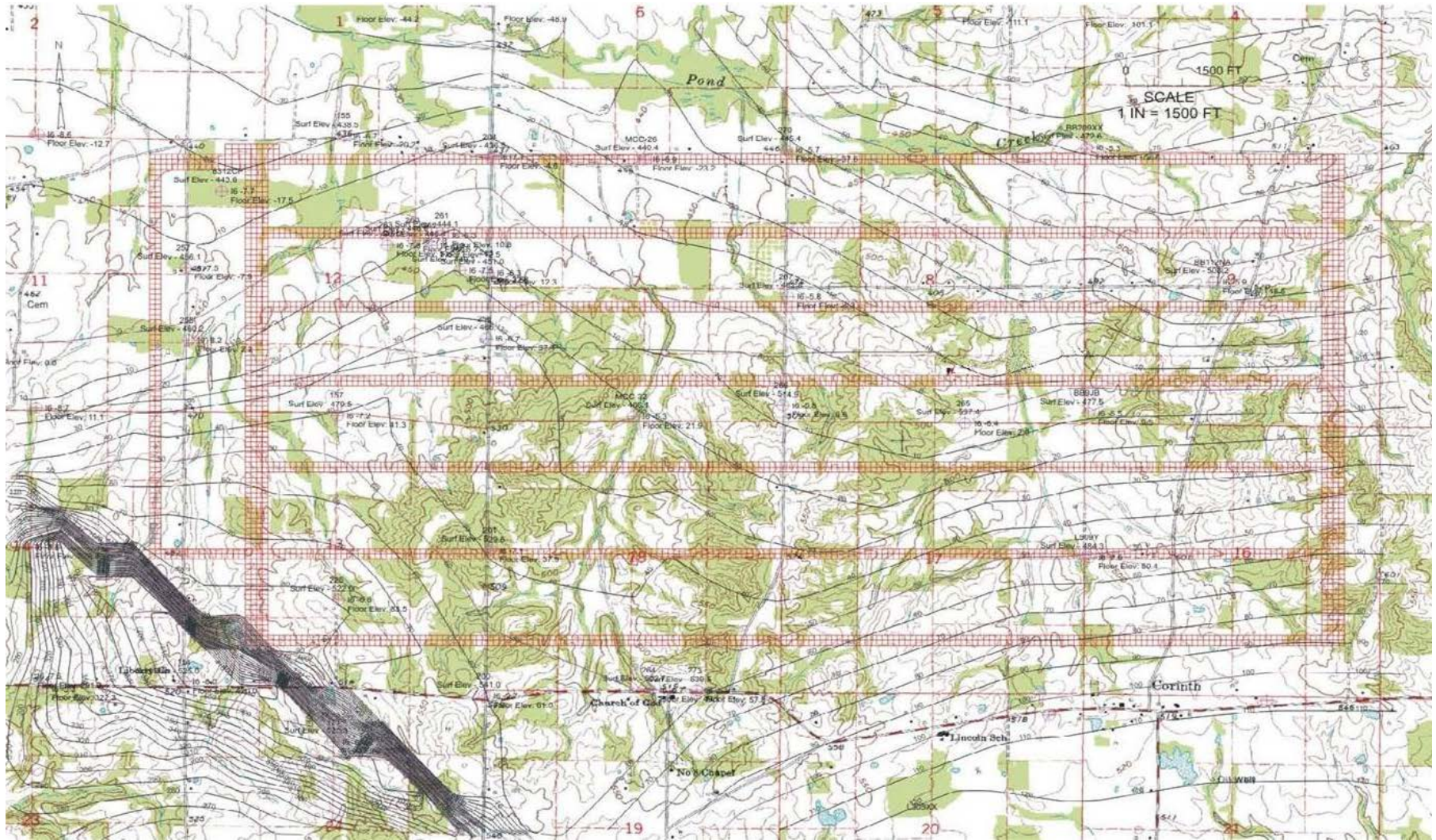


SCHEMATIC OF LONGWALL MINING TECHNIQUE (MARK, 1990)

MINING METHODS - LONGWALL MINING

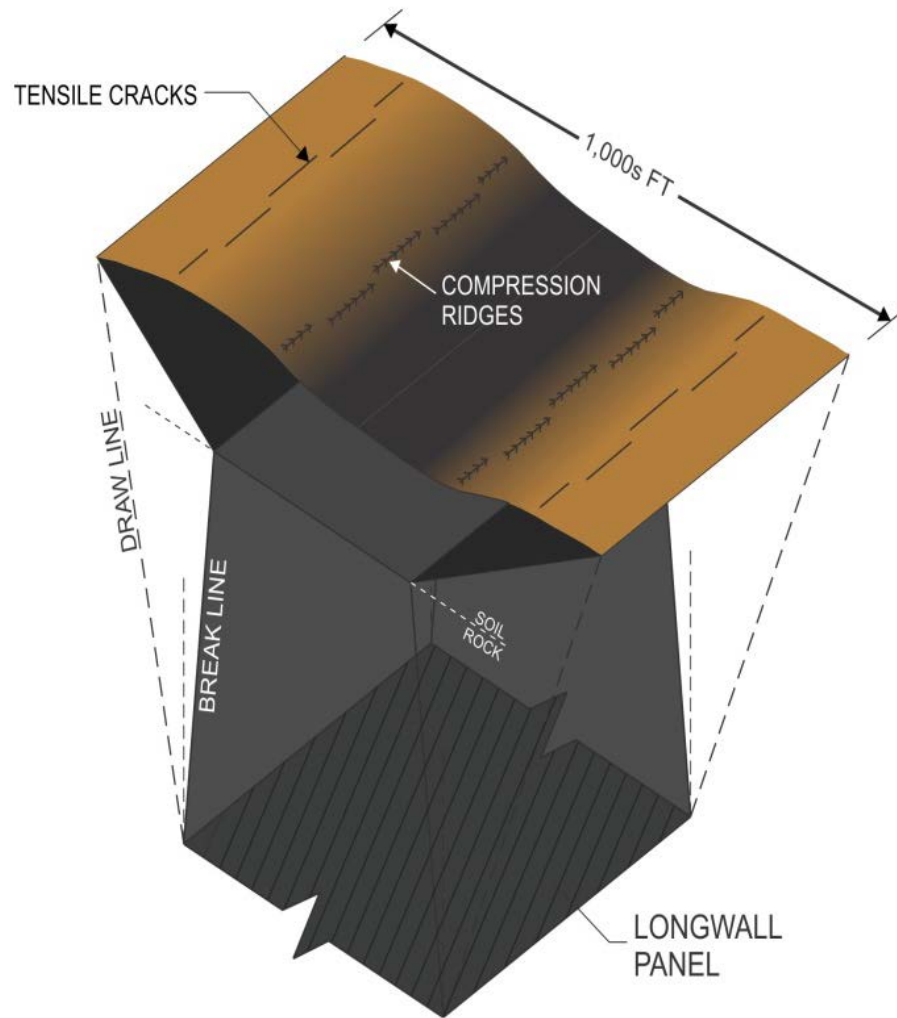


MINING METHODS - LONGWALL MINING



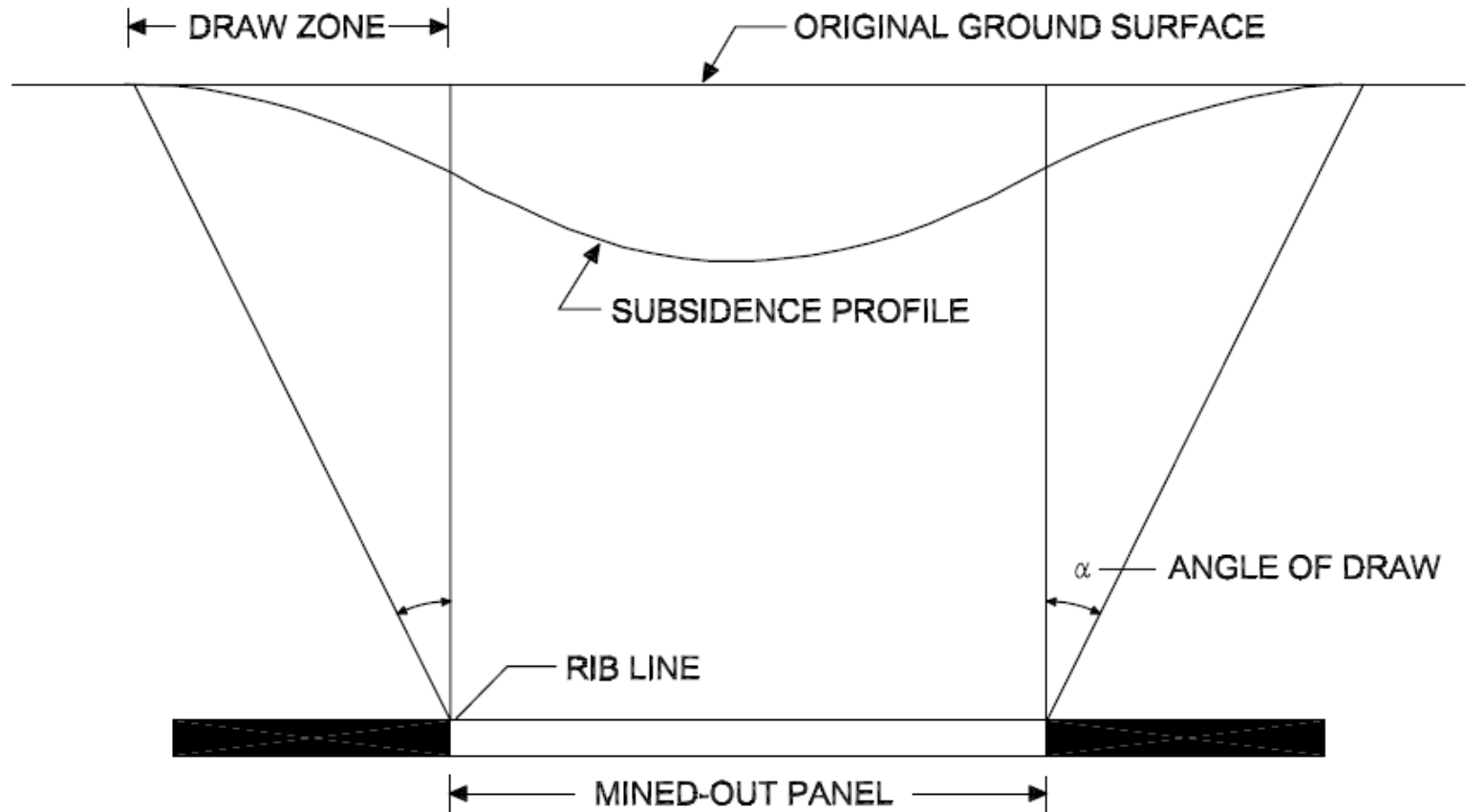
MINE SUBSIDENCE

MINE SUBSIDENCE



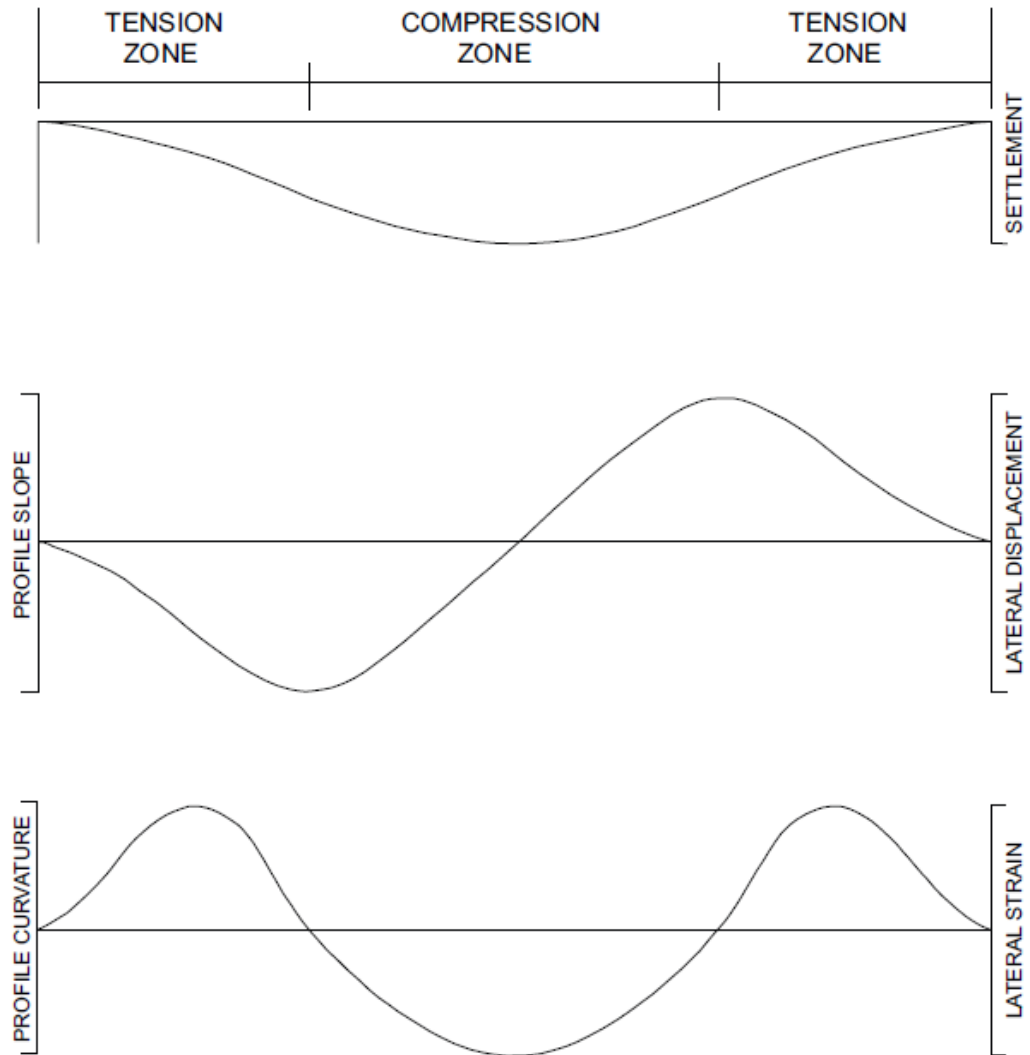
TROUGH SUBSIDENCE

MINE SUBSIDENCE



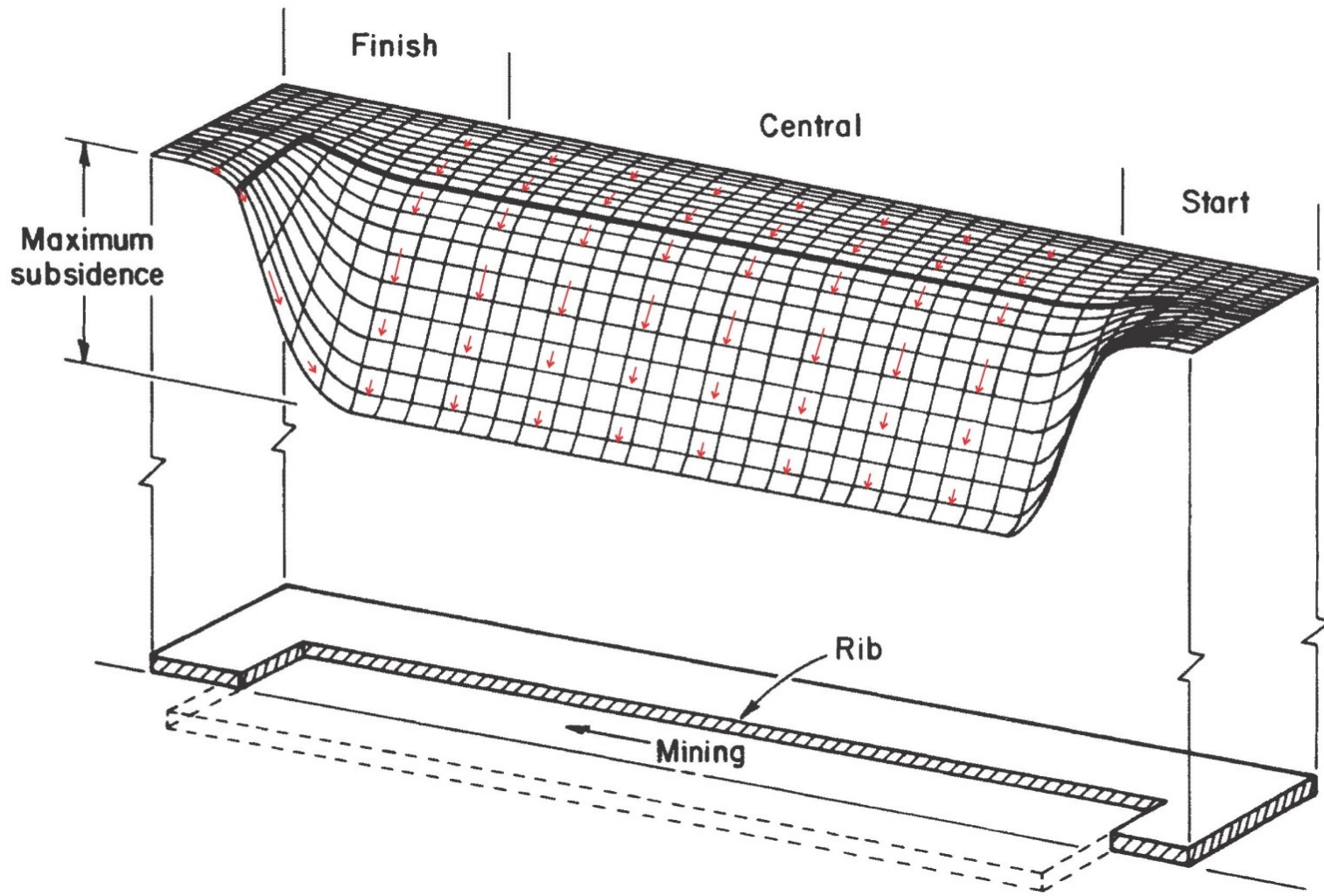
SUBSIDENCE PROFILE OF A LONGWALL PANEL

MINE SUBSIDENCE

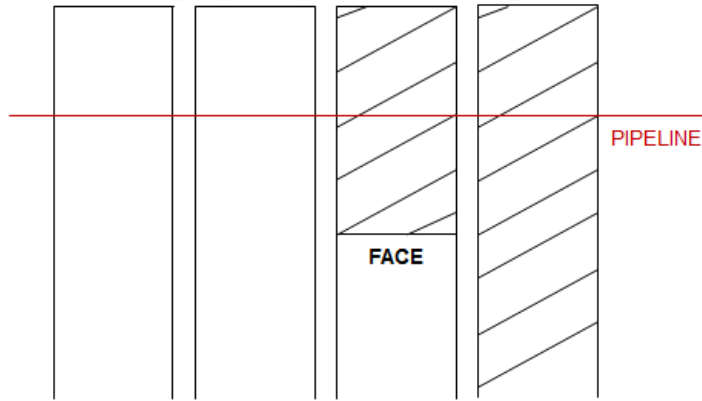


CHARACTERISTICS ACROSS
A SUBSIDENCE PROFILE

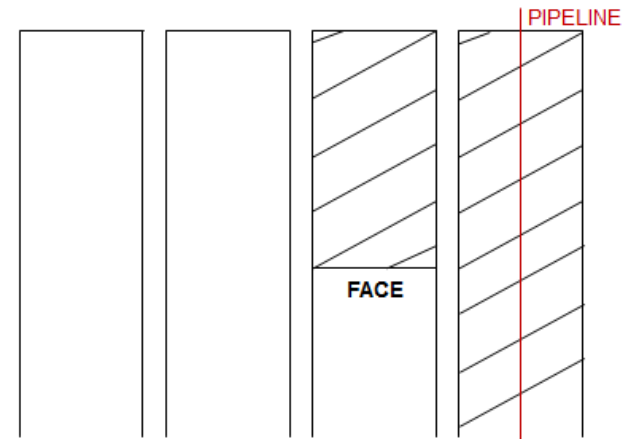
LONGWALL SUBSIDENCE



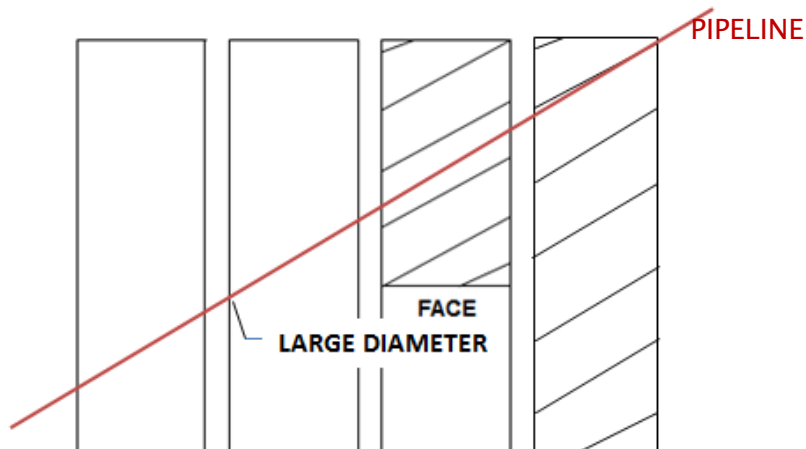
MINE SUBSIDENCE



PIPELINE PERPENDICULAR TO LW PANELS

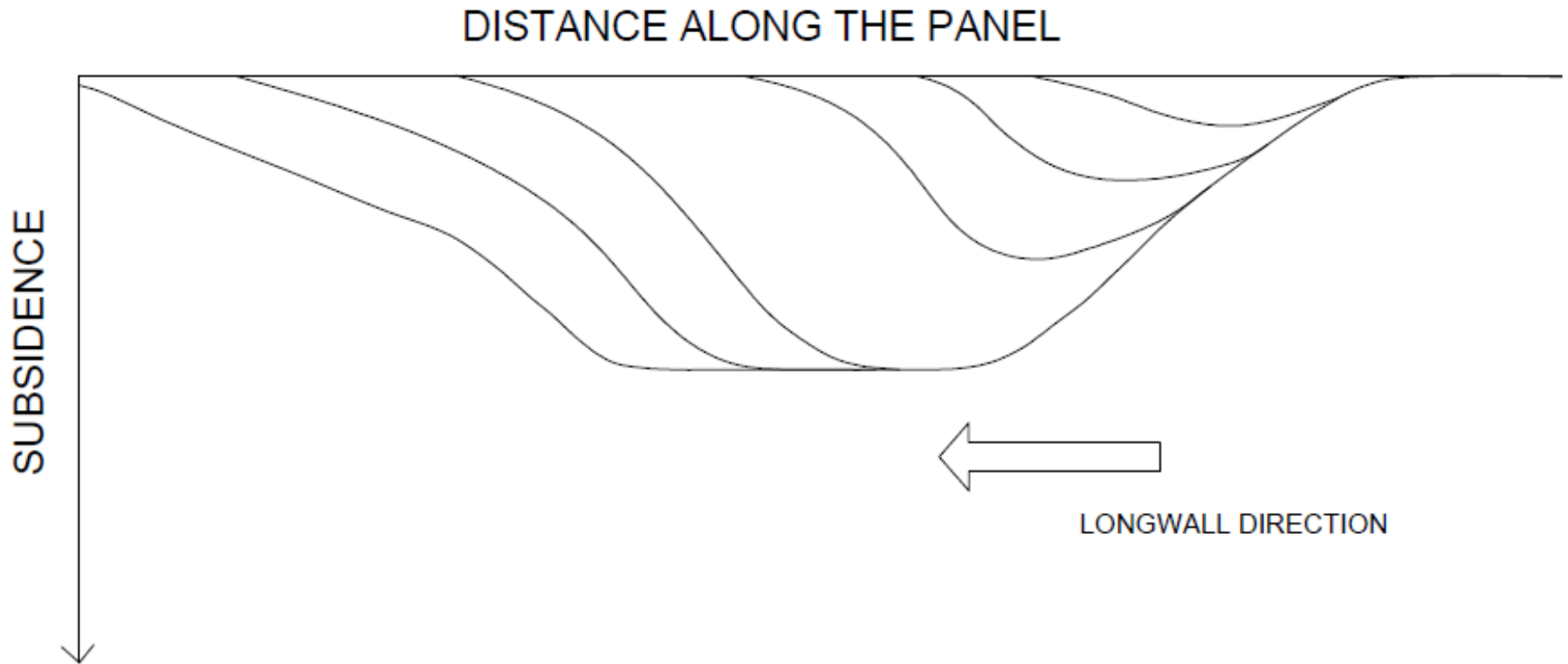


PIPELINE PARALLEL TO LW PANELS



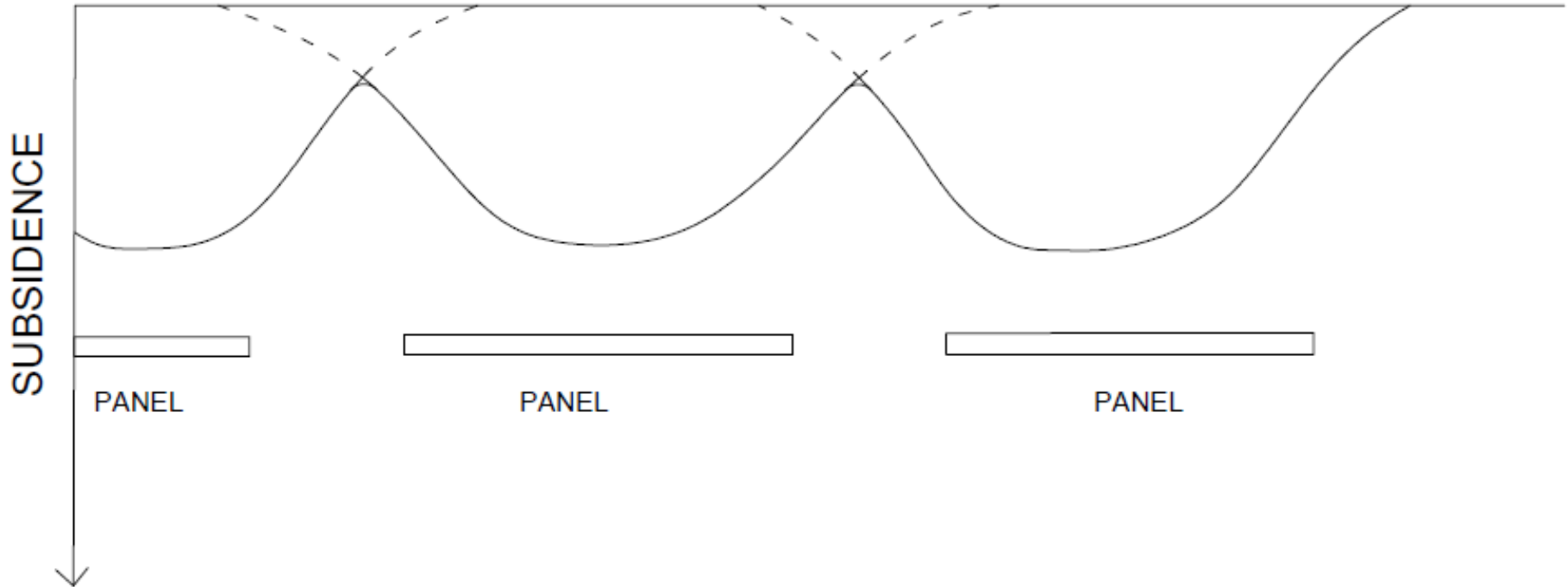
PIPELINE DIAGONAL TO LW PANELS

MINE SUBSIDENCE



MINE SUBSIDENCE

DISTANCE ACROSS THE PANELS

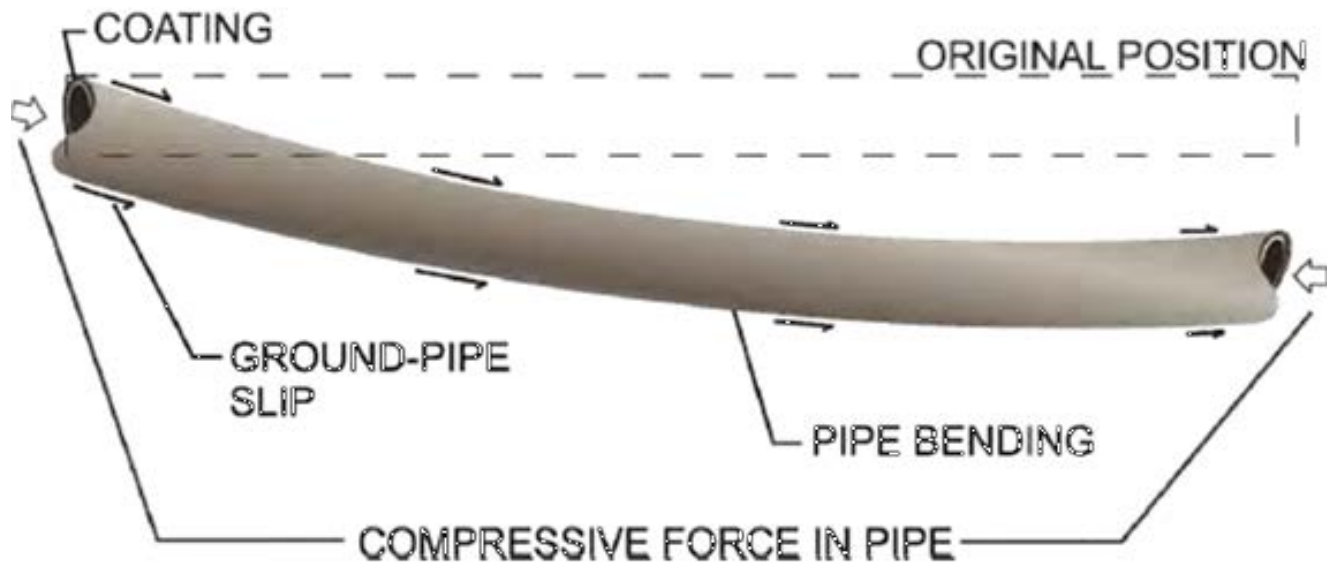
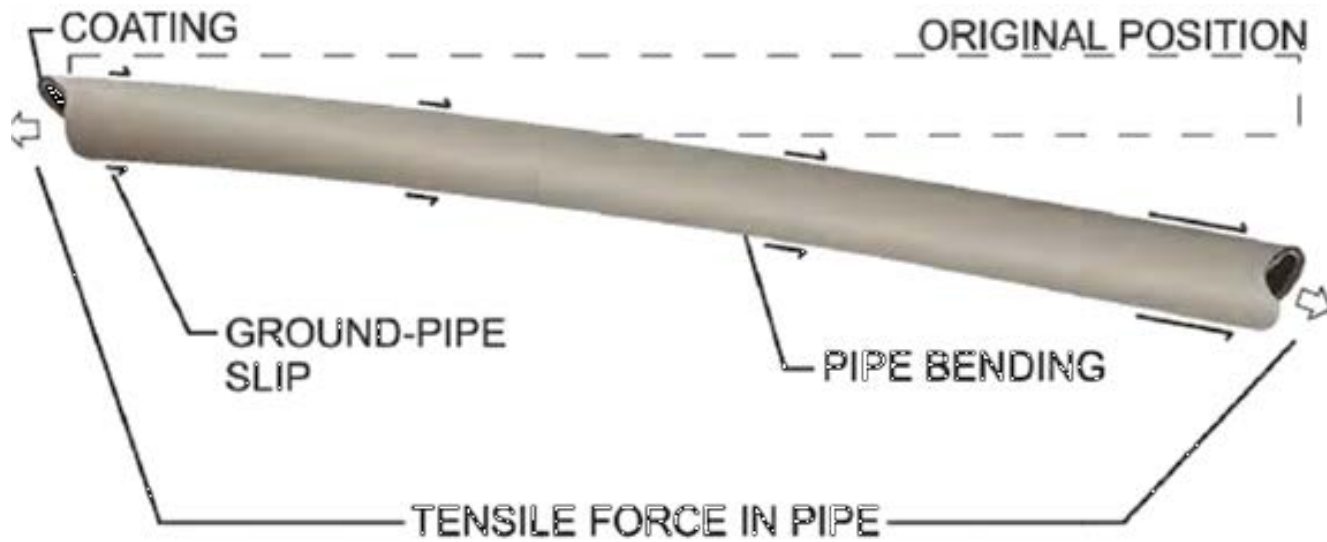


MINE SUBSIDENCE

Location	H_{\max}/S_{\max}	Reference
Illinois Basin	0.11-0.41	Lin, et al., 1996
		O'Rourke, T.D. and Turner S.M., 1979
		Peng, S.S. and Luo, Y., 1991
		Van Roosndall, D.J., et al., 1997
Wyoming	0.23-0.28	Inhouse files
U.S. Appalachian Field	0.3	Peng and Geng, 1982
Germany	0.35-0.45	Brauner, 1973
USSR	0.3-0.35	Brauner, 1973
France	0.4	Brauner, 1973
Great Britain	0.04-0.32	Breeds, 1976
	Averages: 0.22	all
		0.15 limestone classes
		0.24 others

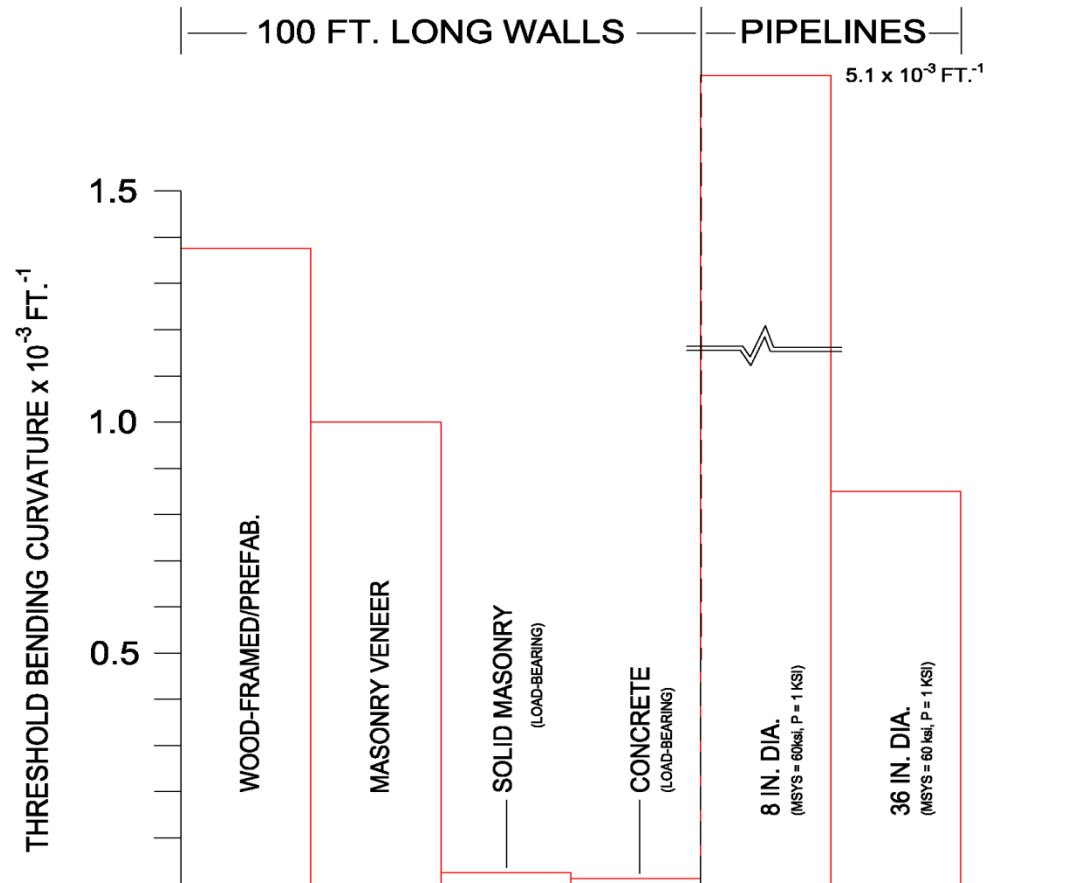
MAXIMUM HORIZONTAL TO VERTICAL DISPLACEMENT RATIOS,
 H_{\max}/S_{\max} FROM LONGWALL MINING

SUBSIDENCE RESPONSE

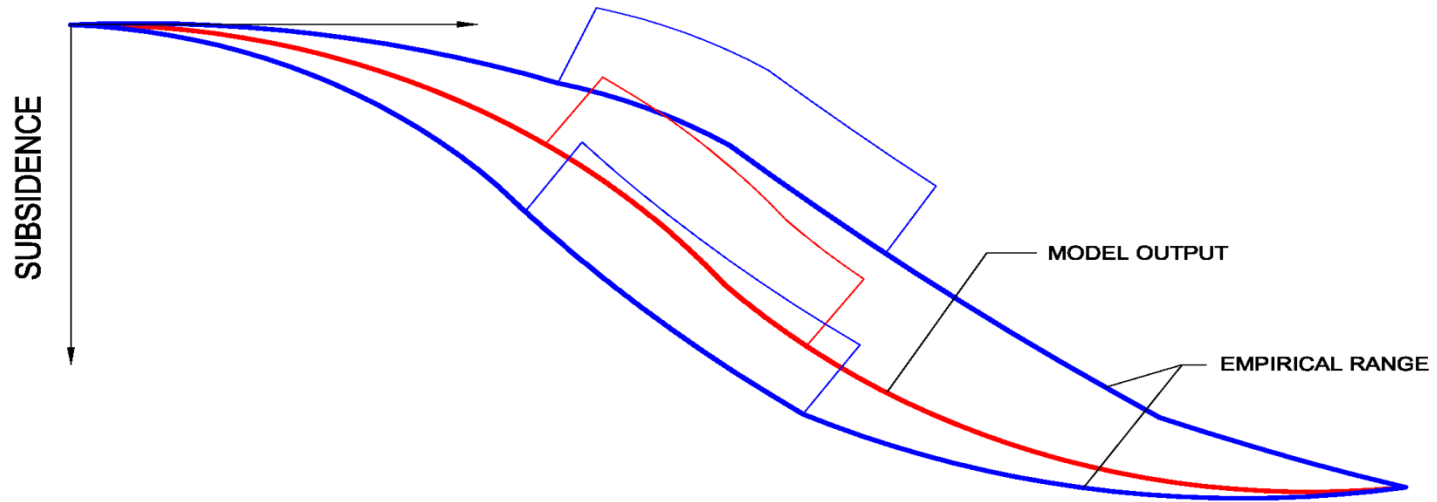


TYPICAL LONGWALL SUBSIDENCE INDUCED STRESSES

SUBSIDENCE RESPONSE/PREDICTION

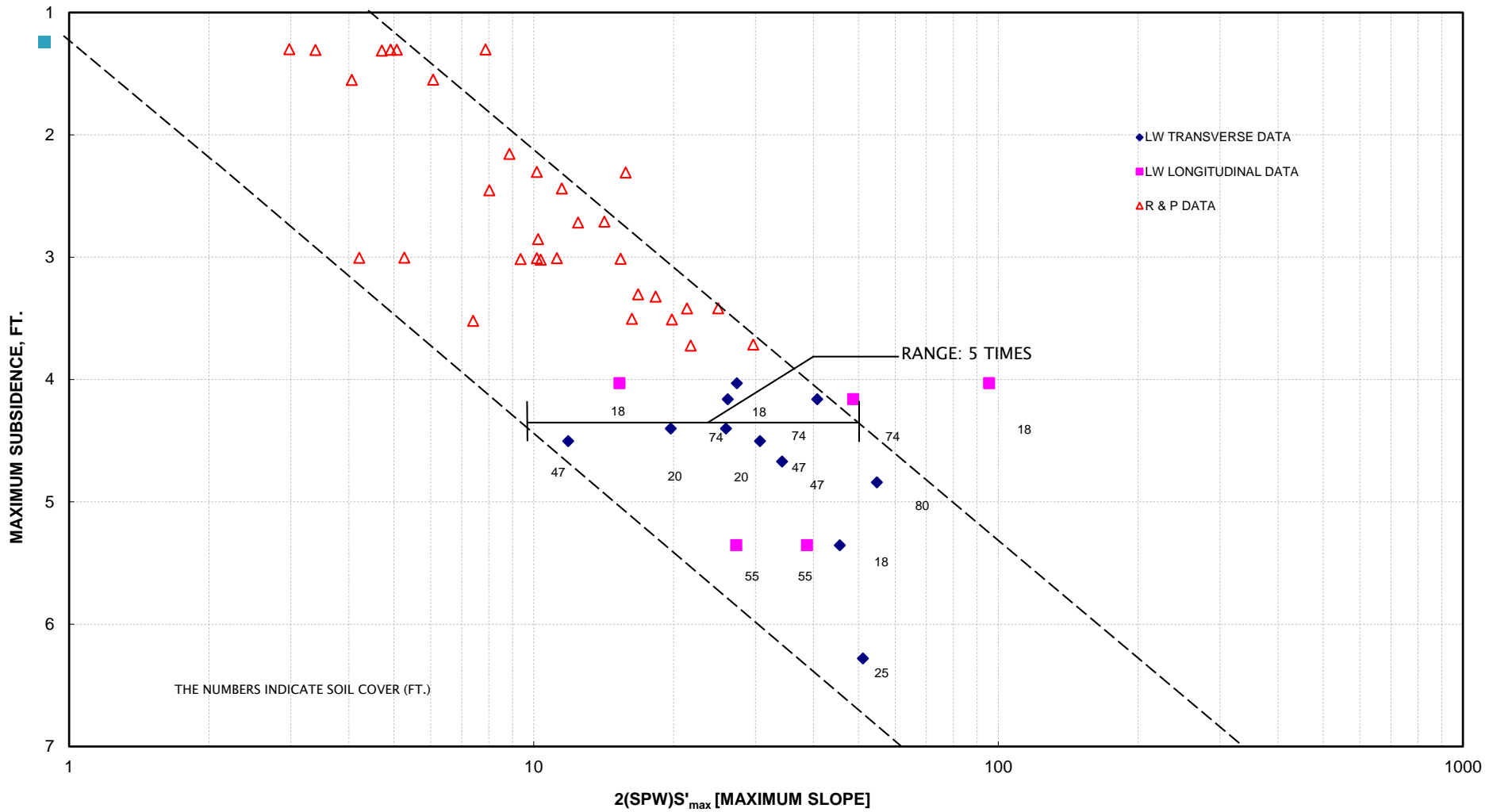


SUBSIDENCE RESPONSE/PREDICTION

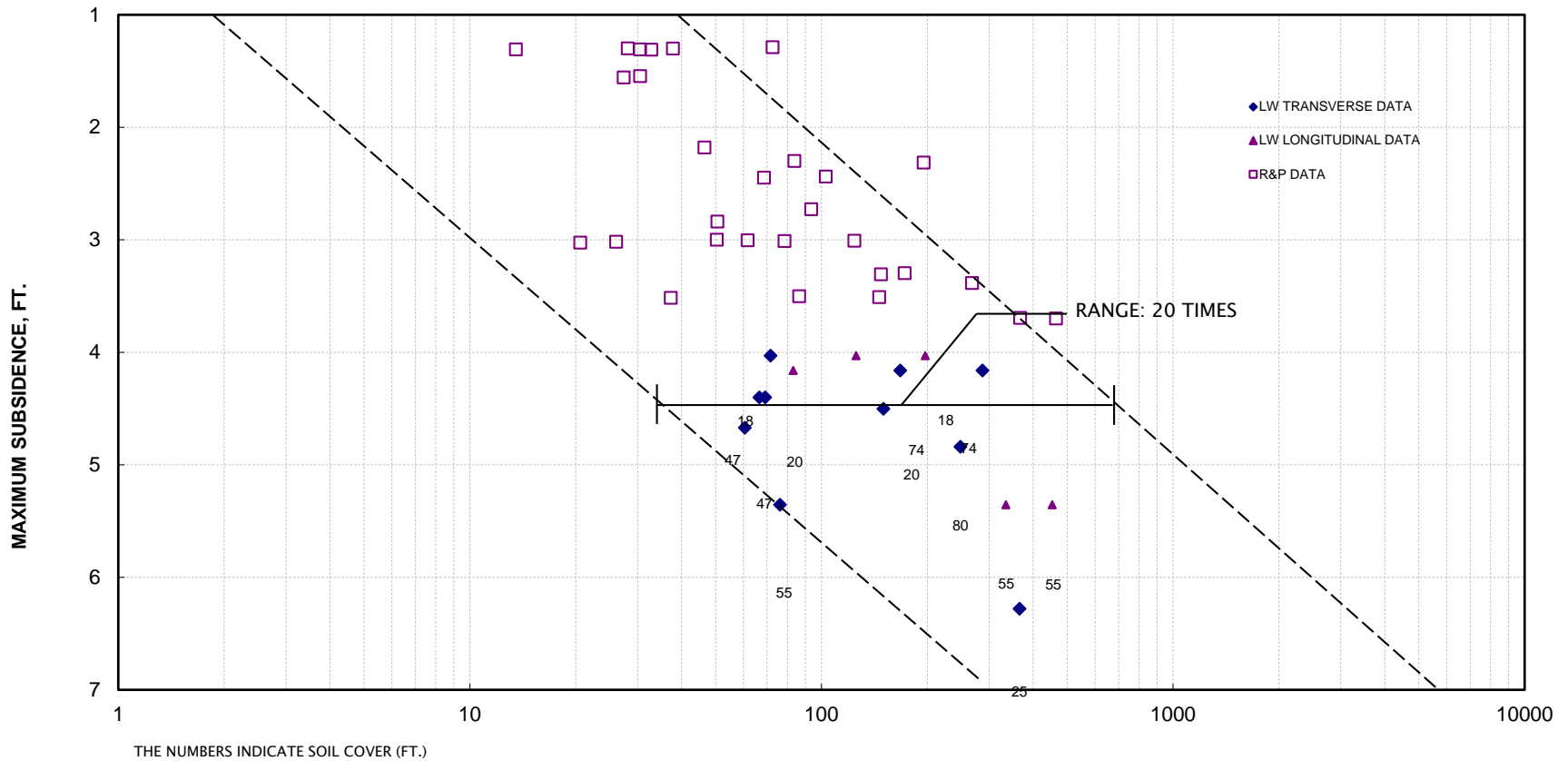


SUBSIDENCE PROFILE ANALYSIS

SUBSIDENCE RESPONSE/PREDICTION

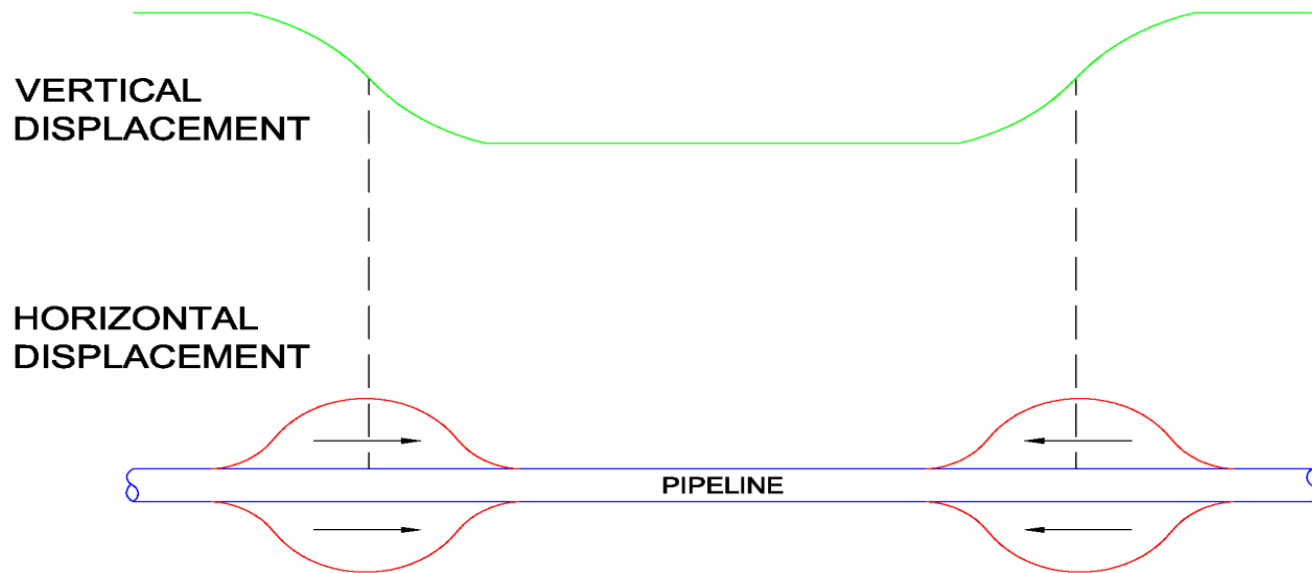


SUBSIDENCE RESPONSE/PREDICTION



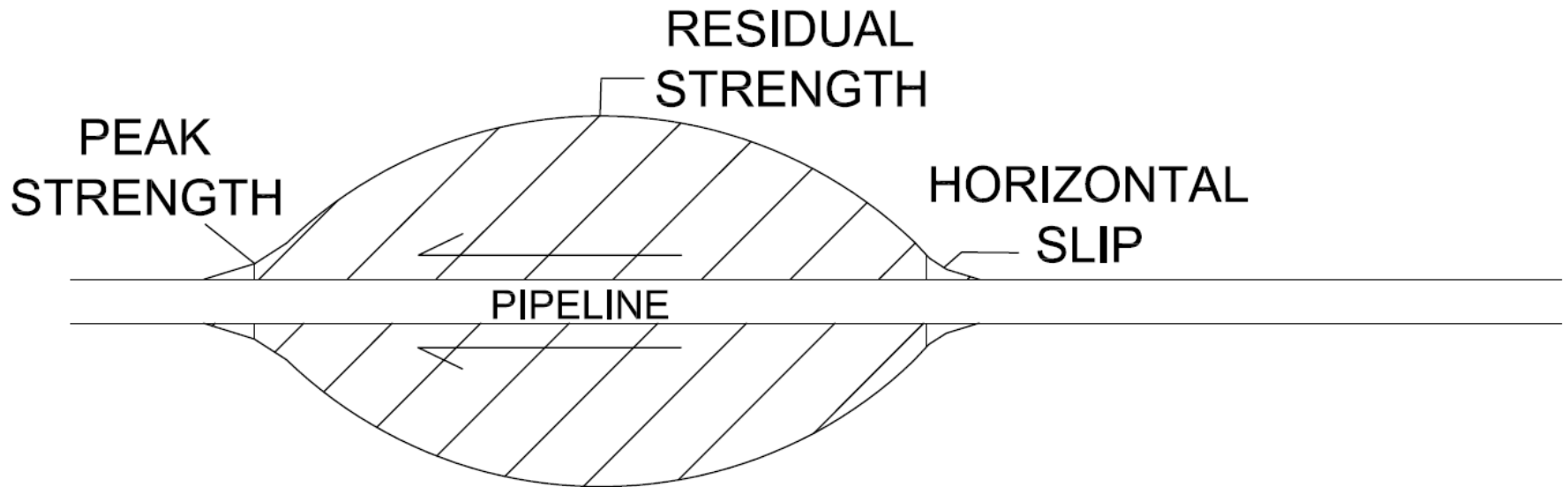
$$4(\text{SPW})^2 S''_{\max} [\text{MAXIMUM CURVATURE}]$$

MINE SUBSIDENCE RESPONSE



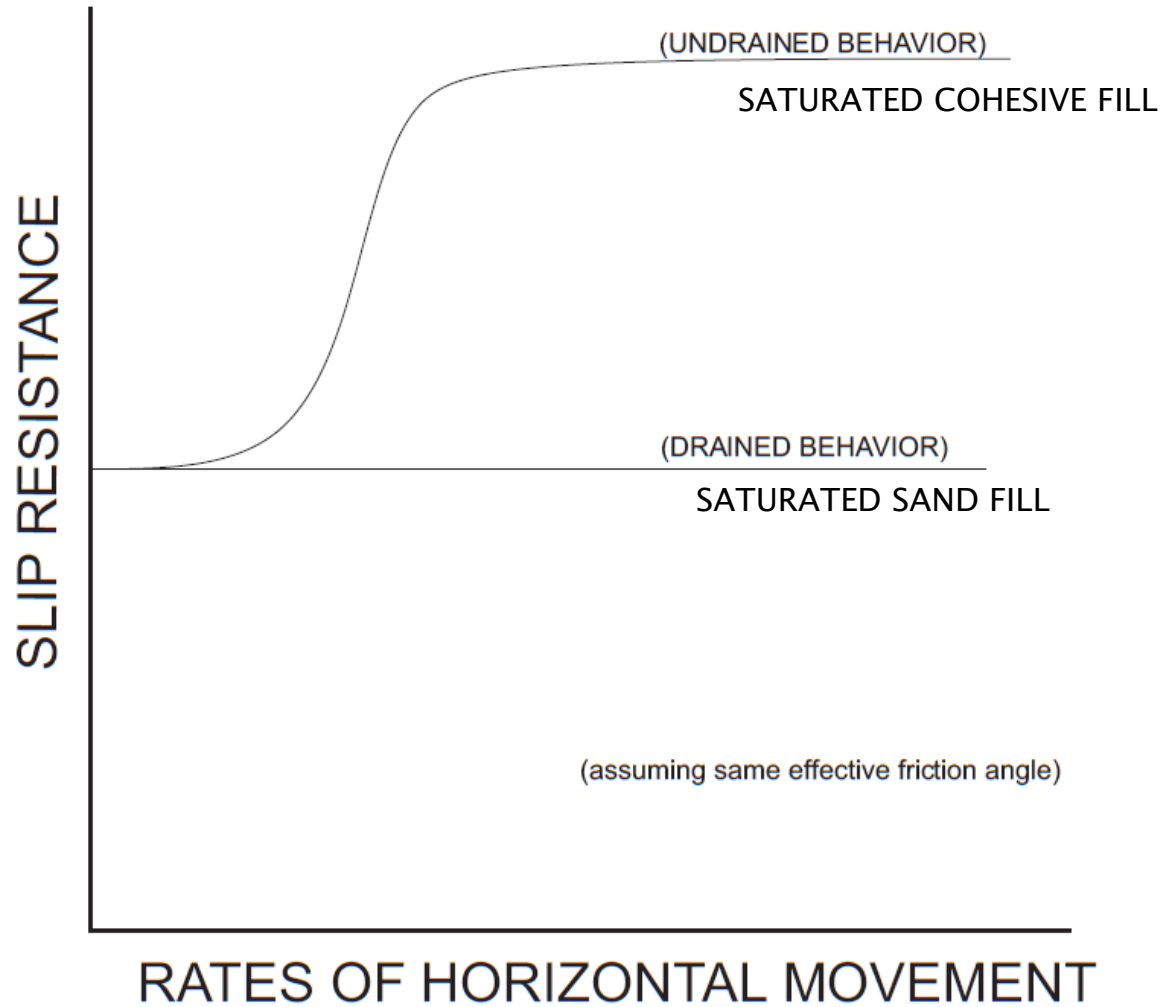
SUBSIDENCE INDUCED LONGITUDINAL PIPELINE STRESSES

MINE SUBSIDENCE RESPONSE

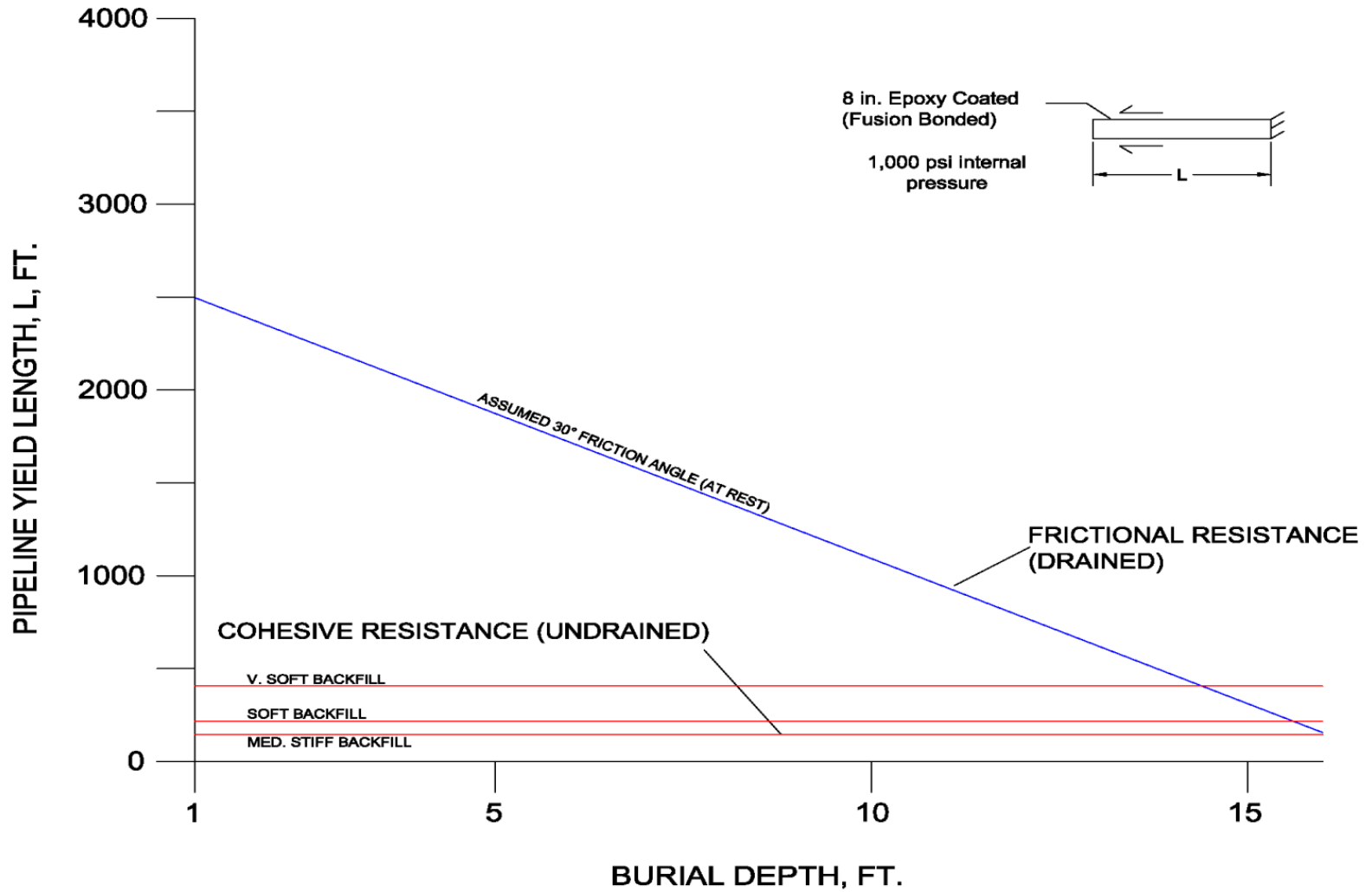


RESIDUAL STRENGTH CONDITIONS ALONG PIPELINE

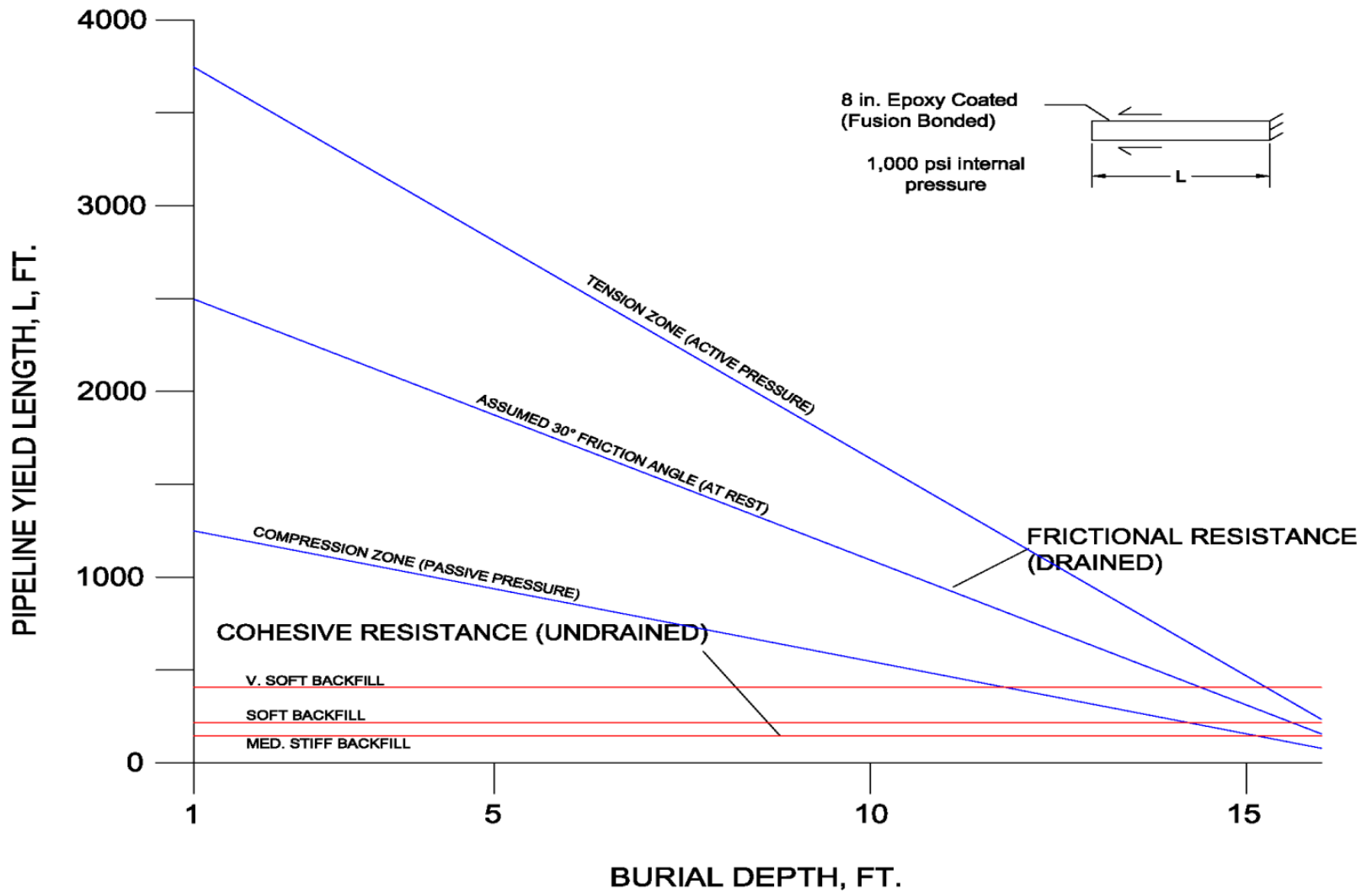
MINE SUBSIDENCE RESPONSE



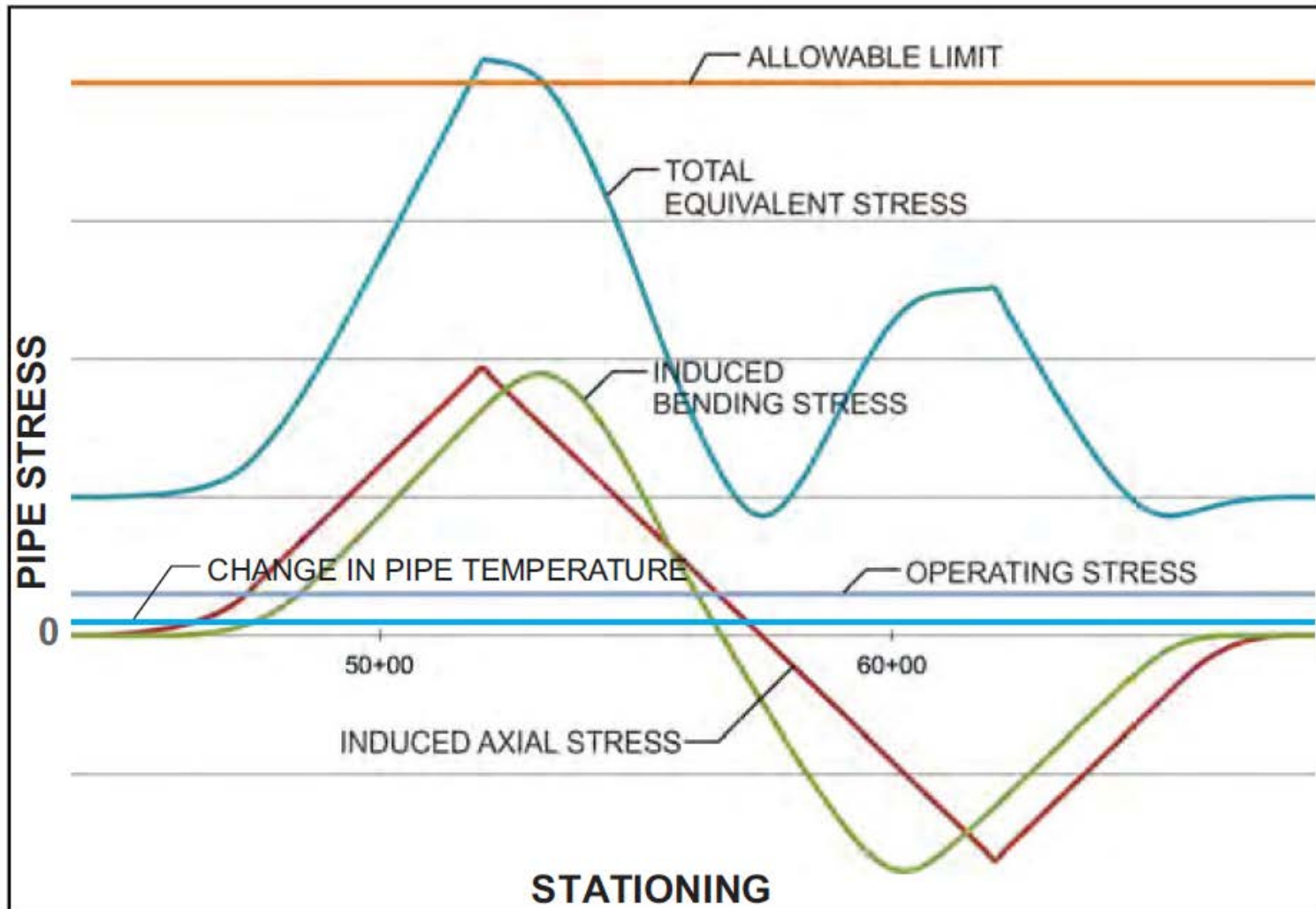
MINE SUBSIDENCE RESPONSE



MINE SUBSIDENCE RESPONSE



MINE SUBSIDENCE RESPONSE



SUBSIDENCE INDUCED PIPELINE STRESSES

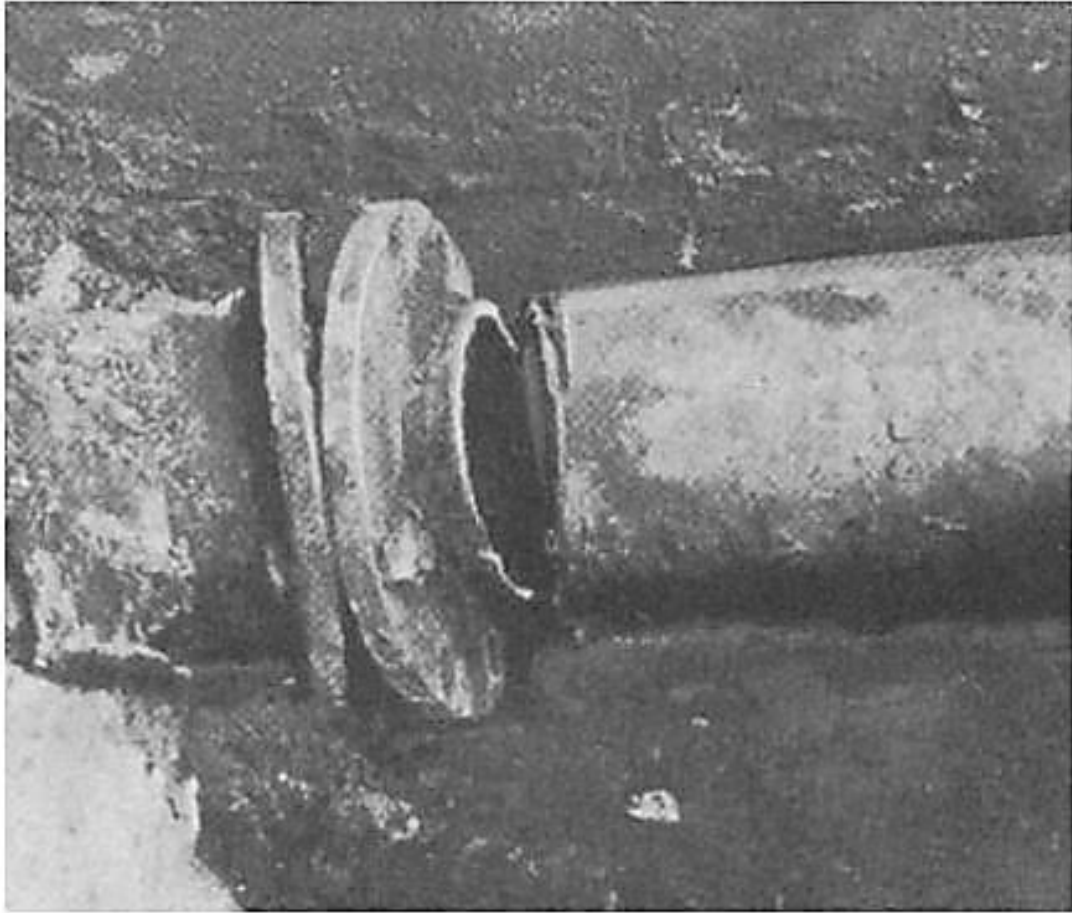
MINE SUBSIDENCE RESPONSE

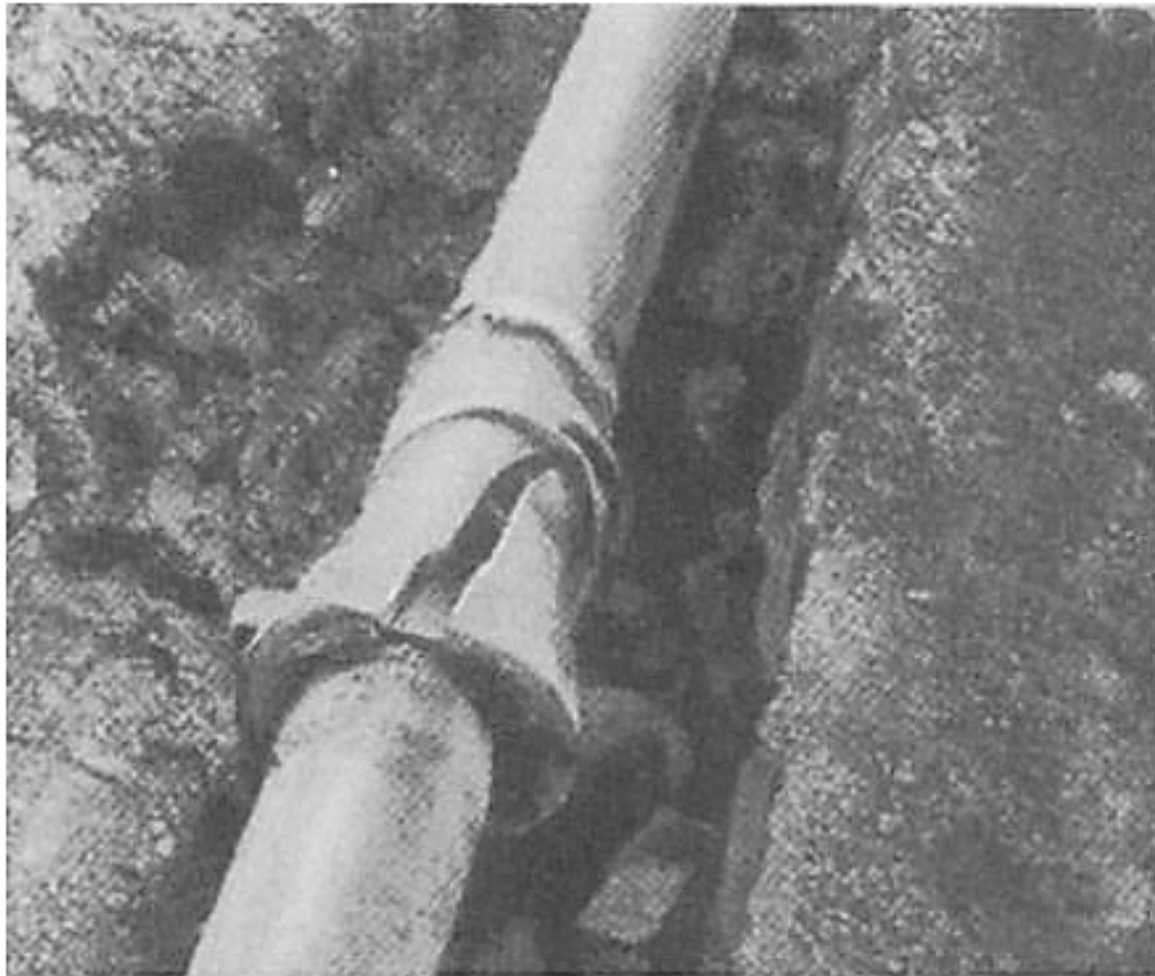
Alert Level

Action

- | | | |
|-----------------|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Moderate Stress | - | More frequent/close monitoring of survey/strain readings with modeling to better understand pipeline response and to identify magnitude(s) and location(s) of peak stress. |
| High Stress | - | For better accuracy monitoring based on modeled peak stress conditions. If necessary, perform effective decoupling. Lowering operating pressure to maintain stress level below acceptable limit at least until mitigation measures are in place, if needed. |
| Threshold | - | Based on modeled peak stress conditions. Where reduction to minimum operating pressure is inadequate, possible line shutdown until decoupling of pipeline, and lower pipe stress verified. |

SUBSIDENCE DAMAGE









SUBSIDENCE DAMAGE MITIGATION

SUBSIDENCE DAMAGE MITIGATION

- ▶ IMPLEMENTED APPROACHES: A FUNCTION OF RISK TOLERANCE

SUBSIDENCE DAMAGE MITIGATION

- ▶ SURFACE METHODS
- ▶ UNDERGROUND MEASURES

SUBSIDENCE DAMAGE MITIGATION

PIPELINE MITIGATION ALTERNATIVES – LONGWALL

TYPE	MEASURES
MINE LEVEL	• Leave protection block of trona.
	• Void fill behind longwall by grouting.
	• Reduce extraction height.
	• Reduce panel face and increase chain pillar support.
	• Leave room and pillar protection area.
	• Panel Orientation

SUBSIDENCE DAMAGE MITIGATION

PIPELINE MITIGATION ALTERNATIVES – LONGWALL

TYPE	MEASURES
SURFACE: MOVE LINE	<ul style="list-style-type: none">• Relocate pipe outside subsidence area.
	<ul style="list-style-type: none">• Install temporary line above ground surface on ROW - segment and monitor permanent pipe - monitor in place pipe.
	<ul style="list-style-type: none">• Install temporary line above ground surface on ROW, install expansion joints or sleeves at predetermined intervals, and reconnect to permanent line - monitor pipe and reduce fluid pressure as needed.

SUBSIDENCE DAMAGE MITIGATION

PIPELINE MITIGATION ALTERNATIVES – LONGWALL

TYPE	MEASURES
<p>PIPE DECOUPLING</p>	<ul style="list-style-type: none"> • Uncover all or portions of the pipeline and monitor. Reduce internal pressure if necessary.
	<ul style="list-style-type: none"> • Install protective cover and backfill pipe - monitor pipe. Reduce internal pressure if necessary.
	<ul style="list-style-type: none"> • Install "slip" interface around pipe - monitor pipe and reduce internal pressure if necessary.
<p>PIPE DEFLECTION CONTROL</p>	<ul style="list-style-type: none"> • Uncover pipe in severe subsidence curvature areas. Support and control deflection of pipe with cribbing/airbags. Reduce internal pressure if necessary.
	<ul style="list-style-type: none"> • Uncover pipe in severe subsidence curvature areas. Undercut subgrade where required to control deflections. Monitor pipe. Reduce internal pressure if necessary.
	<ul style="list-style-type: none"> • Suspending pipe off twin steel beam across the trench via hanging rods which are bolted to a steel hoop secured around the pipe. Rods are treaded to allow vertical adjustment. Also use of bracing to prevent lateral movement inside the trench. Monitor pipe. Reduce internal pressure if necessary.
	<ul style="list-style-type: none"> • Uncover pipe in severe curvature areas. Preset pipeline elevations prior to subsidence to control resulting subsidence-induced bending. Monitor pipe. Reduce internal pressure if necessary.

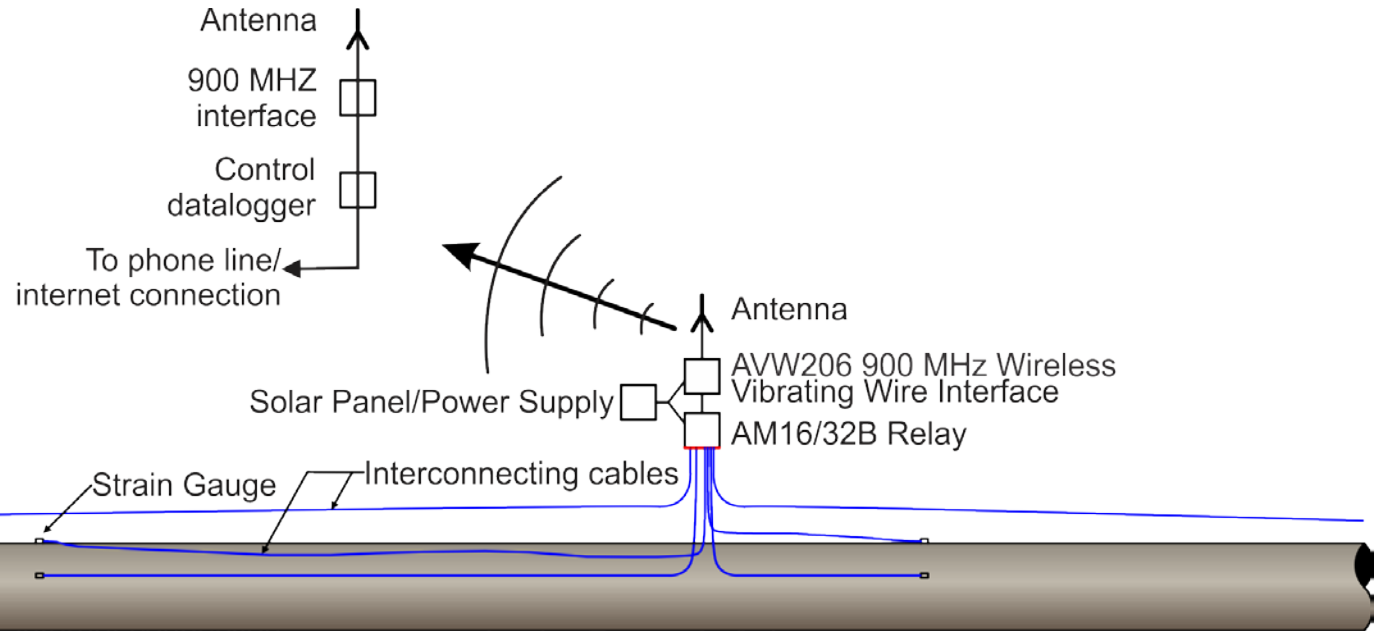
SUBSIDENCE DAMAGE MITIGATION

PIPELINE MITIGATION ALTERNATIVES – LONGWALL

TYPE	MEASURES
FUTURE PIPELINE INSTALLATIONS	• Relocate pipe outside subsidence area.
	• Install expansion/contraction sleeves or joints along pipeline - monitor pipe.
	• Install protective cover/"slip" interface - monitor pipe.



SURFACE METHODS







SUMMARY

- ▶ MORE ADVANCED ASPECTS DISCUSSED
- ▶ USE OF ADVANCED SUBSIDENCE ENGINEERING METHODOLOGY CAN BE OF BENEFIT
- ▶ WITH BETTER UNDERSTANDING OF THE PROBLEM, THE BETTER THE HANDLING OF THE PROBLEM

QUESTIONS?

Thank You!