

Frost Action and Highways

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Frost Action

The detrimental effects of seasonal freezing and thawing.

It requires:

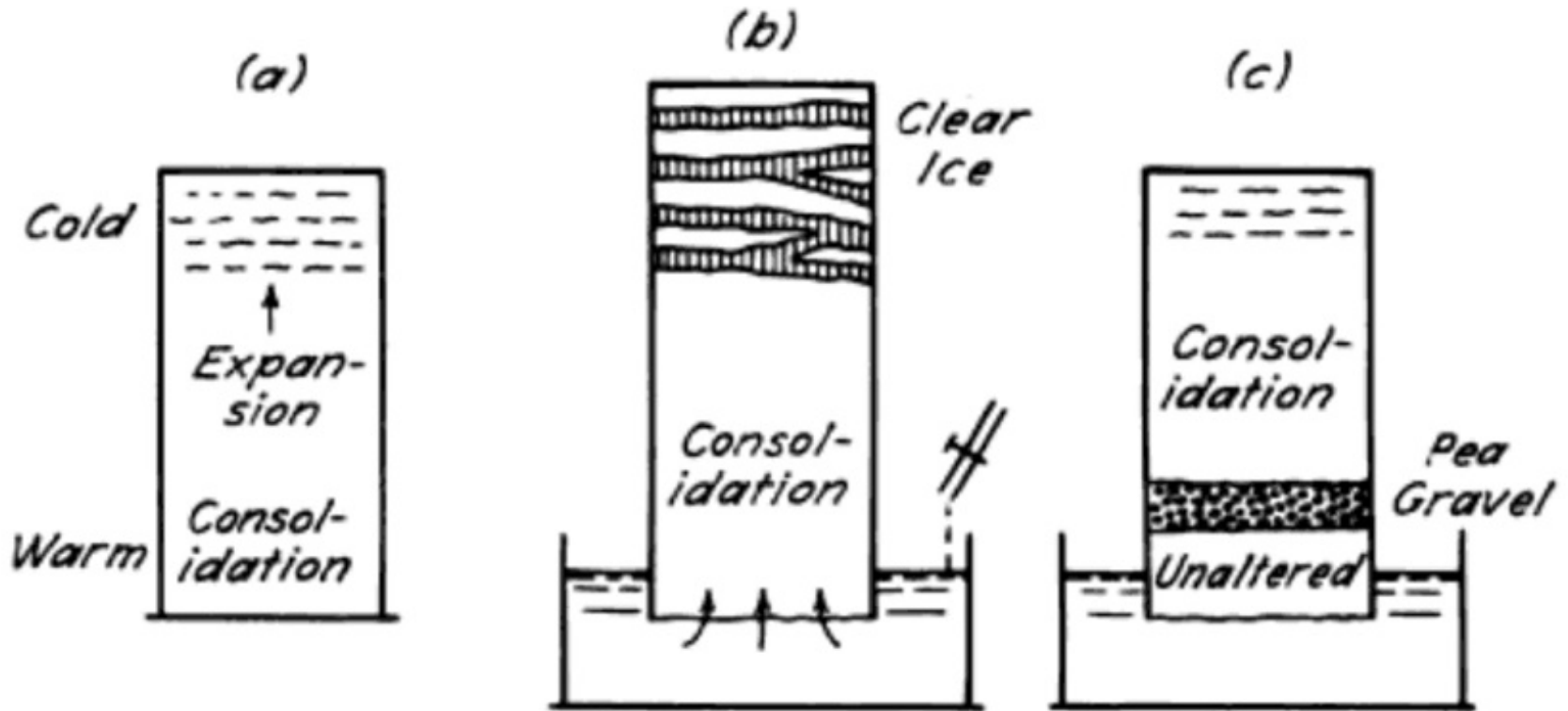
- 1) A frost-susceptible soil
- 2) A supply of water
- 3) Below-freezing soil temperature
- 4) A period of above-freezing air temperature

Frost Design Classification

Frost Group	Kind of Soil	Percentage Finer than 0.02 mm by Weight	Typical Soil Types Under Unified Soil Classification System
NFS ¹	(a) Gravels Crushed Stone Crushed Rock	0-1.5	GW, GP
	(b) Sands	0-3	SW, SP
PFS ²	(a) Gravel Crushed Stone Crushed Rock	1.5-3	GW-GP
	(b) Sands	3-10	SW-SP
S1	Gravelly Soils	3-6	GW, GP, GW-GM, GP-GM
S2	Sandy Soils	3-6	SW, SP, SW-SM, SP-SM
F1	Gravelly Soils	6-10	GM, GW-GM, GP-GM
F2	(a) Gravelly Soils	10-20	GM, GW-GM, GP-GM
	(b) Sands	6-15	SM, SW-SM, SP-SM
F3	(a) Gravelly Soils	Over 20	GM, GC
	(b) Sands, except very fine silty sands	Over 15	SM, SC
	(c) Clays, PI > 12	--	CL, CH
F4	(a) Silts	--	ML, MH
	(b) Very fine silty sands	Over 15	SM
	(c) Clays, PI < 12	--	CL, CL-ML
	(d) Varved clays and other fine grained, banded sediments	--	CL, ML, CL-ML, CL, ML, and SM, CL, CH, and ML, CL, CH, ML, and SM

¹ Nonfrost susceptible.

² Possibly frost susceptible, requires laboratory test to determine frost design soil classification.



Closed and Open System Freezing

after Terzaghi (1952)

MichiganTech

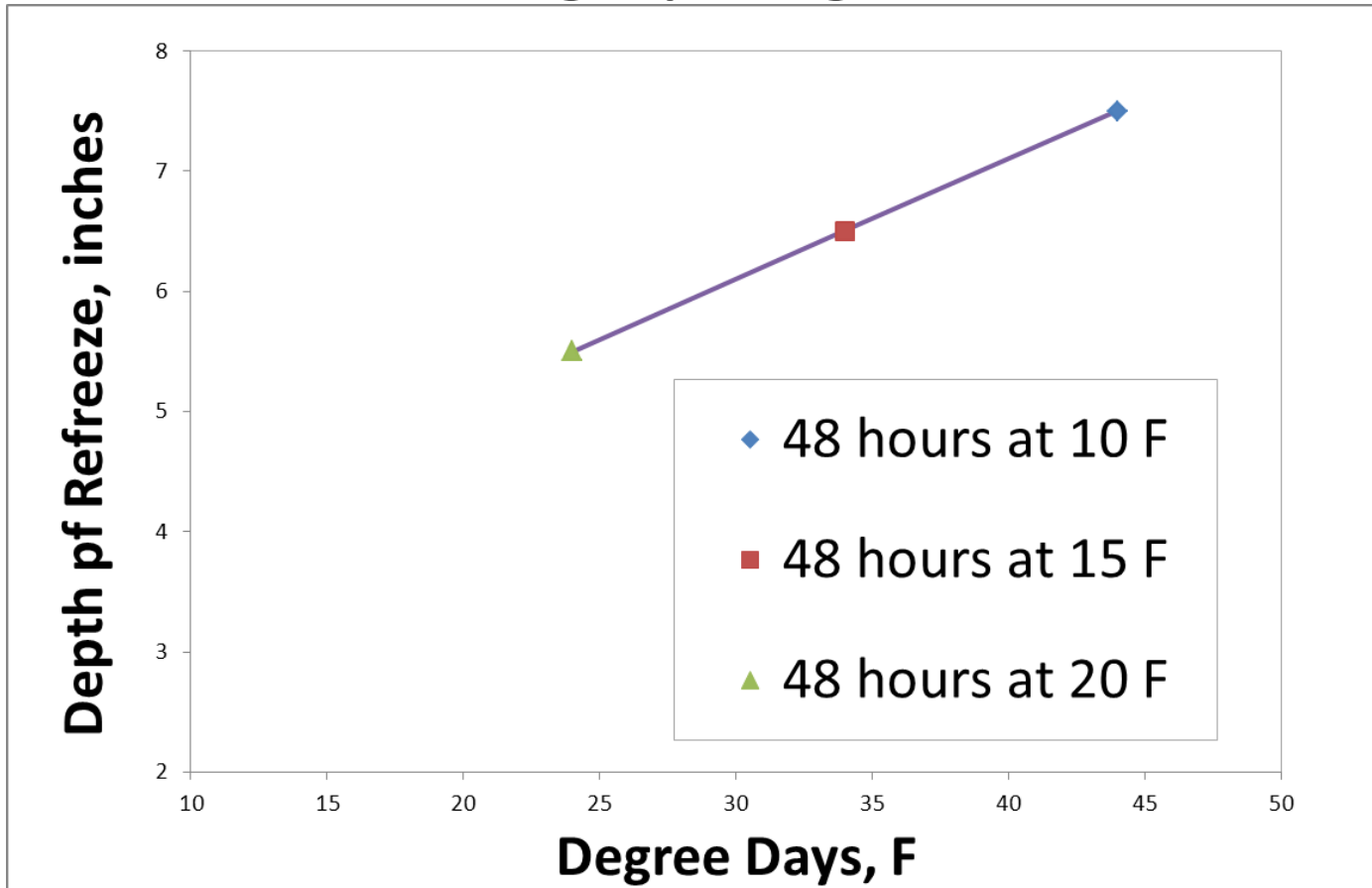
Transportation Institute

Modified Berggren Eq. for Depth of Frost Penetration

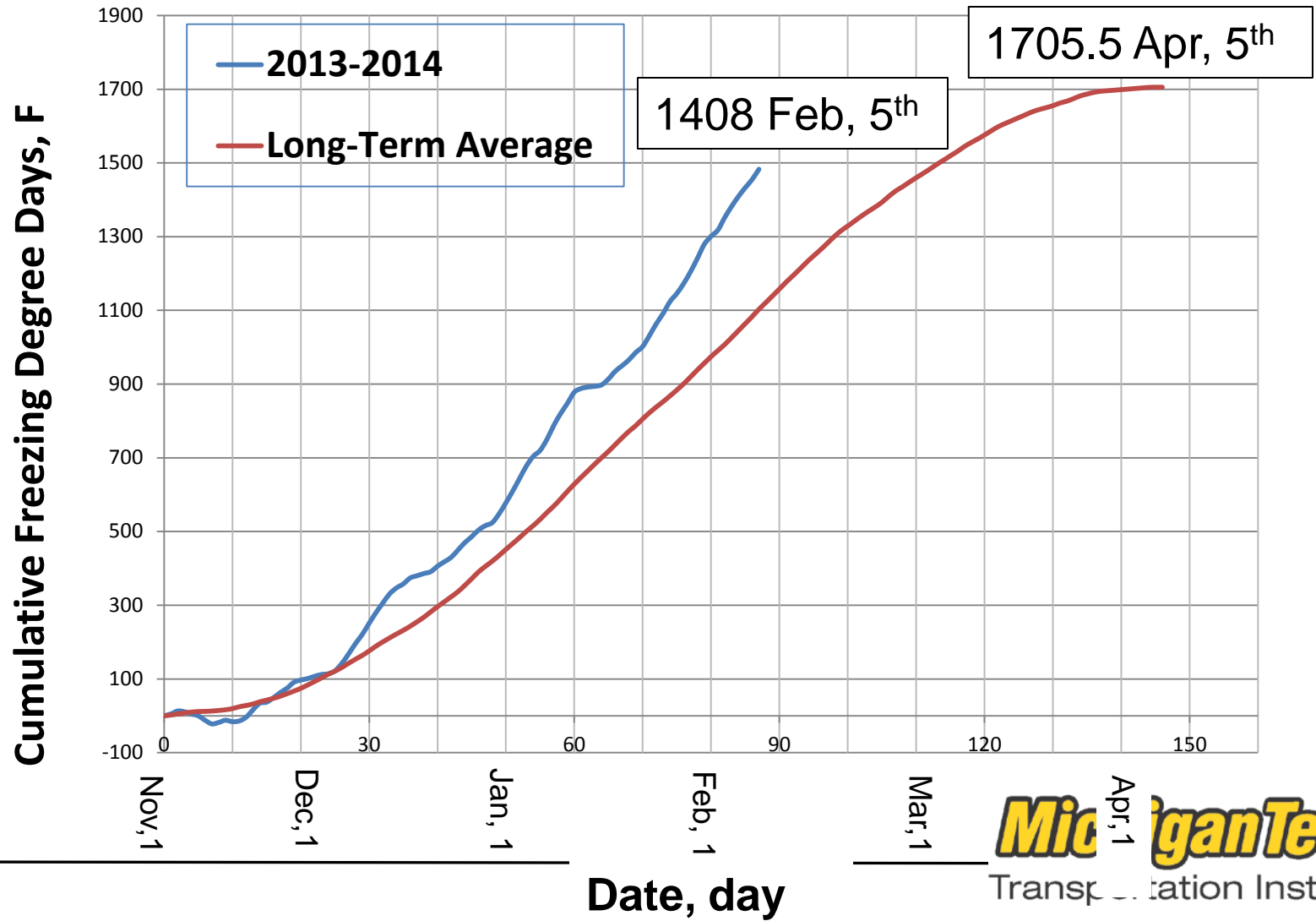
$$X = \lambda(48K_f n_f I_{af} / L)^{1/2}$$

- X = frost penetration, ft
- λ = a dimensionless correction factor
- K_f = thermal conductivity of frozen soil, Btu/hr-ft-°F
- L = latent heat of fusion, Btu/ft³ This is the energy involved in the phase change from water to ice.
- n_f = surface freezing index / air freezing index ~ 0.7 for bare roadway, but it depends greatly on the wind speed.
- I_{af} = air freezing index, degree-days F

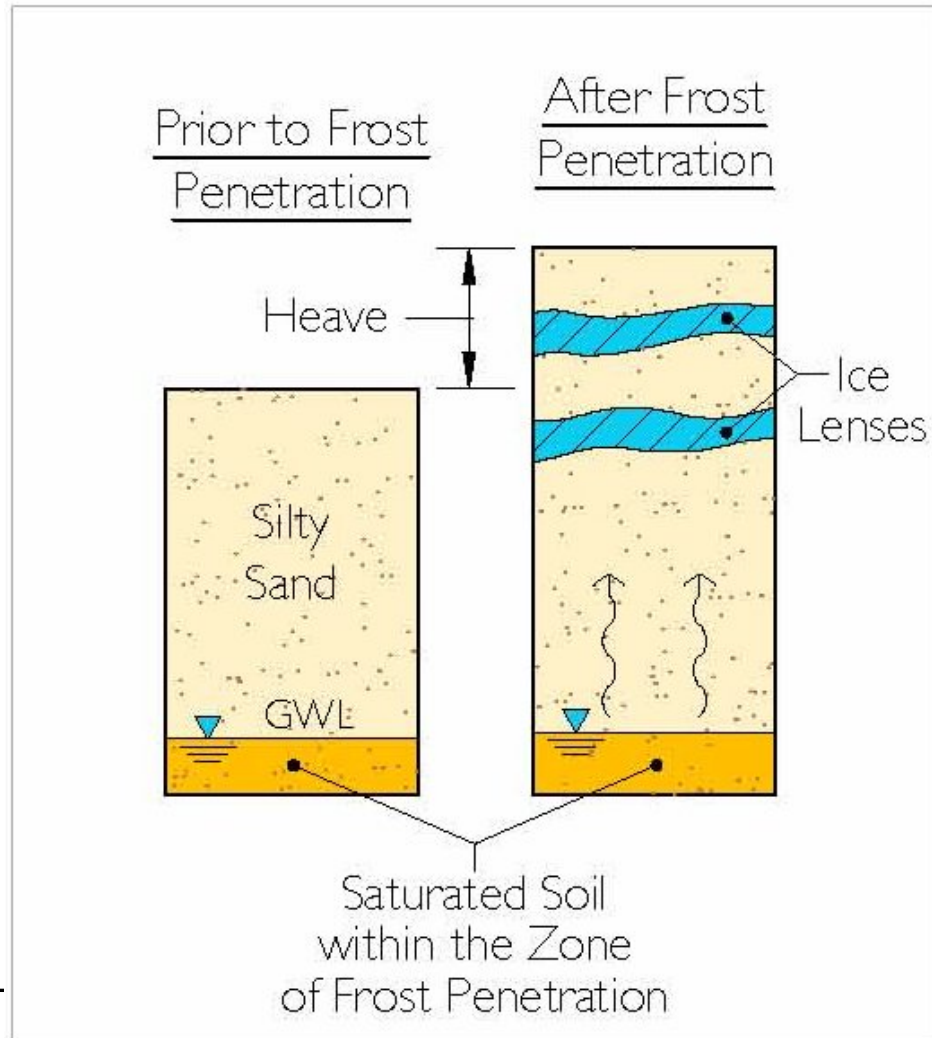
Idealized Roadway Refreeze Depth During Spring Melt



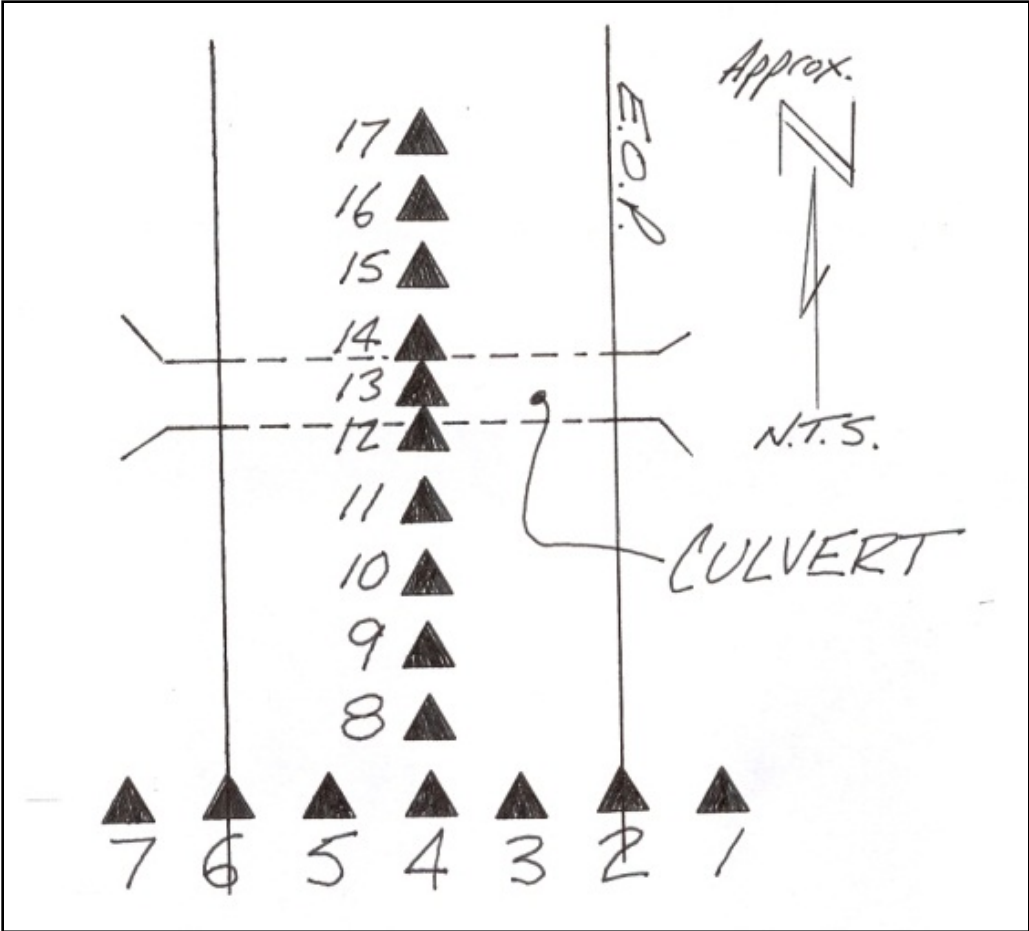
Freezing Index at Houghton County Airport



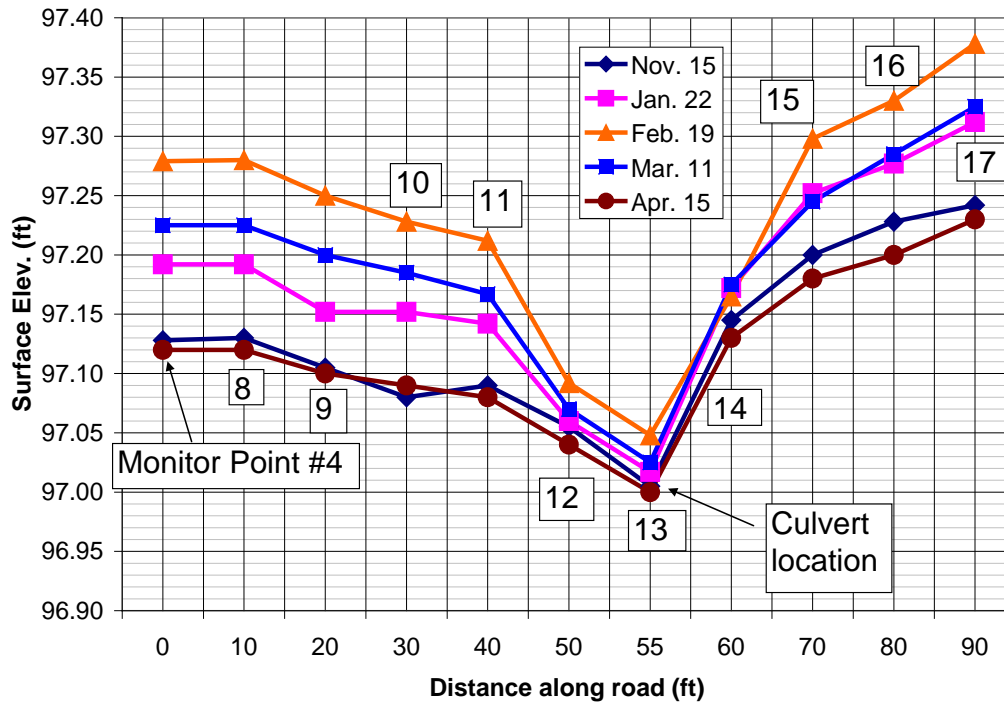
Idealized Situation at Bootjack Road



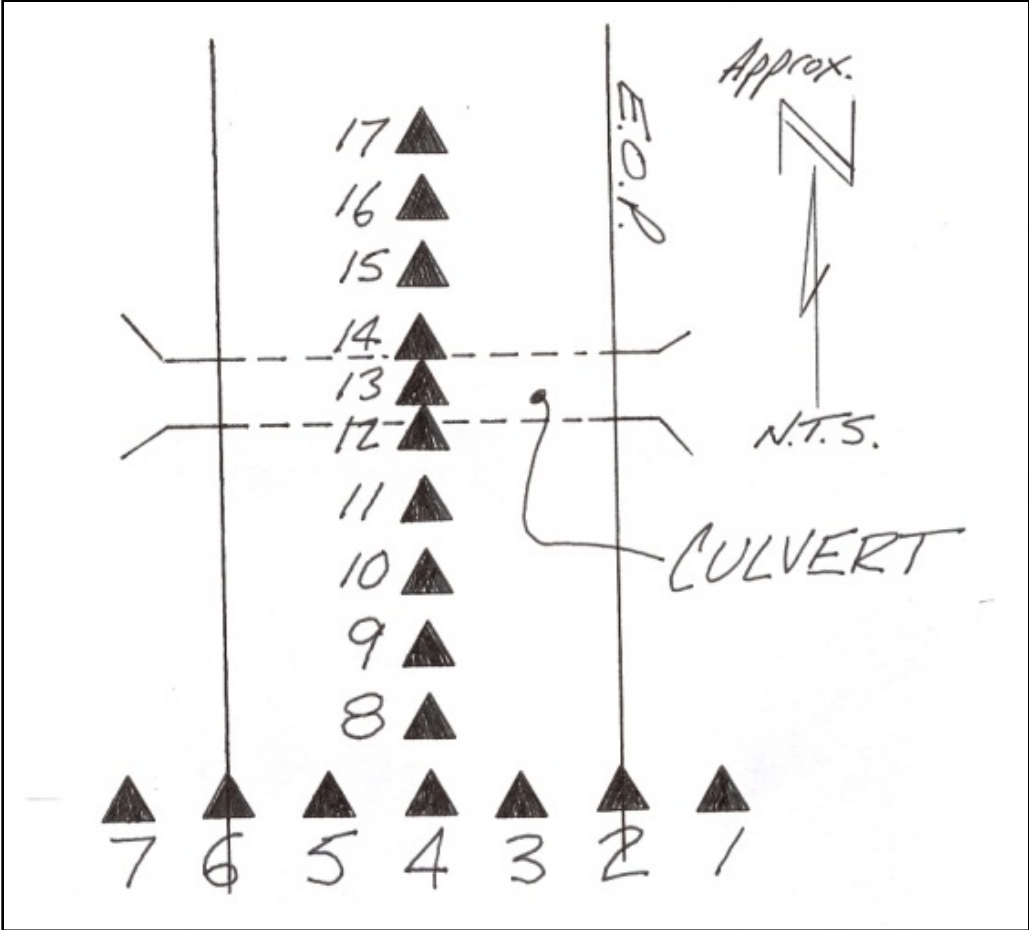
Bootjack Road Reference Points



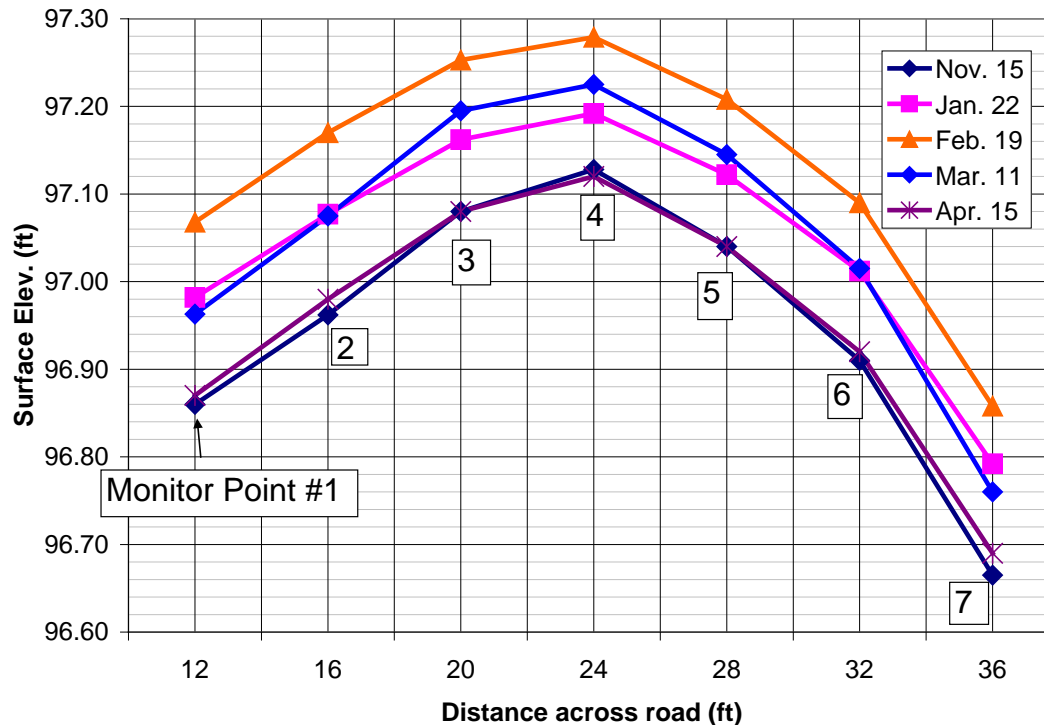
Measured Frost Heave Along Centerline



Bootjack Road Reference Points



Measured Frost Heave Transverse to Centerline

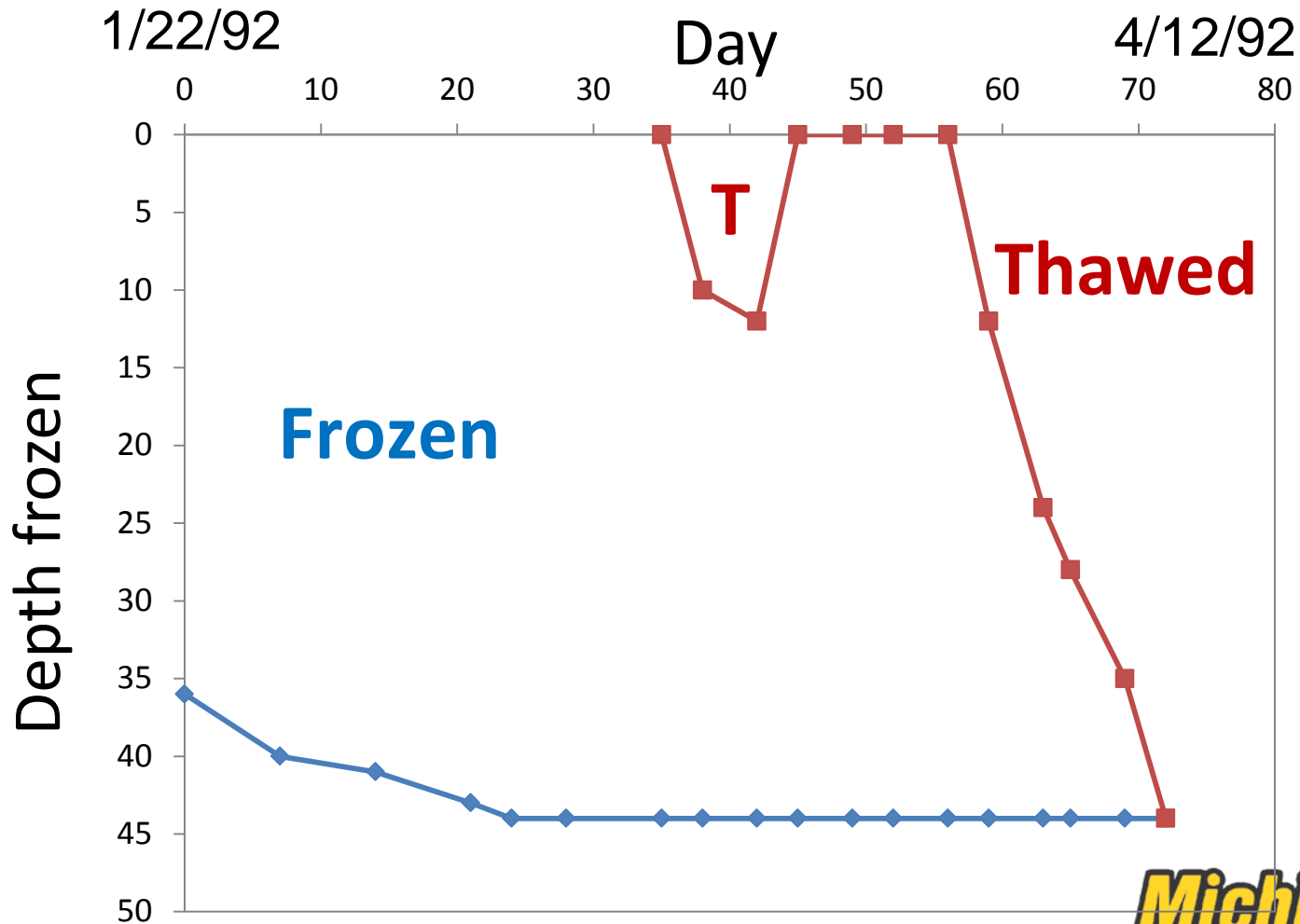


LUCE COUNTY FROST TUBES

- Information from Stan Ronquist
- Data on 3 tubes from 8/81 to present
- Latest frost in the ground 5/16/96
- Deepest frost penetration 3/3/94 (75")

LUCE COUNTY FROST TUBE

Typical thawing pattern



Light Reading for a Cold Winter Night

- Andersland, O. B. and Ladanyi, B., An Introduction to Frozen Ground Engineering, Chapman & Hall, 1994.
- Terzaghi, Karl, “Permafrost”, Contributions to Soil Mechanics, 1941-1953, Boston Society of Civil Engineers, 1953.
- Departments of the Army and Air Force, TM 5-852-6, “Arctic and Subarctic Construction Calculation Methods for Determination of Depths of Freeze and Thaw in Soils”, 1988.
- U.S. Dept. of Transportation, FHWA-HRT-08 057, “Long Term Pavement Performance Computed Parameter: Frost Penetration”, 2008.