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Abstract

Many landslides in Maine have occurred in the marine clay, called the Presumpscot Formation, which covers much of southern Maine. This glacially derived clay was deposited in the sea during the retreat of the late Wisconsinan ice sheet, and subsequently was uplifted by crustal rebound after the glacier receded. Most of the landslides are single rotational slides, but some of them comprise a number of slides formed by retrogressive slope failure. The retrogressive slides are potentially the most destructive, since they occur rapidly with little apparent warning and cover a large area.

Two recent landslides in the Presumpscot Formation were investigated with the objective of developing simple predictive indicators of imminent sliding. One slide was a rotational slide, and the other was a retrogressive slide covering about seven acres. Field geologic investigations, field mapping, field and laboratory testing, and analytical work were conducted on these landslides. The nature of the Presumpscot Formation also was examined through published literature and by comparison with descriptions of similar deposits in eastern Canada and Scandinavia.

The rotational slide occurred in a thick deposit of the Presumpscot Formation along the Maine coast, and was caused by oversteepening from wave erosion at the toe. This erosion was promoted by highly erodible silt layers interbedded in the silty clay and by throughgoing discontinuities. Additional future slides can be expected since coastal erosion removes the stabilizing slide debris. At this location the Presumpscot Formation is insensitive, which appears to be the reason that only a single slide occurs at a time.

The retrogressive slide occurred in the Presumpscot Formation inland from the coast. It is located adjacent to a small river, in the general vicinity of major historical slides. This sudden slide destroyed one home while encompassing a width of about 1000 feet and retrogressing more than 400 feet. The Presumpscot Formation at this location had lower strengths and was more highly sensitive, i.e.the

disturbed shear strength was much lower than the intact shear strength, than the Presumpscot Formation in the coastal slide. The testing indicated that the shear strength peaked at low strains, which may be the reason that this type of failure occurs with little apparent warning. High pore pressures developed during shearing were responsible for the low shear strength of the sediments involved in the landslide. In similar soils of eastern Canada and Scandinavia, high sensitivity likewise has been related to retrogressive slides. A high liquidity index (high water content relative to the Atteberg limits), together with the nearby occurrence of historic slides, appear to be indicators of areas where retrogressive landslides in the Presumpscot Formation are likely to occur in the future.

Landslides
in the
Presumpscot Formation, Southern Maine

Introduction

Understanding the conditions which cause sudden, large landslides in Maine is necessary to protect both residential and commercial landowners, especially in this time of rapid development in southern Maine. This report deals with an engineering investigation of the causes of the landslides and in particular will focus on two recent landslides in glacial-marine clay.

One landslide along the coast is a rotational slide in a bluff eroded in glacial-marine clay. Based on the results of the field and laboratory investigations, the relationships of slope topography and other conditions at failure are used to predict the occurrence of other similar type landslides. The second slide covers an extensive area and is composed of a large number of failures which rapidly spread back from the initial slope failure. The field and laboratory investigations for this extensive slide are used to develop indicators for the cause of this retrogression in order to identify other areas where similar slides may occur. Significant known properties of the glacial-marine clay in Maine and the nature of similar glacial clays and landslides elsewhere are reviewed to shed light on landslide behavior in Maine.

Presumpscot Formation

Both landslides examined during this study and many other landslides in Maine have occurred in a medium-plastic glacial clay known as the Presumpscot Formation, which occurs in coastal Maine and inland along major river valleys (Thompson and Borns, 1985). The origin, deposition history, and subsequent land elevation changes have had significant effects on the clay shear strength.

The Presumpscot Formation consists of glacial debris carried by meltwater into relatively quiet marine waters about 14,000 to 10,000 years ago (Thompson, 1979). With recession of the continental glaciers, the underlying bedrock rebounded more than 300 feet (Schnitker, 1974; Struiver and Borns, 1975) elevating the Presumpscot Formation above sea level in the coastal lowland of southern Maine. The surface of the glacial marine clay ranges in elevation from 20 to 40 feet above present mean sea level along the coastline and gradually slopes upward to over 200 feet farther inland (Thompson, 1979).

The upper part of the Presumpscot Formation above sea level typically is a "brown" or "gray-brown" silty clay grading from a stiff crust at the top to a very soft clay at the bottom of an interval of 6 to 12 feet. This weathered zone is underlain by a soft to very soft "gray", "blue-gray" or "blue" silty clay (Andrews, 1985). The silty clay may contain occasional thin layers of fine sand, or it may grade to a fine sandy, clayey silt. The Presumpscot Formation also may contain lenses of sand or gravel, as well as boulder "dropstones" (Andrews, 1985). The Presumpscot Formation can reach a thickness of more than 100 feet in places, and can be quite variable in thickness where it overlies irregular surfaces of glacial till or bedrock.

Composition The composition of glacial deposits reflects variations in parent bedrock, and the presence of various particle sizes reflects the amount of sorting. Similar deposits which have glacial origins and were deposited in sea water occur in the Boston area, in eastern Canada and in Scandinavia. The Presumpscot Formation is a varied mixture of fine sand, silt, and clay sizes. Bloom (1960) found that the mineralogy in the brown clay is the same as the underlying gray clay. Reported grain size compositions (Goldthwait, 1951; Caldwell, 1959; Bloom, 1960; Maine State Highway Commission and others, 1969; Novak and others, 1984; Andrews, 1985) are shown in Table 1.

Table 1

Presumpscot Formation Composition

Description	Percentage
Fine Sand (0.4-.07 mm)	0 to 35
Silt (.07-.002 mm)	20 to 55
Clay Size (<.002 mm)	35 to 75

The component which has the most effect on the strength of soil is the amount and type of clay-size fraction in the deposit. The composition of the clay-size fraction has been reported (Caldwell, 1959; Bloom, 1960; Day, 1980) to be only the product of glacial erosion, i.e. pulverized rock fragments which have not had time to be weathered and altered to clay minerals. Using differential thermal analysis and X-ray diffraction, Lambe and Martin (1954,1956) and Mitchell (1956) reported that quartz, feldspar, and mica occur in the clay-size fraction of the Presumpscot Formation, but they also identified illite in significant proportions (Table 2). Bjerrum (1954) and Karrow (1961) noted that quartz rock flour occurs in the clay-size fraction of Norwegian clay and eastern Canadian clay respectively, but they also reported clay minerals. Typical compositions of Boston Blue clay, clay from eastern Canada, and Norwegian clay are somewhat similar to that found by Lambe and Martin (1954,1956) for the Presumpscot Formation (Table 2).

Cementation, as well as the presence of iron oxide, was also noted (Mitchell, 1956). Loiselle and others (1971) indicated the presence of ferrous oxides, calcium carbonate or gypsum cementing agents in the eastern Canadian clay called Leda clay. The brittle nature during shear and the change in strength with straining of the Leda clay is linked to the cementing. Organic material which is adsorbed on the clay surfaces and at the particle contacts has been found in the Presumpscot Formation and the eastern Canadian clays (Mitchell, 1956). The presence of organic material usually causes a clay to have reduced strength and more compressibility.

Classification Properties The physical properties of clay depend to a large extent on the type of clay mineral that dominates the colloidal fraction, the nature of the substances present on the adsorbed layers, the environment of deposition, the organic matter content, and the cementing agents. Determination of these constituents is not practical for general purposes since it requires sophisticated equipment, such as X-ray equipment, and highly trained personnel. Grain sizes of soil can be determined with tests which are available in a number of practicing geologist's and engineer's laboratories. Two clays with identical grain size curves can have quite different physical properties, and thus grain size is not such a good indicator of physical properties. Instead, properties have been found to correlate in a general way with the easily measured Atterberg limits which establish water content boundaries between slurry and plastic states, the liquid limit (ASTM, 1982a) and between plastic and semisolid states, the plastic limit (ASTM, 1982b). Atterberg limits for selected samples are shown in Table 2 and are typical of the

Table 2

Composition of Marine Glacial Clays

		Percent Finer		Composition [1]				Atterberg Limits		
Clay	Location	.074	.002	Illite	Chlorite	Quartz	Feldspar	LL	PL	W
Presumpscot[2]	Portland	90	48	45	10	35	10	49	21	42
Presumpscot[3]	Liv. Falls	82	19	30	5	30	-	33	18	-
Presumpscot[3]	Searsport	95	30	45	15	35	-	37	19	26-30
Presumpscot[4]	Fore River	-	43	40	5	20	-	49	21	42
Boston Blue[4]	Camb, Ma	-	52	30	5	15	-	41	20	36
Boston Blue[4]	Charl, Ma	-	56	45	5	20	-	49	26	38
Beauharnois[4]	Quebec	-	56	30	8	15	-	56	22	61
St. Lawrence[4]	Quebec	100	78	40	10	10	20	55	22	54
Norwegian[5]	Oslo	-	46	55	-	-	-	36	20	33

Notes:

1. Percent by weight for percent finer than .074 mm for Lambe and Martin (1954, 1956). Percent finer than .002 mm for others.
2. Lambe and Martin (1956).
3. Lambe and Martin (1954).
4. Mitchell (1956).
5. Bjerrum (1954).

values for the Presumpscot Formation. Reported values of plasticity index (the difference in water content between the liquid limit and the plastic limit) of the Presumpscot formation vary from 6 to 33 (Caldwell, 1959; Hedstrom, 1974; LaGatta and Whiteside, 1984; Novak and others, 1984; Andrews, 1985). This value of plasticity index indicates a possible illite clay in the clay-size fraction. A plasticity index greater than zero indicates the presence of clay minerals, whereas the plasticity index for silt or rock flour is near zero (Casagrande, 1932). The Atterberg limits for pure illite are 60-120 for liquid limits and 35-60 for plastic limits (Mitchell, 1956). The magnitudes depend on the ionic form. These values are consistent with the plasticity indices of the Presumpscot Formation since the value of the plasticity index has been shown to decrease accordingly as the percentage of particular clay in a sample decreases (Odell and others, 1960).

The specific gravity of Presumpscot Formation is reported to be 2.74 to 2.79 (Maine State Highway Commission and others, 1966; Ladd, 1972; Young, 1966; Andrews, 1985). This is higher than what one would expect from primarily pulverized quartz and feldspar, which has a specific gravity near 2.65. It probably reflects the content of clay minerals such as chlorite with a specific gravity of 2.6 - 2.96 and illite with a specific gravity of 2.6 - 3.0 (Mitchell, 1976).

Consolidation Effects Normal consolidation, i.e. void space reduction of Presumpscot Formation clay due to its self weight, increases the strength of the clay with depth. The liquid limit and natural water content can often be used to identify a normally consolidated clay, since the natural water content for a normally consolidated clay is usually near the liquid limit. Since the consolidation stress, as well as the shear strength, progressively increase with depth for a normally consolidated soil, there is a constant relation between the shear strength (c) and the overburden pressure (p) known as the c/p ratio, (Skempton, 1953). The c/p ratio often is established from the shear strength measured by the vane shear test corrected for anisotropic and time effects (Bjerrum, 1973). The correction is related to the plasticity index of the soil. The value of the c/p ratio depends on the composition, with typical values of 0.23 to 0.27 having been found for the Presumpscot Formation (Maine State Highway Commission and others, 1969; LaGatta and Whiteside, 1984). Correlations of the c/p ratio to the plasticity index indicate that a plasticity index of 15 to 25 typically has a c/p ratio of 0.17 to 0.25 (Skempton,1953; Bjerrum, 1954). If the c/p ratio for a normally consolidated Presumpscot Formation deposit is known, the strength can be immediately found from the easily calculated overburden pressure.

Effect of Bedrock Rebound The uplift of the Presumpscot silty clay resulted in the formation of bluffs caused by stream and ocean erosion and also brought about changes in the soil strength. Stability failures have occurred when the induced stresses in the soil due to the steepness and height of the bluff were greater than the soil strength.

Uplift caused the groundwater levels to drop within the clay, and this change increased the clay strength in two different ways. Because the effective overburden weight increased with a drop in the groundwater table below the top of the clay, there was increased strength from increased consolidation stresses. Capillary stresses occurring above the groundwater table compressed the clay further and produced clay strength greater than the normally consolidated strength. Weathering and oxidation above the groundwater table have altered the strength in the upper part. The strength grades from the stiff crust down to the very soft gray clay (Andrews, 1985). Desiccation of the upper portion also introduces some cracking, and thus there may be planes of weakness in the brown clay (Andrews, 1985). Not only are the origin and composition of eastern Canadian and Norwegian clays somewhat similar to Maine clays, but marine deposited clays in Norway (Bjerrum, 1954) and in Canada (Kenney, 1964) were likewise lifted above present sea level by crustal rebound after the glaciers receded. Eastern Canadian clay, Boston Blue clay and Norwegian clay also have overconsolidated crusts on top of the clay due to capillary stresses and weathering.

Another significant effect of the uplift, which has been documented in Norway, is the decrease in strength due to leaching by the replacement of the saline pore water by fresh water (Bjerrum, 1954). Measurements in Norway have shown that the leaching has lowered the salt concentration from 35 g/l for sea water to as low as 0.2 g/liter. Leaching has been found to lower the Atterberg limits, lower the strength and to increase the sensitivity (undisturbed strength/remolded strength) of the soil. For a given amount of clay in a soil, the plasticity index has been found to be related to the degree of leaching. For a normally consolidated soil, the change in strength can be estimated by the change in plasticity index since the c/p ratio is related to the magnitude of the c/p ratio. The sensitivity, which is usually found from field vane tests, is taken as a measure of the degree of leaching. Soils have been classified according to the level of sensitivity (Table 3) by Rosenqvist (1953). For the quick glacial marine Leda clay near Ottawa, the measurement of the salt concentration has shown that it has dropped from its initial 35 g/l to near 1 g/l (Crawford, 1961; Bozozuk and Leonards, 1972). Salt concentration in Presumpscot Formation has been measured at 2 to 20 g/l for a sample currently below sea level but subject to artesian pressures (Maine State Highway Commission and others, 1969).

Table 3
Sensitivity Classification

Classification	Sensitivity
Insensitive	~1
Slightly Sensitive	1-2
Medium Sensitive	2-4
Very Sensitive	4-8
Slightly Quick	8-16
Medium Quick	16-32
Very Quick	32-64
Extra Quick	>64

Bjerrum (1954) has found that the liquidity index (eq. 1) is related directly to the sensitivity.

$$\text{Liquidity Index} = (w_n - w_p)/(w_l - w_p) \quad \text{eq. (1)}$$

where w_n = Natural Water Content, %

w_l = Liquid limit, %

w_p = Plastic limit, %

The liquidity index of the Presumpscot Formation has been reported to be 0.86 to

2.2 with the values near 2.0 reported to be a soft sensitive silty clay (Andrews, 1985). Using Bjerrum's correlation, a liquidity index of 2.0 corresponds to a very quick soil, while a liquidity index of 0.86 to 1.0 corresponds to a very sensitive soil.

If overburden erosion has occurred, then the soil has an overburden less than in the past and is termed overconsolidated. The normally consolidated soil c/p ratio no longer can be used to estimate the soil strength for an overconsolidated soil, since the strength (c) is more related to the maximum past pressure rather than the present overburden pressure (p).

Landslides

Eden and Mitchell (1973) state that the one common property for the landslide areas in the eastern Canadian clays is the high sensitivity, i. e. loss of strength upon disturbance. The cause of 'inexplicable' slides in Norway has been related to sensitive soils (Bjerrum, 1954).

Bunganuc Landslide

One landslide site investigated as part of this study is located on Maquoit Bay, northwest of Bunganuc Point in Brunswick, Maine (Figures1, 2). This site is situated on wave-cut bluffs cut into the glacial marine Presumpscot Formation silty clay. At one unfailed location, the bluff was approximately 38 feet high and had an estimated slope angle of up to 54^{o} (Figure 3). At high tide the ocean laps up approximately two feet on the toe of the slope, and at low tide the area directly in front of the toe is a tidal flat.

This bluff extends along the coastline for a distance of several thousand feet and has a number of distinct rotational slides (Figure 4). A profile of one of the slides (Figure 5) indicates that the failed material rotates, and there is a well-defined circular failure surface. The failure surface appears to emerge close to the toe or slightly below it. Rotational slides are common in homogeneous material, particularly clay, and in deposits where there are numerous discontinuous planes of weakness (Sowers, 1979).

Materials Visual and laboratory classifications of the material exposed on the

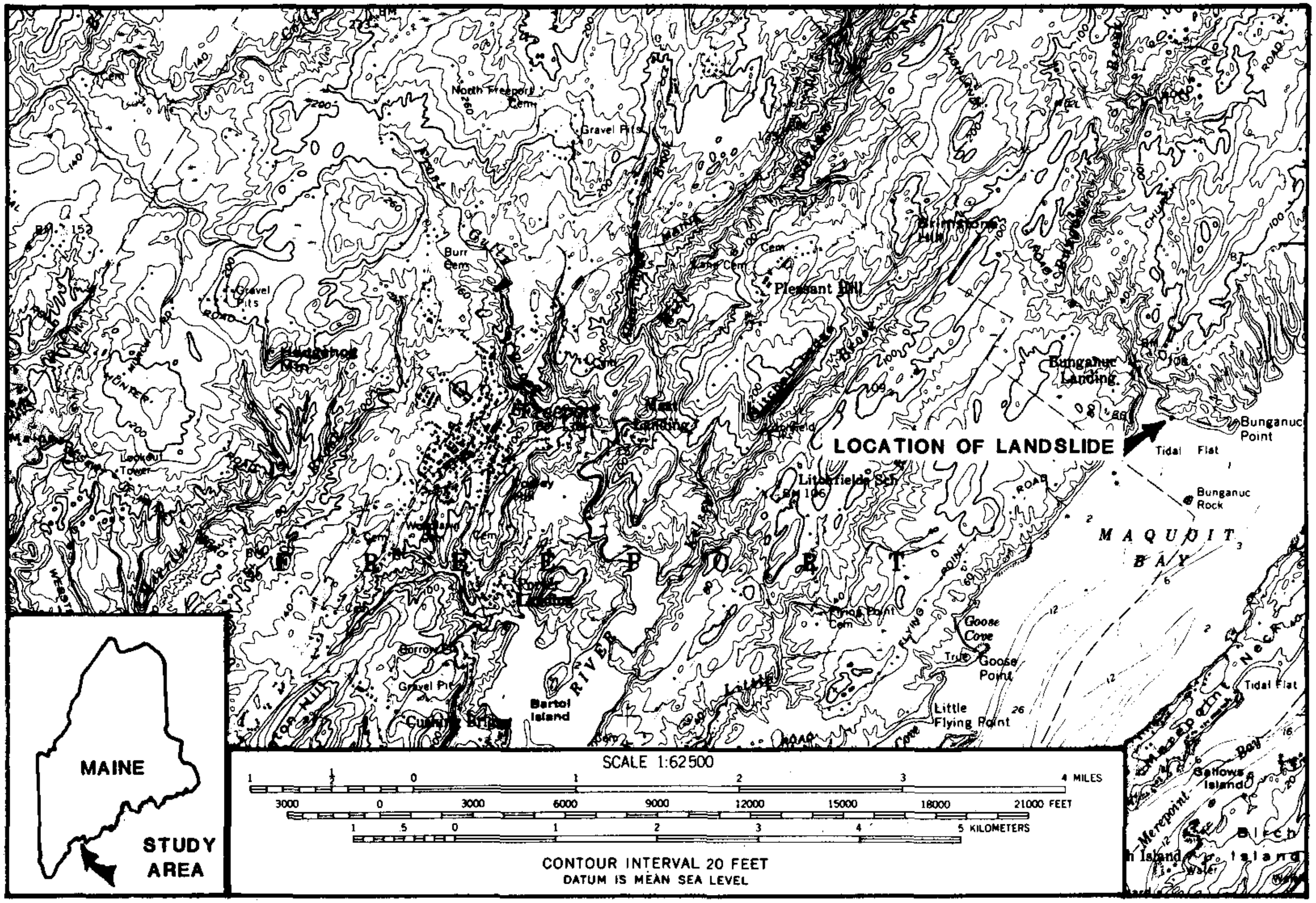


Figure 1. Location of Bunganuc landslide, Freeport 15 minute quadrangle.

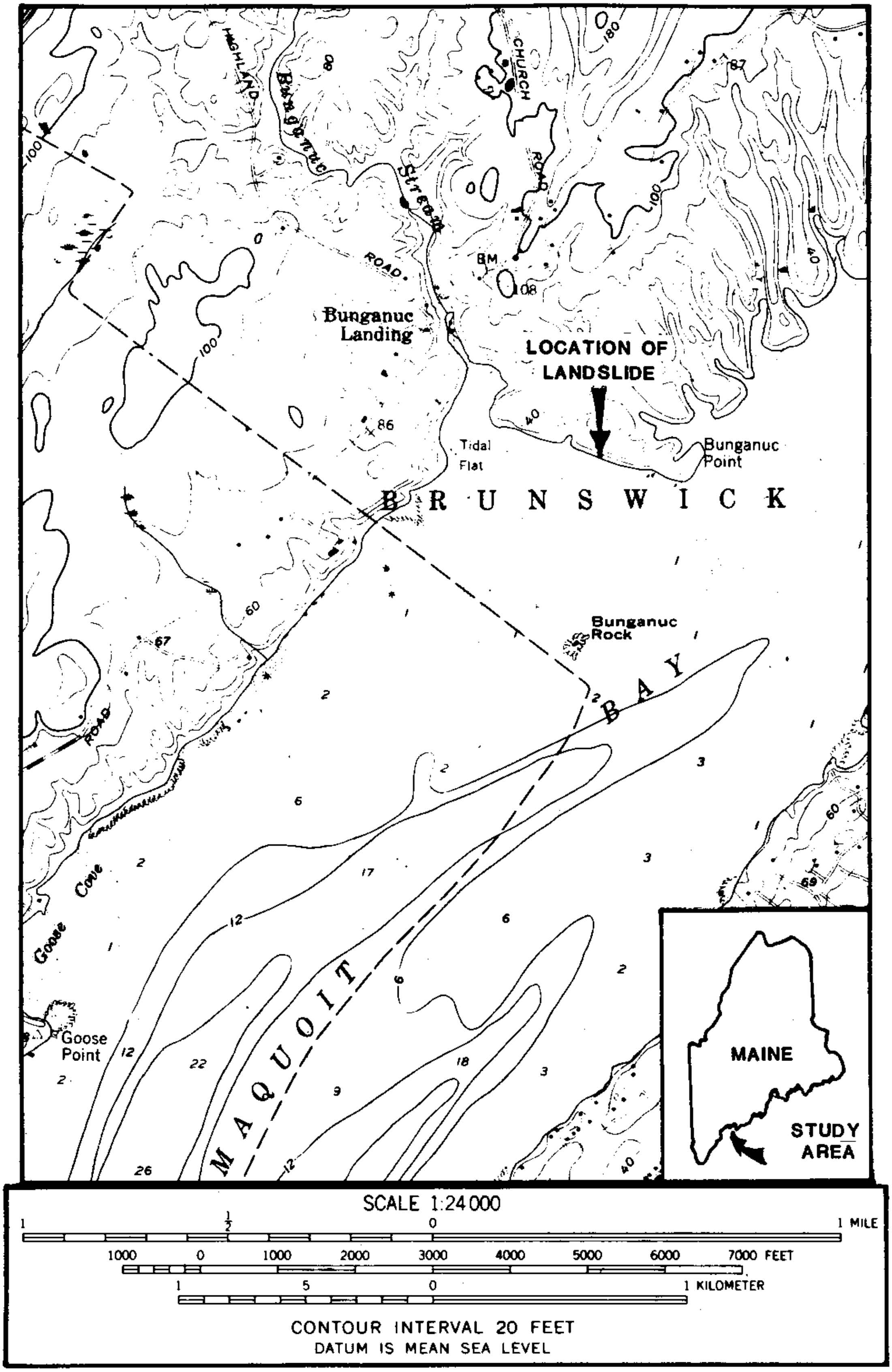
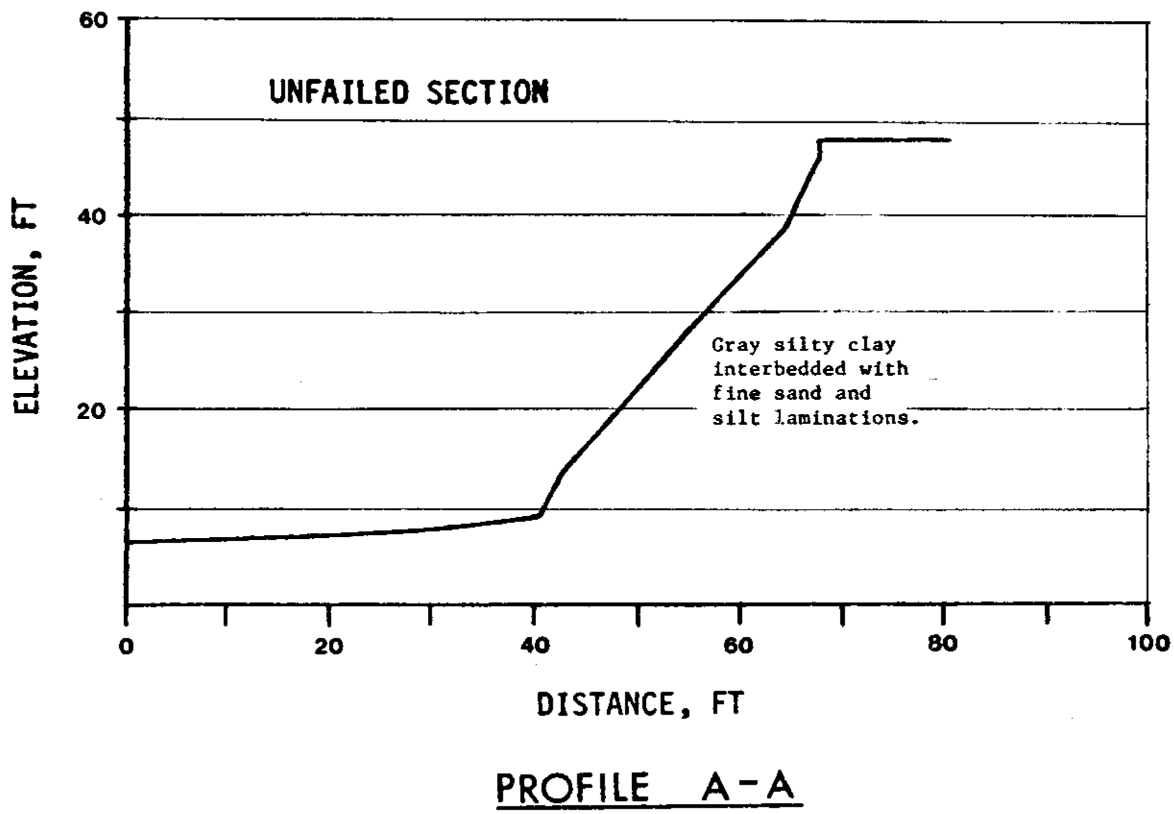


Figure 2. Location of Bunganuc landslide, Freeport 7.5 minute quadrangle.



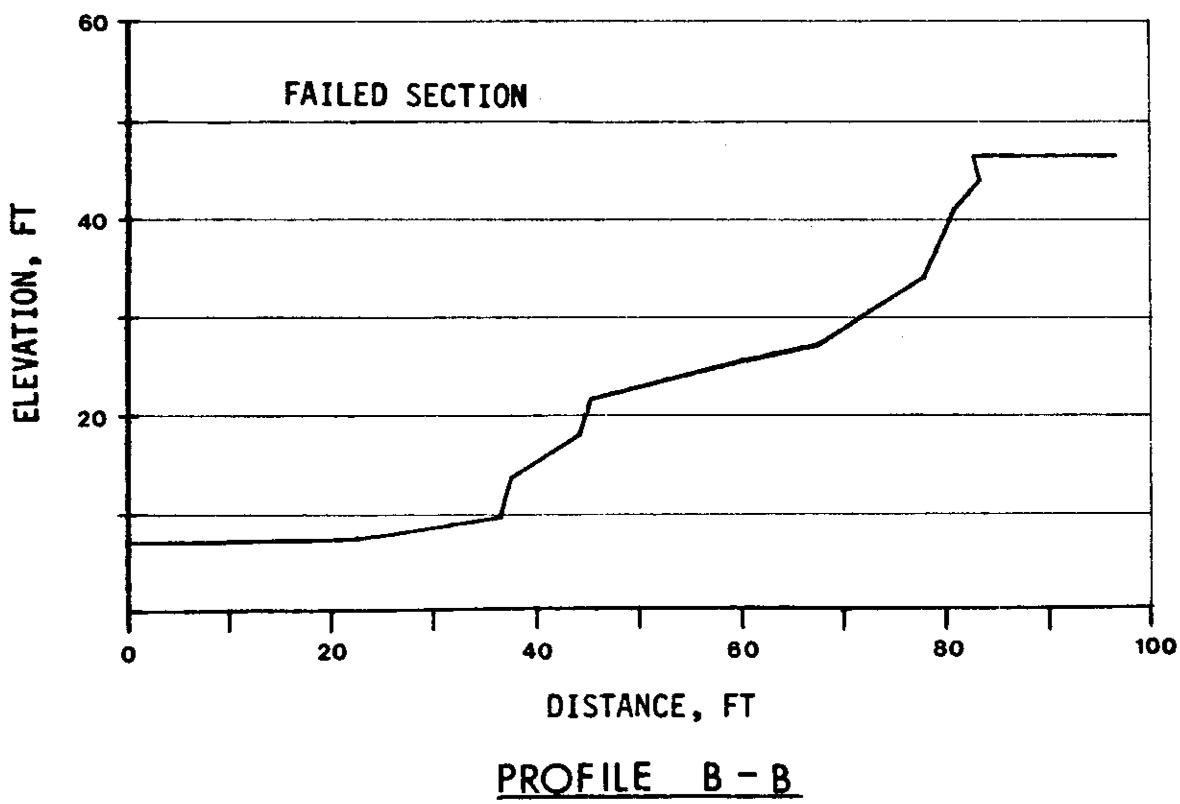


Figure 3. Profiles of failed and unfailed sections at Bunganuc landslide.

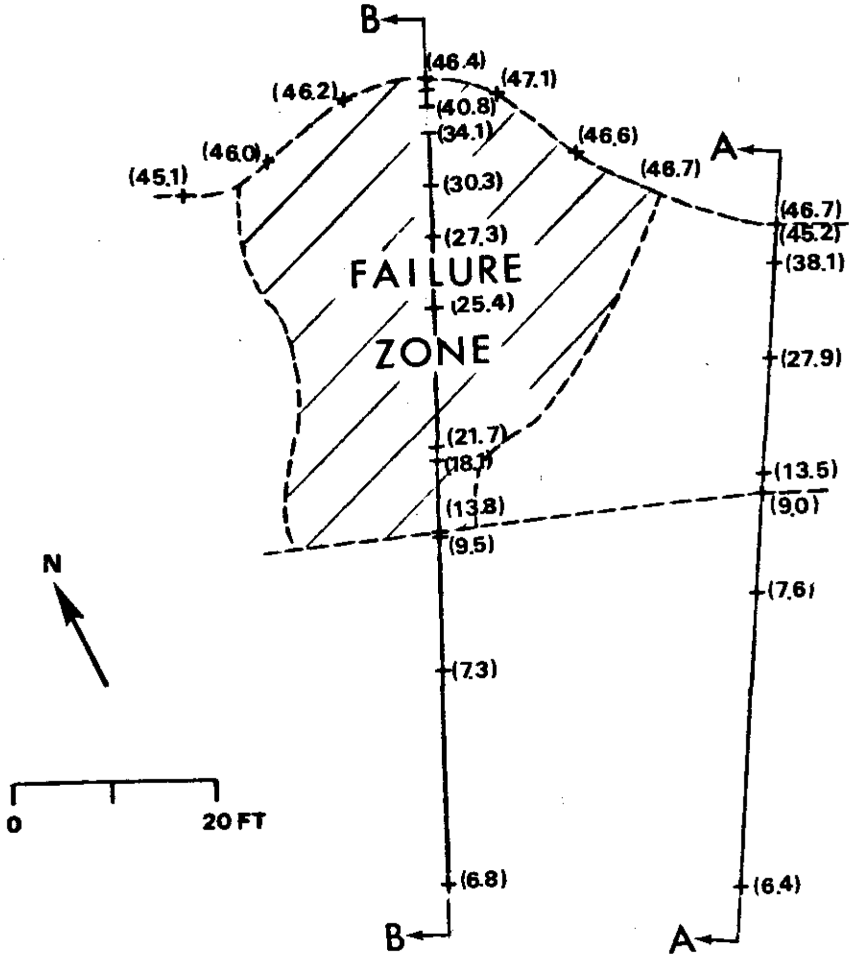


Figure 4. Plan view of failure zone at Bunganuc landslide.
(0.0) - indicates elevation in feet above msl.

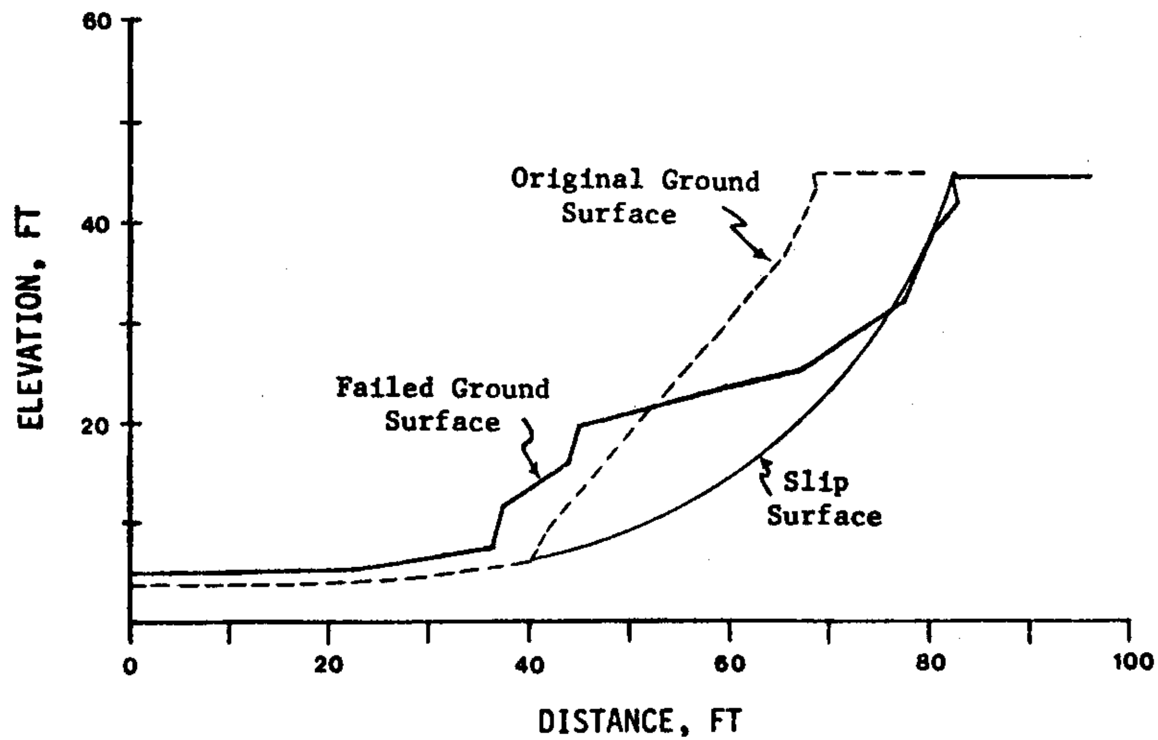


Figure 5. Original surface, failed surface, and slip surface for Bunganuc landslide.

face of the bluff (Figures 6,7) indicated three zones of silty clay interspersed with thin seams of fine sand and silt and with discontinuities (Table 4).

Table 4

Bunganuc Landslide Soil Profile

Depth, ft	Description
0 - 6.5	Hard blocky, desiccated brown silty clay with fine sand and silt laminations. Liquidity index less than zero. Numerous closely spaced fissures.
6.5 - 12	Hard blocky, desiccated gray silty clay with fine sand and silt laminations. Liquidity index between zero and 0.5. Fissures decreasing with depth, spacing to 3 inches.
12 -38	Medium to soft blocky, gray silty clay with fine sand and silt laminations. Liquidity index about 0.5. Fissures decreasing with depth.

The Presumpscot Formation zones in the bluff exposure are typical of the profile that others have found throughout the state as pointed out on page 2. The upper brown crust at this location appears to be weathered Presumpscot Formation. The weathering has proceeded from the surface and is probably the result of freezing and thawing, drying during the summer, infiltration of surface water carrying air into the fissures and leaching some clay minerals, and roots of surface vegetation removing groundwater and acting upon the clay minerals.

The overconsolidated gray clay, which underlies the brown crust and extends to a depth of 12 feet, is still gray because it is below significant effects of weathering coming from the surface. Saturation by capillary action above the groundwater table probably prevents the entrance of oxygen-bearing surface water, except along some fissures, and is also probably responsible for the greater strength than the zone below it. Weathering to a brown clay on the face of the bluff is only superficial, apparently because the face was recently exposed. This weathered skin could be scraped off to reveal the gray clay beneath.

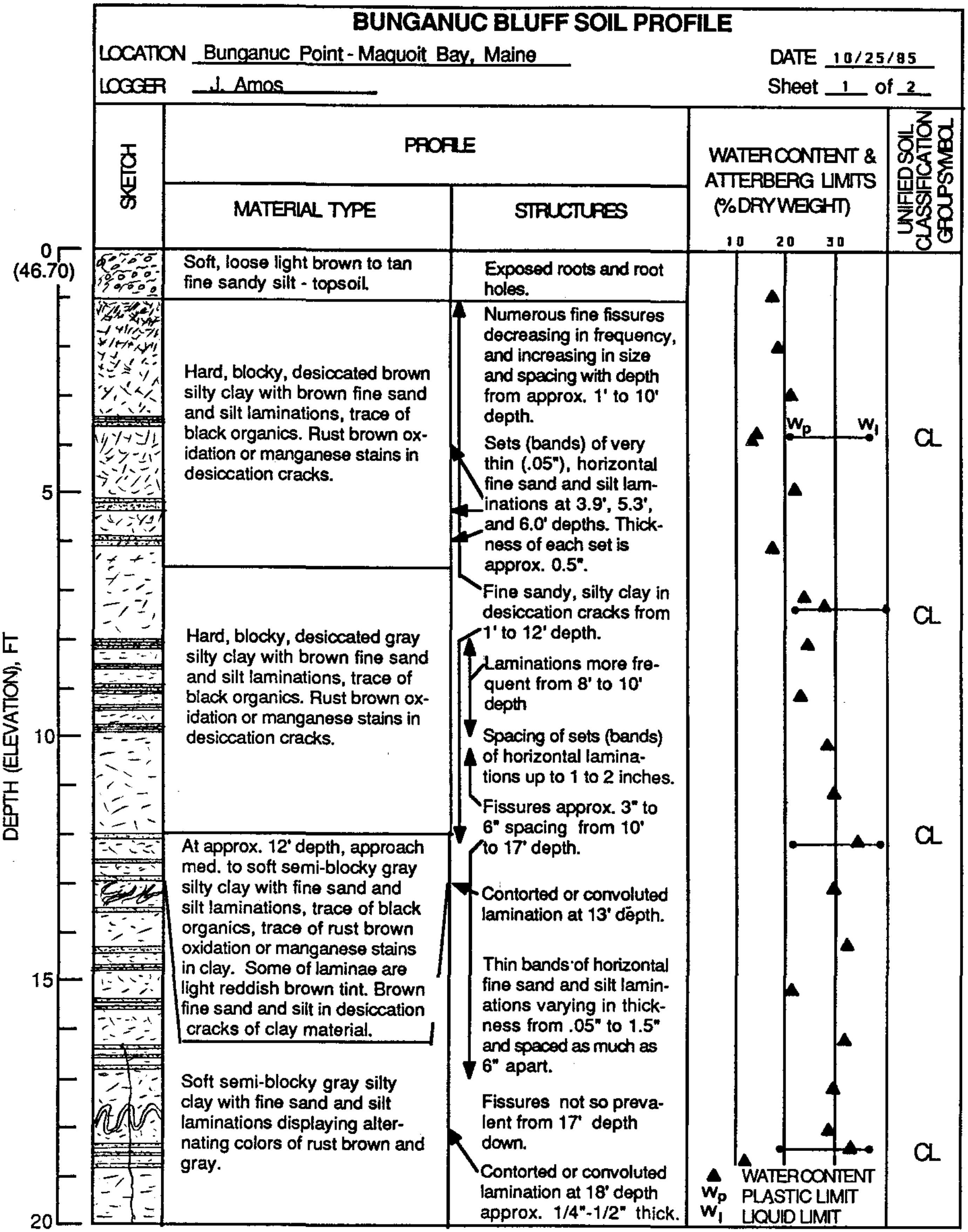


Figure 6. Bunganuc landslide soil profile and composite of test data, 0.0 to 20.0 ft. depth.

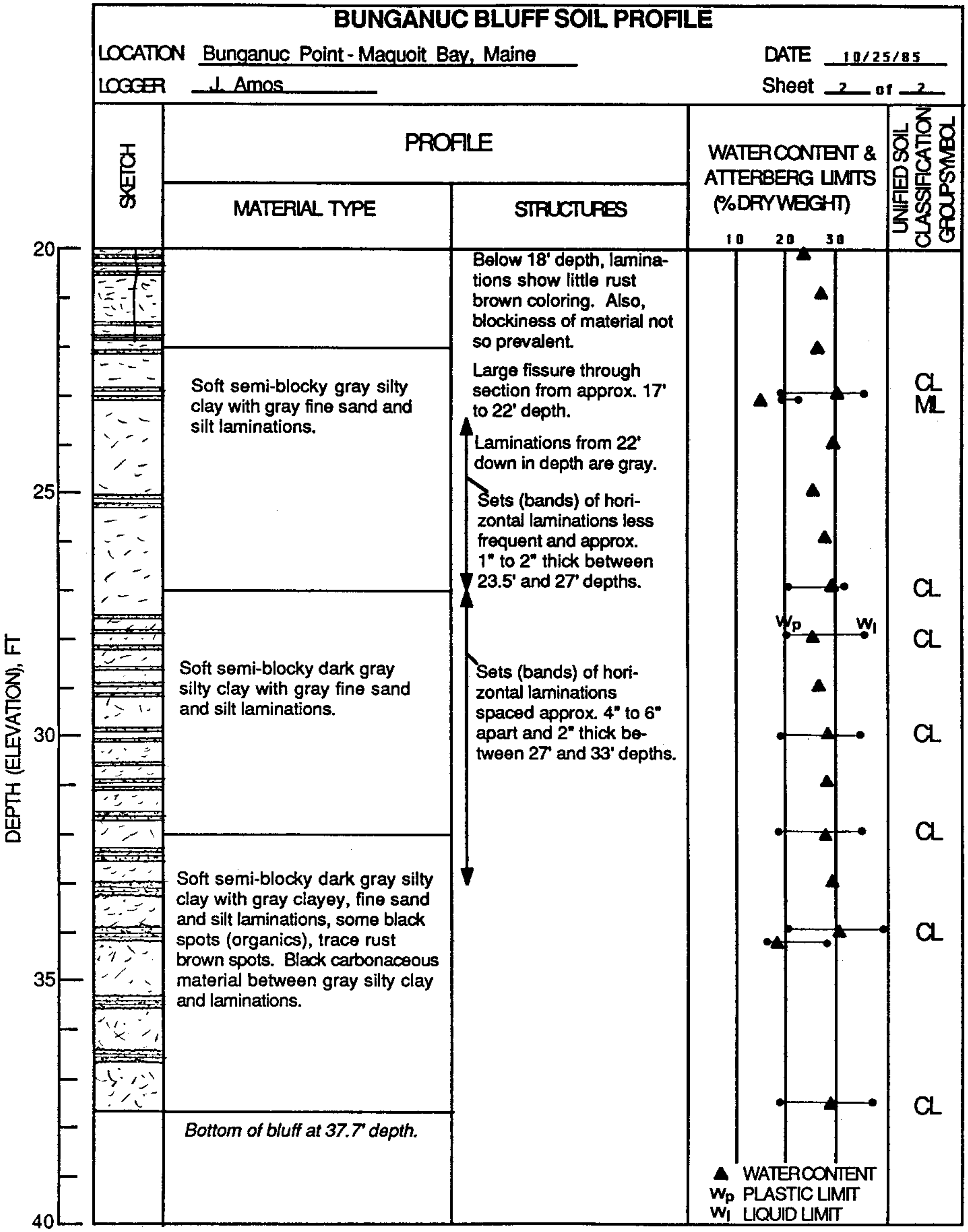


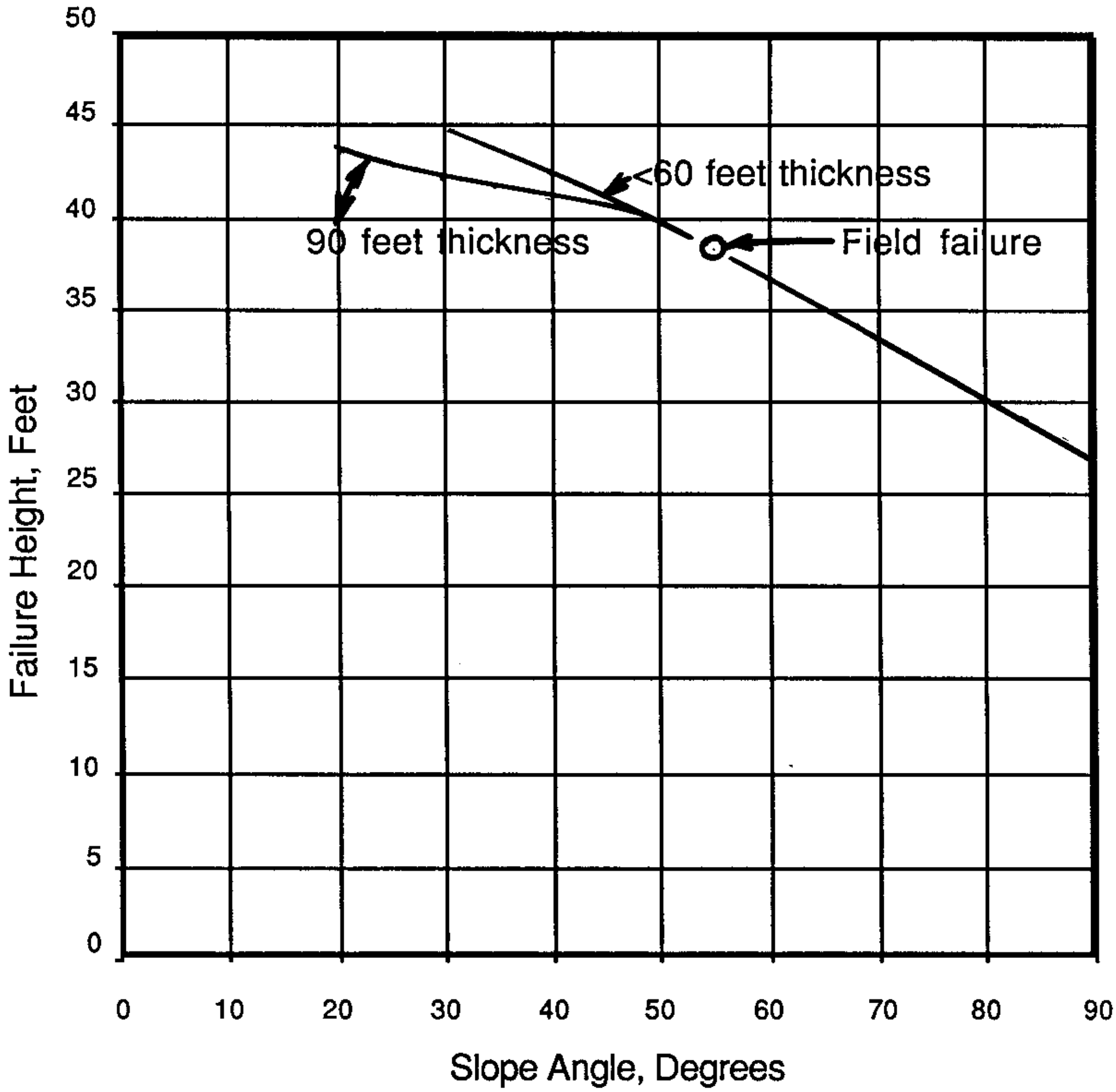
Figure 7. Bunganuc landslide soil profile and composite of test data, 20.0 to 37.7 ft. depth.

Groundwater Although it was anticipated that the natural groundwater table or level was between the bottom of the brown crust at the 6.5 feet depth and the tidal flat at a depth of 38 feet, there was no evidence of water seeping from the fine sand and silt seams on the face of the bluff. However, the silty clay did appear to be saturated. It is possible that evaporation had removed excess water, and the flow of water was small. Staining on fissures, even at greater depths in the gray clay, indicates that there has been some movement of water along the fissures. If a buildup of hydrostatic pressure in fissures parallel to the slope occurs after rainy periods or snowmelt, then the probability of failure can significantly increase.

Vegetation The top of the bluff was forested. However, on the face of the slide area there was little or no vegetation. Except for a possible role in the weathering of the brown crust and in the modifying of surface water infiltration into the fissures, it appeared that the vegetation at this site did not affect the stability of the slope.

Erosion The major role of the sand and silt seams in affecting the stability of the bluff appeared to be related to erosion at the toe of the landslide by ocean waves at high tide. The highly erodible fine sand and silt were washed out by the waves and there was local calving in conjunction with the fissures in the gray clay. This continuous erosion steepened the bluff slope until stresses in the soil exceeded the soil shear strength, and the slope failed.

Failure Analysis The failure conditions for a rotational slide can be used as a gigantic shear test to determine the equivalent average shear strength generated along the failure surface (Navfac, 1982). The equivalent average shear strength was determined by assuming that the profile (Figure 5) next to the landslide was at the verge of failure. The average shear strength was found to be 840 psf. The equivalent average shear strength includes the effects of groundwater pressures, of fissures, and of the different contributions of each zone. If it is assumed that the same soil and water conditions act along the bluff, then the results from this one failure can be used to predict failures at other locations along the bluff. The relation between the height of the bluff at failure and the slope angle is given in Figure 8. The relation in Figure 8 applies in the Bunganuc area if it is anticipated that the soil conditions are relatively the same throughout the site. It will apply at other locations



Notes:
1. Based on failure at Bunganuc with shear strength of 840 psf.
2. Increase height by 5% for toe submergence of 5 to10 feet.
3. Total Presumpscot thickness from top of slope.

Figure 8 Slope angle vs height at failure beyond the Bunganuc area only if the average shear strength is the same. It thus is necessary to obtain some simple measure of the shear strength to estimate the possible failure at other locations.

Gorham Landslide

The location of the site is in the southeastern section of Gorham, Maine, at the intersection of the Stroudwater River and Indian Camp Brook, which is a tributary of the Stroudwater River. The landslide is off the southern side of Longfellow Road (Figure 9). The geomorphology and structure of the Gorham landslide has been described in detail by Novak and others (1984).

Topographic Profile To obtain a profile of the landslide's surface topography, two survey lines were run (Figure 10). Figure 11 shows the locations of the survey lines in relation to the landslide's structural features (Novak and others, 1984). The first survey line (Survey Line1) was laid out parallel to the movement of the slide and at approximately the center of the slide (in plan view) to include the portion of the slide where the house was located and maximum movement had occurred. The second survey line (Survey Line 2) was laid out approximately parallel to Survey Line1 at the northwest end of the slide. Topographic profiles for the two lines are shown in Figures 12 and 13.

Subsurface Exploration Program Exploratory drilling was conducted to classify subsurface materials visually, to conduct field strength tests, and to obtain samples for strength and classification testing in the laboratory. Three test borings (denoted as TB-1, TB-2, and TB-3) were drilled with casing, and one cone penetrometer (P-1) was driven. All of the subsurface exploration was performed close to the first survey line (Survey Line1) as shown in Figure 11. The first test boring (TB-1) was located beyond the head of the slide in material which had not participated in the slide, and the second test boring (TB-2) was located within the slide area, near the toe. A third hole (TB-3) was drilled between the first and the second test borings (TB-1 and TB-2, respectively). Remaining drilling funds did not allow drilling a fourth test boring; therefore the less expensive cone penetrometer was driven.

Sampling consisted of taking disturbed and undisturbed samples at intervals.

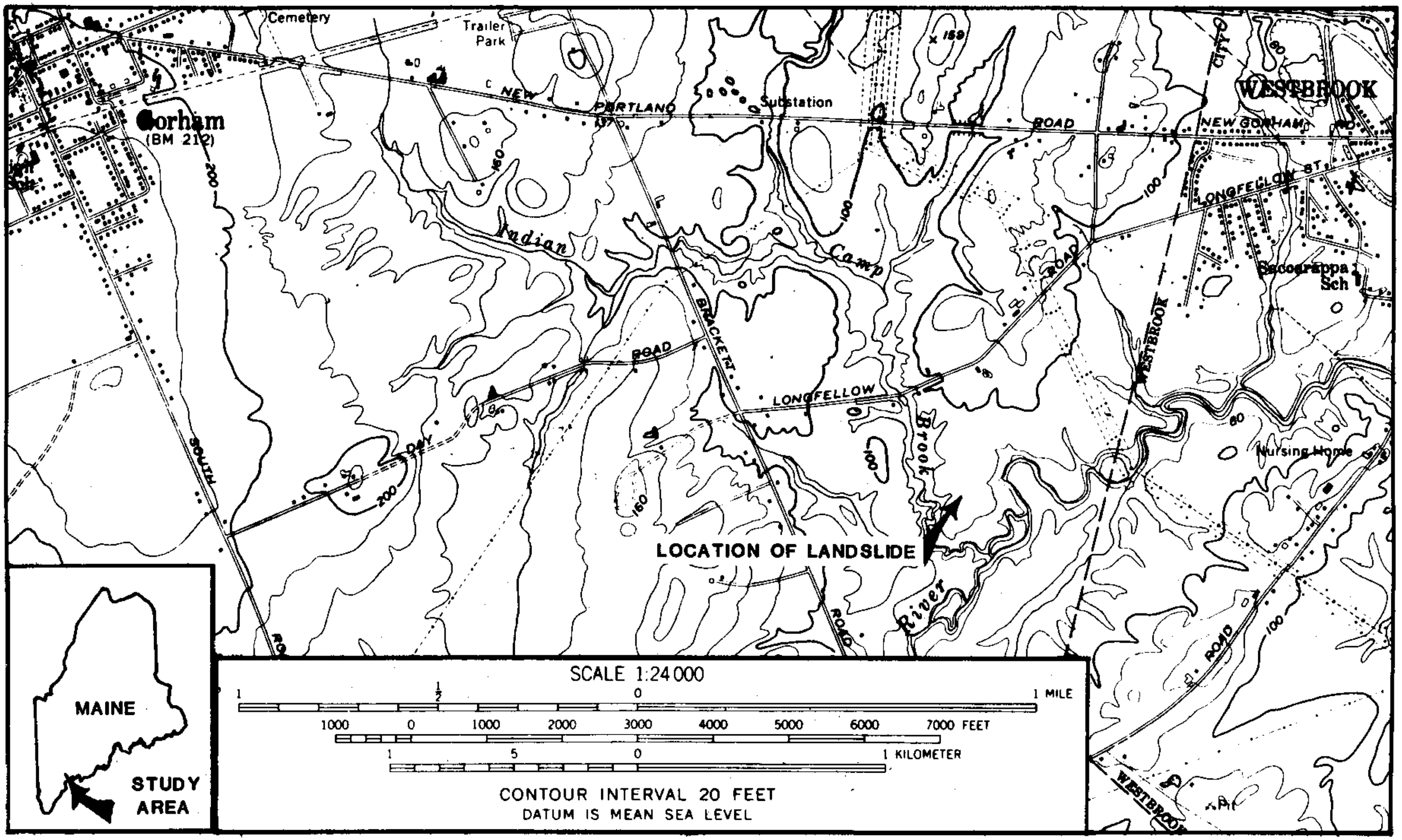


Figure 9. **Location of Gorham landslide, Gorham 7.5 minute quadrangle.**

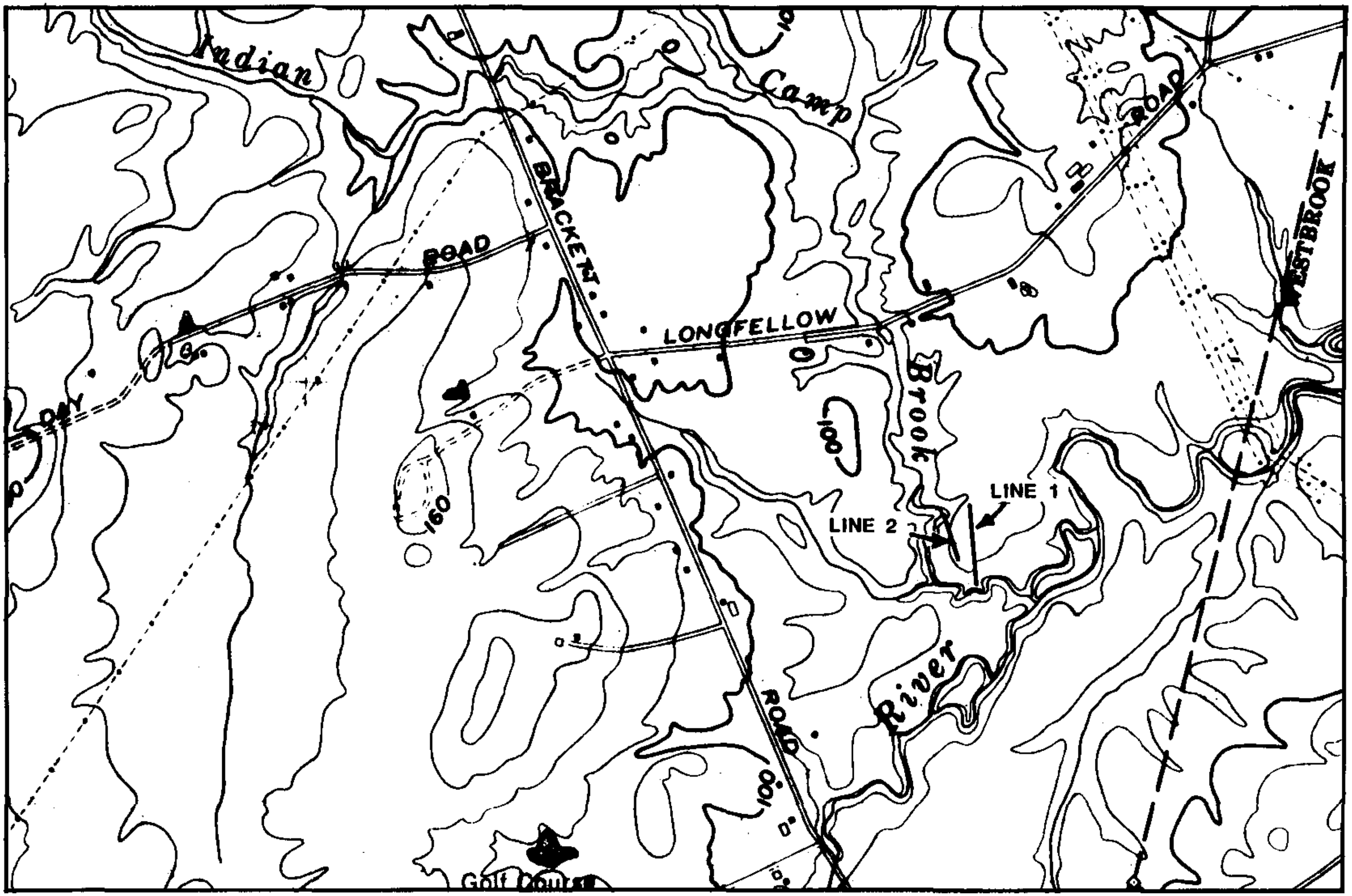


Figure 10. Topographic map of Gorham landslide showing location of Survey Lines 1 and 2.

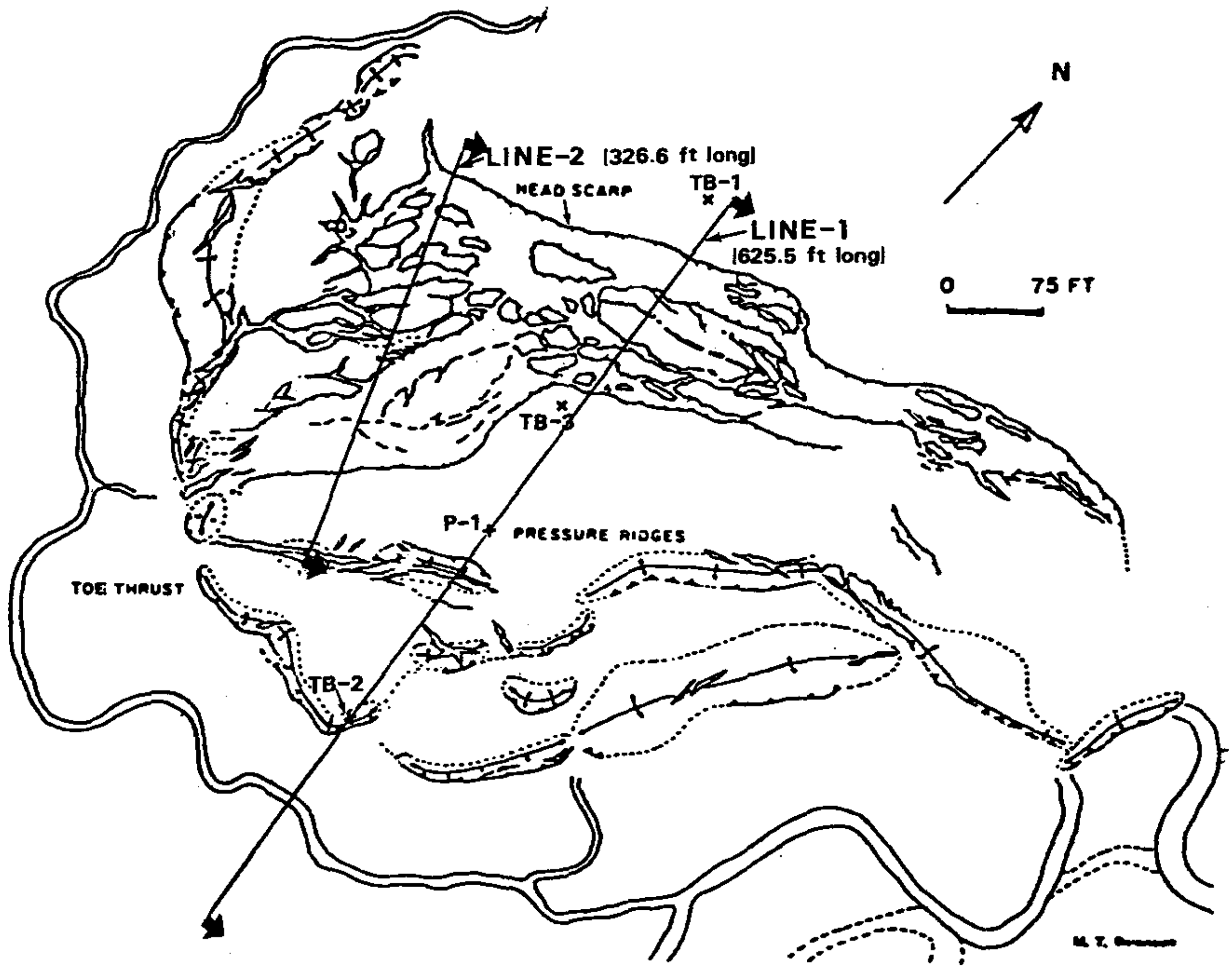


Figure 11. Structural features of Gorham landslide (after Novak and others, 1984) showing location of Survey Lines 1 and 2, Test Borings (TB-1, TB-2, and TB-3) and Penetrometer (P-1).

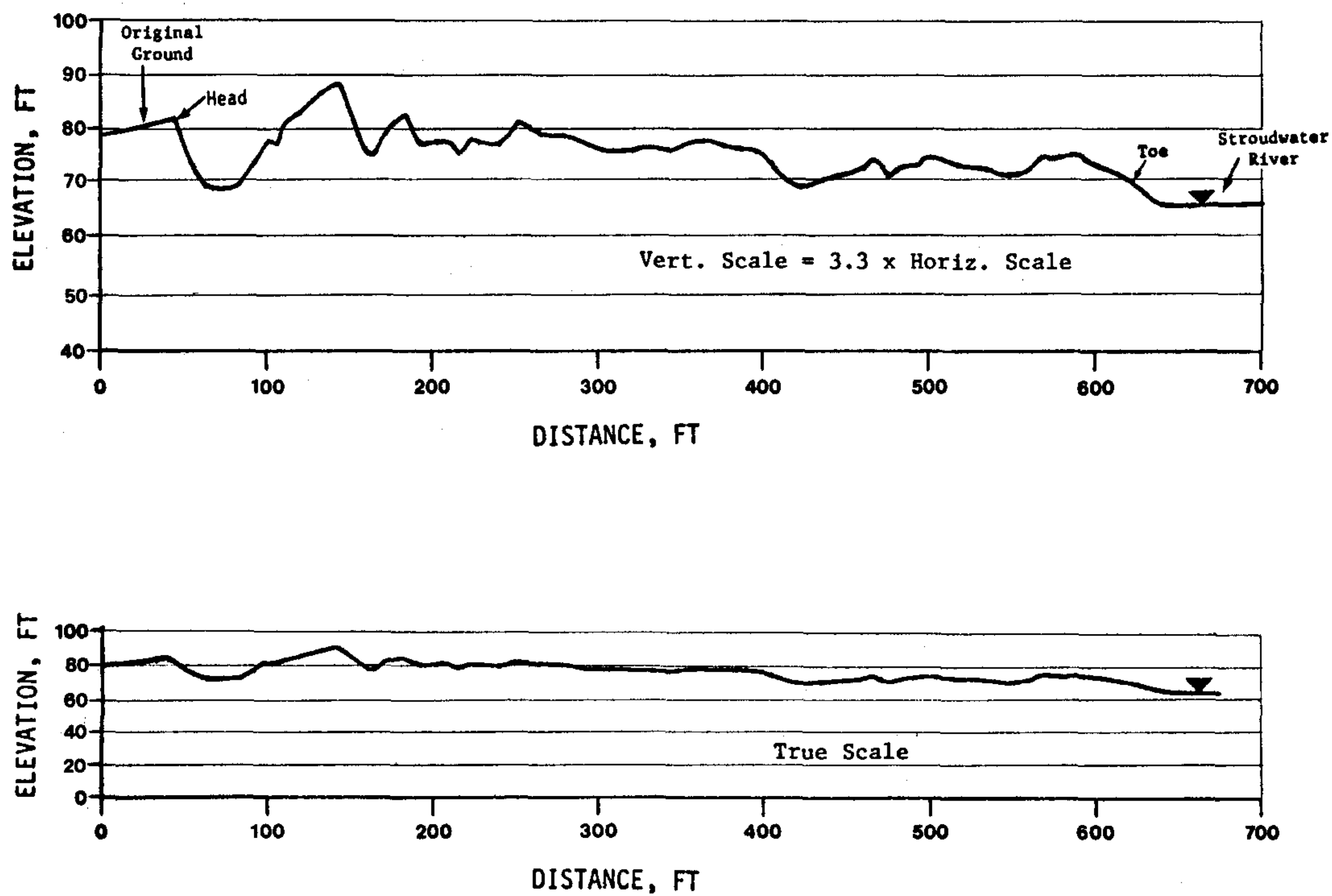
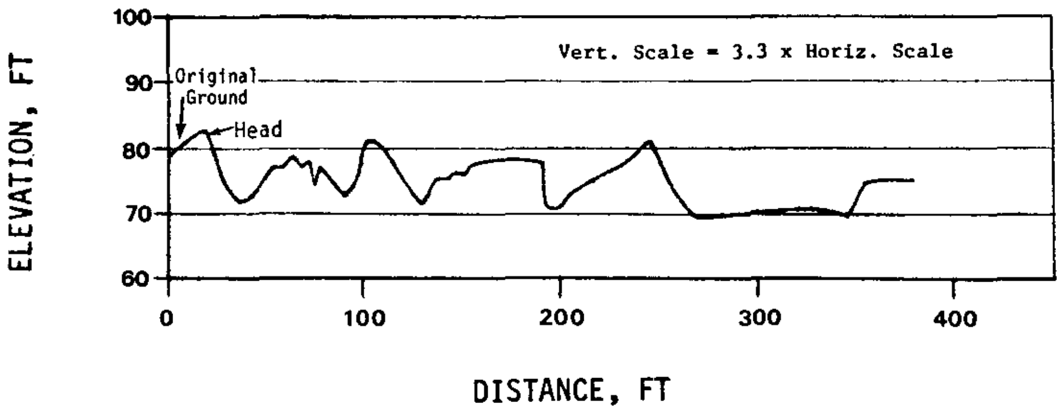


Figure 12. Profile along Survey Line 1, Gorham landslide.



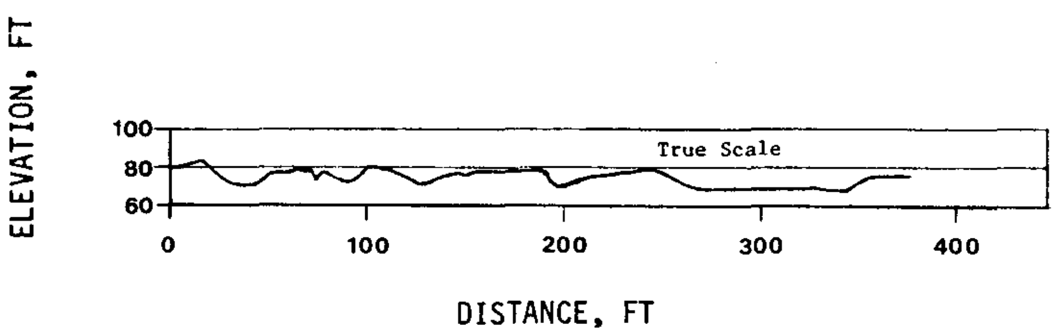


Figure 13. Profile along Survey Line 2, Gorham landslide.

Disturbed samples were obtained for visual identification and Atterberg limit classification tests at approximately 5-foot intervals using a 1 3/8" inside-diameter split-spoon sampler. Standard penetration tests (ASTM,1982c), which consists of counting the number of blows required to drive the sampler, were conducted when possible during this sampling. At approximately 15-foot intervals, an undisturbed sample was obtained using a thinwall Shelby tube (ASTM, 1982d) for use in laboratory strength testing. Below the depth where each undisturbed sample was obtained, a field shear strength test was conducted using a field vane shear device (ASTM, 1982e). This device measured peak and remolded strength.

The penetrometer cone test is a type of field test that indicates changes in the underground conditions by the number of blows it takes to drive a conical point attached to a 1 3/4" diameter driving rod a distance of 1 foot with a 300 lb. hammer falling a distance of sixteen inches. The cone penetrometer was advanced until refusal (100 blows) was reached. No samples were obtained.

Boring logs with the soil descriptions including the type and location of the sampling and testing, standard penetration blow counts, and a summary of classification test results are given in Appendix A. Grain size analyses are given in Appendix B. Field logs which show the results of the number of blows to drive the casing and the results of the cone penetrometer test are given in Appendix C.

Subsurface Profile The subsurface investigations (Appendix A) at the Gorham site are summarized in Figures 14, 15, and 16. They indicated the strata summarized in Table 5 and shown in Figure 17.

Variations in Gray Presumpscot with Depth In the gray Presumpscot sediments there are some variations in classification properties with depth. Although there are not enough strength tests to establish trends with depth, the variations in plasticity index and water content with depth indicate probable changes of strength with depth. The plasticity index remains relatively constant, generally near 20, for the upper 5-20 feet of the gray clay and then shows a gradual decrease with depth. Near the bottom of the deposit the plasticity index is near 13. This probably indicates greater silt and fine sand content in the Presumpscot Formation at greater depths. The natural water contents increase to a peak within the first 5-20 feet and then decrease with depth below the peak. The peak natural water contents

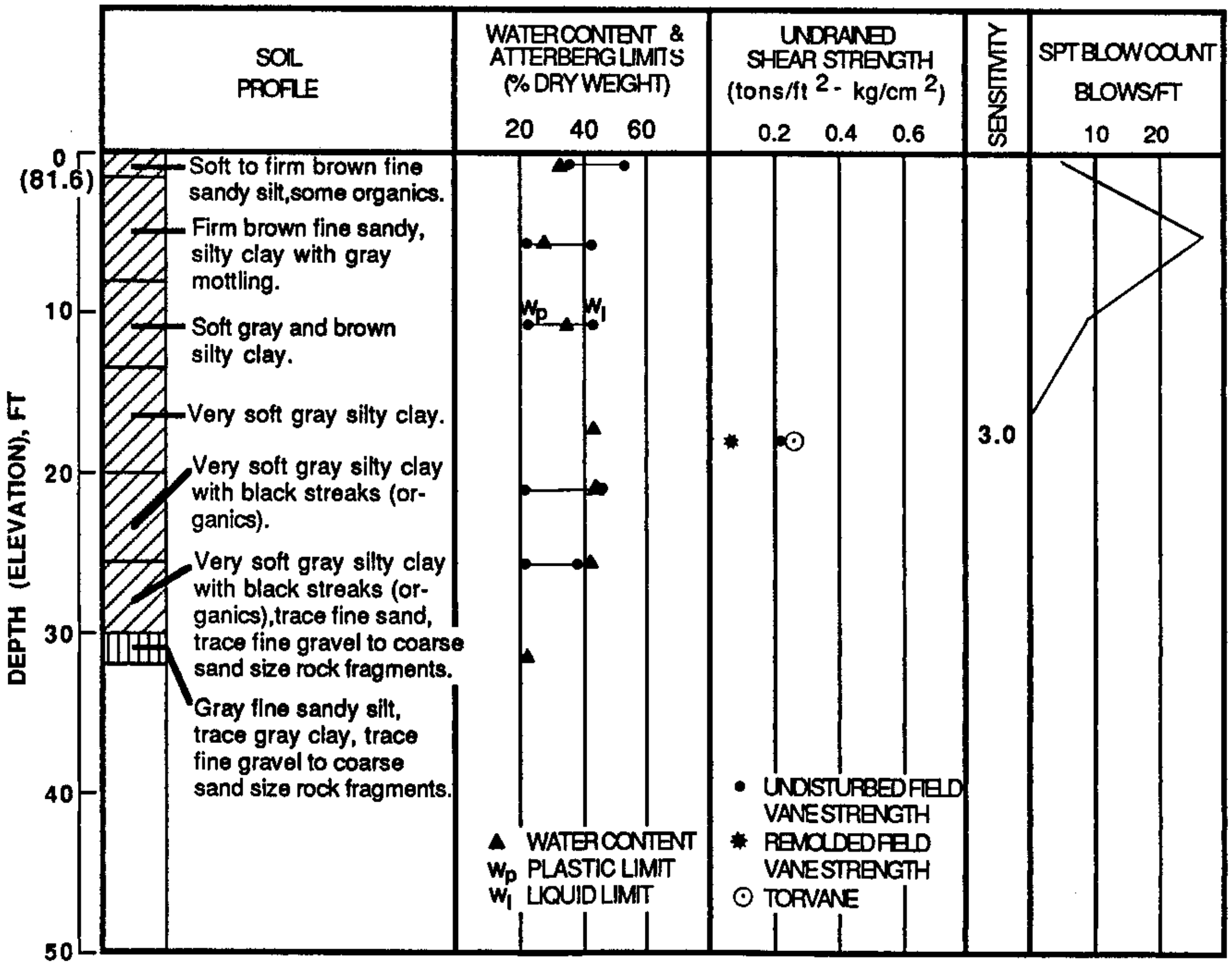


Figure 14. Gorham landslide soil profile and composite of test data for TB-1.

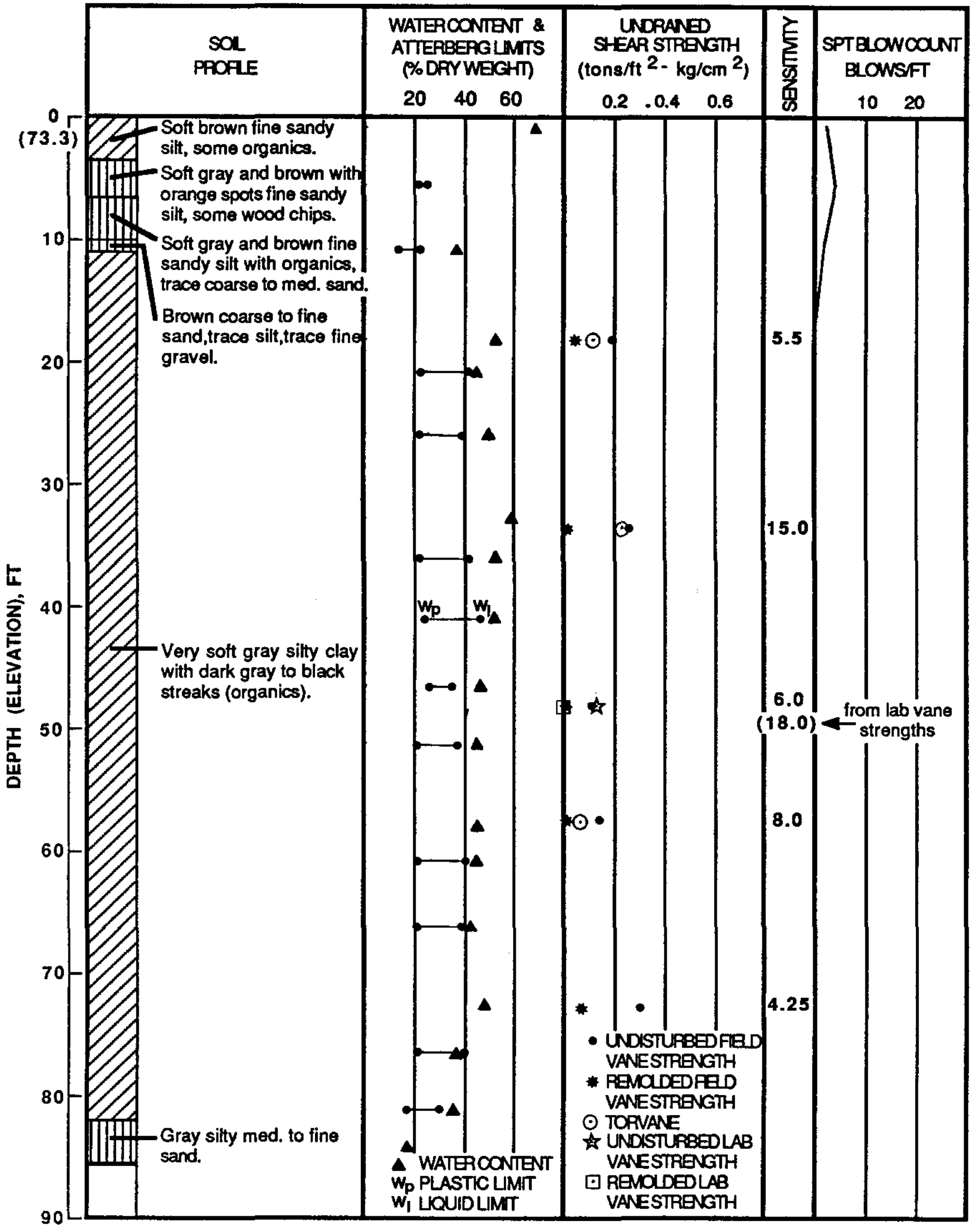


Figure 15. Gorham landslide soil profile and composite of test data for TB-2.

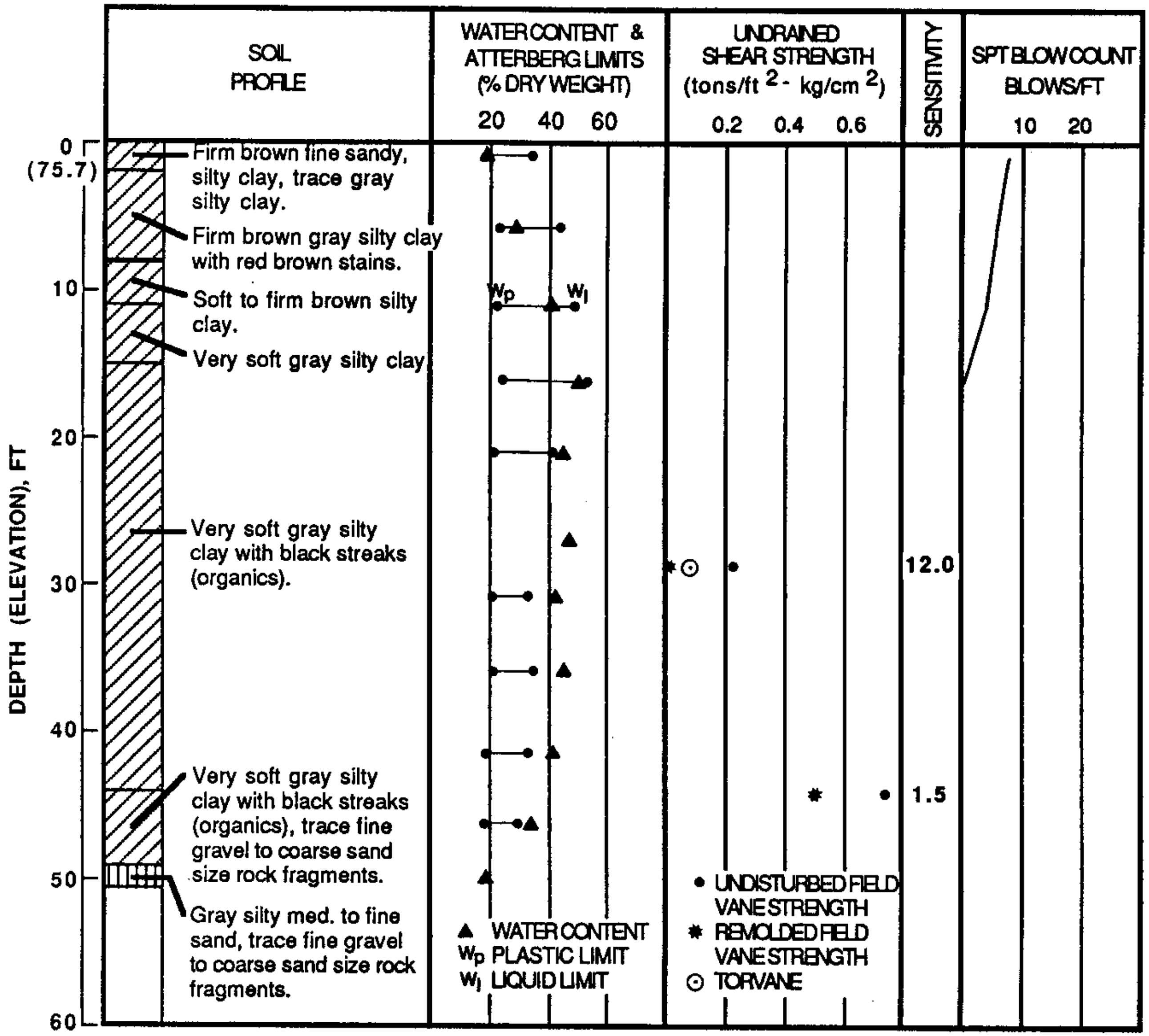


Figure 16. Gorham landslide soil profile and composite of test data for TB-3.

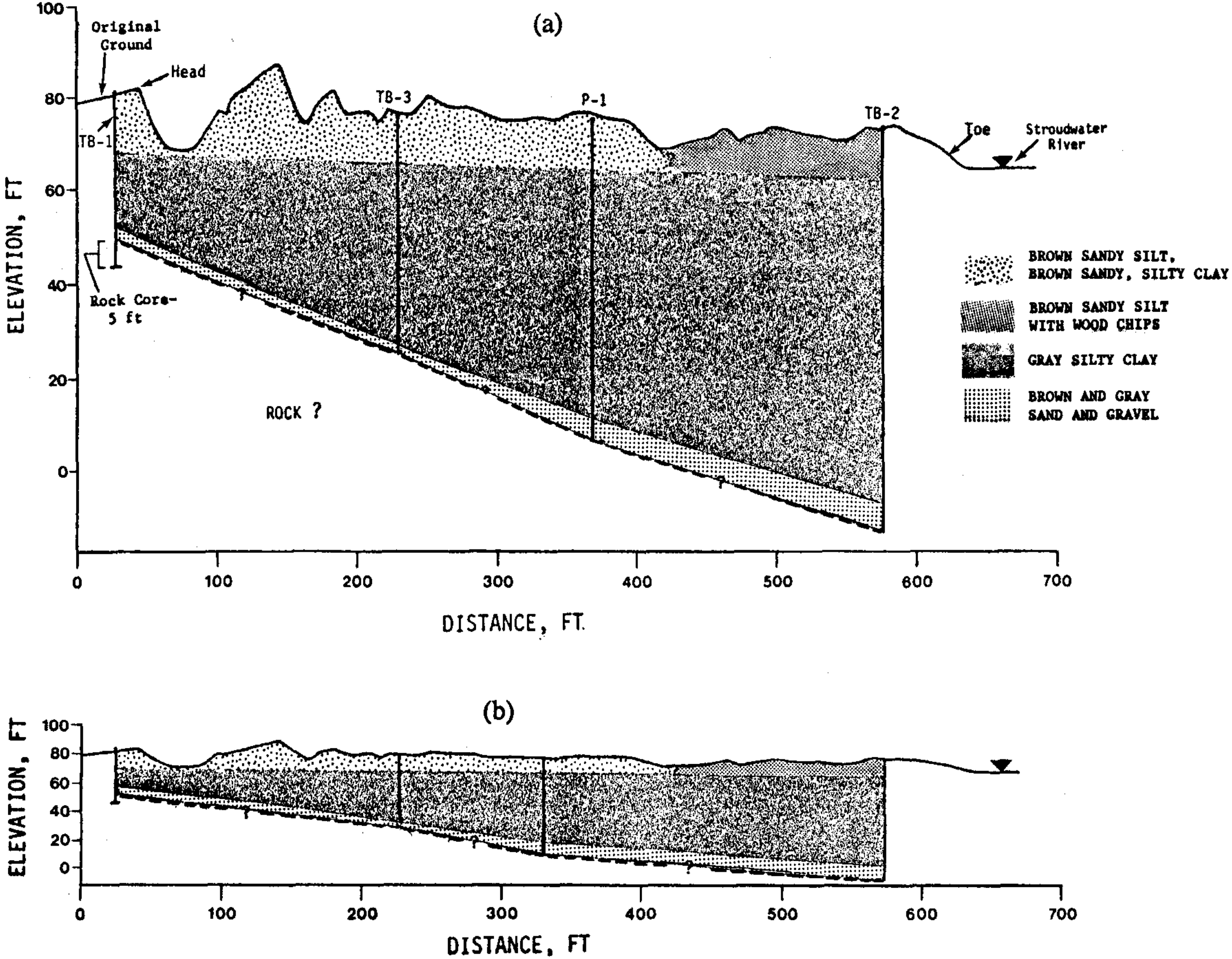


Figure 17. Cross section of Gorham landslide along Survey Line 1, (a) vertical scale = 3.3 x horizontal scale, (b) true scale.

ranged from 44 to 54 percent. The lower water contents in the upper part of the gray Presumpscot Formation likely indicate some light overconsolidation caused by historical groundwater fluctuations. The reduction in water contents below the peak value with depth is normally related to the increased consolidation pressure with depth. In the deepest boring, TB-2, the strength increased with depth as the water content and plasticity indices decreased with depth.

Table 5

Gorham Landslide Soil Profile

Stratum	Description
Top Soil or Alluvium	Brown fine sandy silt with some organics. Soft to firm. Thin (1'-2') layer except close to Indian Camp Brook (TB-2) where thickness is 11'.
Brown Presumpscot Formation	Brown silty clay. Firm but grading to soft at lower levels. Also mixed with top soil and gray layer beneath. Thickness is 6'-9' except near Indian Camp Brook where this stratum is missing.
Gray Presumpscot Formation	Gray silty clay. Very soft but soft near upper surface. Very sensitive to slightly quick. Thickness varies due to changing bedrock elevation from 17' at head of slide to 71' at toe.
Sand	Gray silty medium to fine sand, trace fine gravel and coarse sand. Thickness 1' -3'.
Bedrock	Dark gray mica schist. Bedrock was confirmed only in TB-1. Refusal was taken as top of bedrock in others.

Undisturbed Shear Strength The undisturbed shear strength of the brown Presumpscot sediments is estimated to be 500 psf to 3250 psf by correlation to the

Standard Penetration test blow count of 4 to 26 (Terzaghi and Peck, 1967).

The most critical stratum for stability is the gray Presumpscot silty clay because of its low strength. The undisturbed strength was measured by vane tests in all three borings at various depths for a total of 8 measurements. The measured vane shear strength ranged from 215 psf to 1507 psf (Table 6). However, if two values near the bottom of the layer in TB-2 and TB-3 are not included, then the range is 215 psf to 538 psf. At a depth of 45'-48' in TB-2, three different measurements of the strength were obtained (Table 7).

Table 7
Strength Measurements
TB-2 at 45'-48'

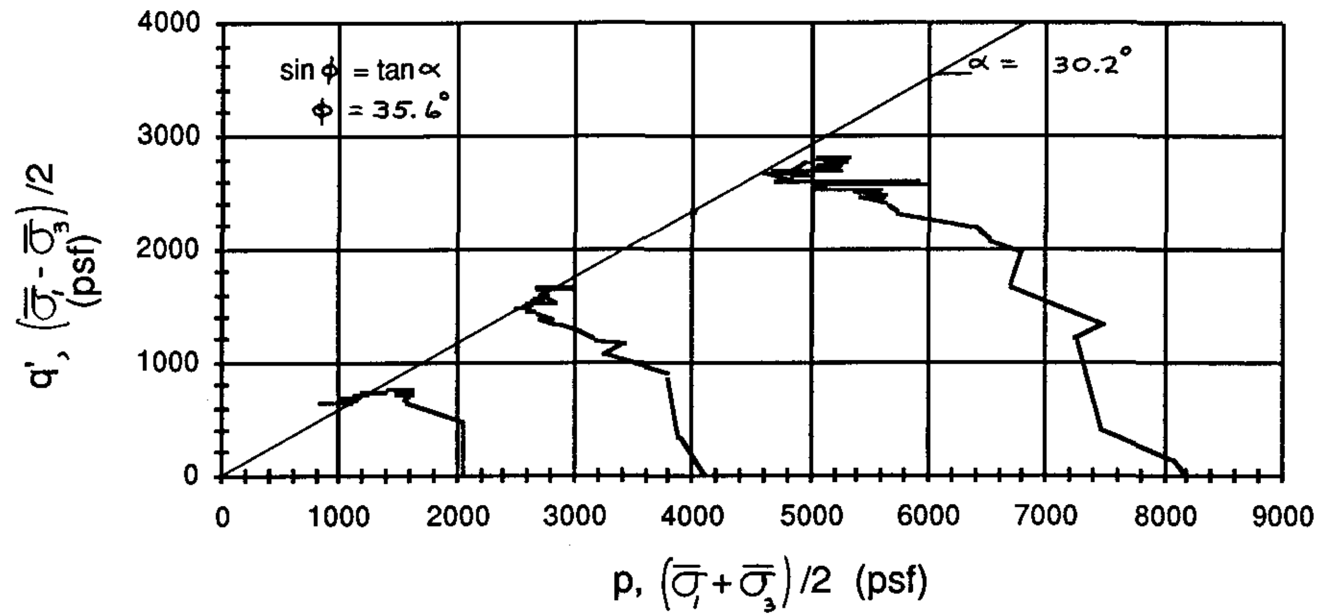
Measurement Type	Strength, psf
Field Vane	215
Lab Vane	220
Triaxial	748

For the triaxial test it was estimated that an equivalent isotropic pressure of 2050 psf (1.0 kg/cm^2) represented the in situ anisotropic stresses of 2990 psf vertical stress and 1255 psf horizontal stress. The ratio of the horizontal to vertical stress, K_o, was set equal to (1-sin ϕ) where $\phi = 35.6^o$ was obtained from the triaxial testing effective stress p-q plot (Figure 18). Stress-strain measurements during the triaxial testing (Figure 19) indicate the brittle behavior of this soil, i.e., most of the shear strength is mobilized within one half of 1% strain. The lower strengths of Presumpscot formation are not caused by the frictional properties of the soil since the effective angle of friction is 35.6^o (Figure 18). The lower strengths are caused by the generation of pore pressure during shearing (Figure 20). During shearing of the specimen, the pore pressure generated is about equal to the axial load applied. Determination of whether the triaxial test shear strength or the field vane shear strength more truly represents in situ strength can only be determined from a failure analysis where both the topography prior to failure and the shear surface are known.

Remolded Strength Remolded strengths, which are measured after large

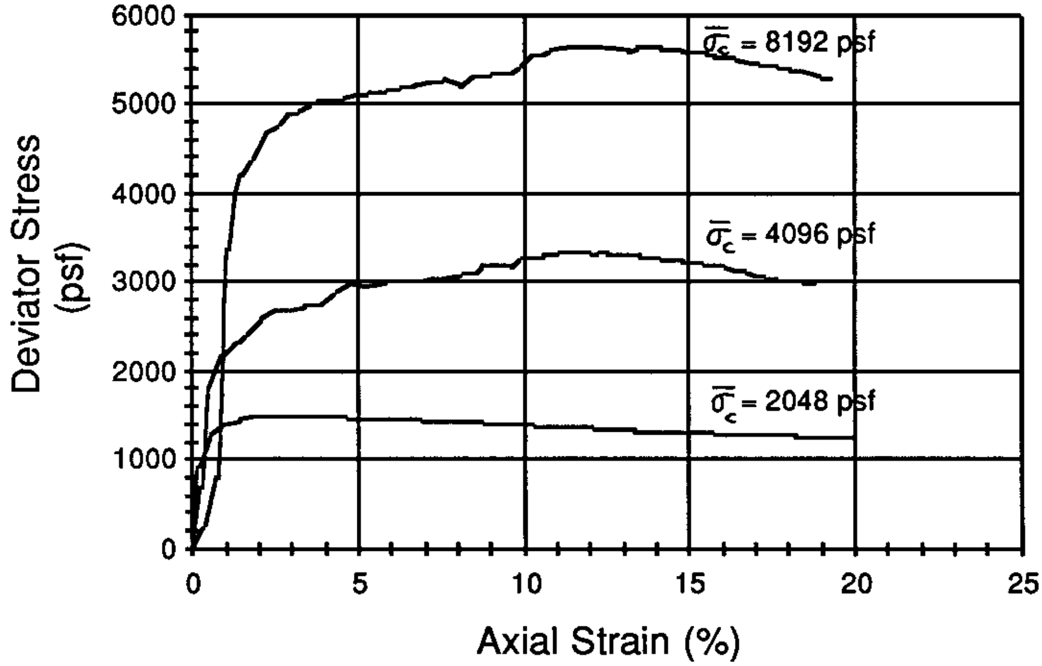
Table 6 - Summary of undrained field vane shear strength results, undisturbed and remolded.

Test Boring	Shelby Tube	Depth to bottom of vane (feet)	Undrained Shear Strength	
			Undisturbed tsf (psf)	Remolded tsf (psf)
TB-1	ST-1	17.7	0.215 (430.5)	0.072 (143.5)
TB-2	ST-1	18.0	0.197 (394.6)	0.036 (71.7)
	ST-2	33.6	0.269 (538.1)	0.018 (35.9)
	ST-3	47.6	0.107 (214.5)	0.018 (35.9)
	ST-4	57.6	0.144 (287.0)	0.018 (35.9)
	ST-5	72.6	0.305 (609.8)	0.072 (143.5)
TB-3	ST-1	28.6	0.215 (430.5)	0.018 (35.9)
	ST-2	43.8	0.753 (1506.6)	0.502 (1004.4)



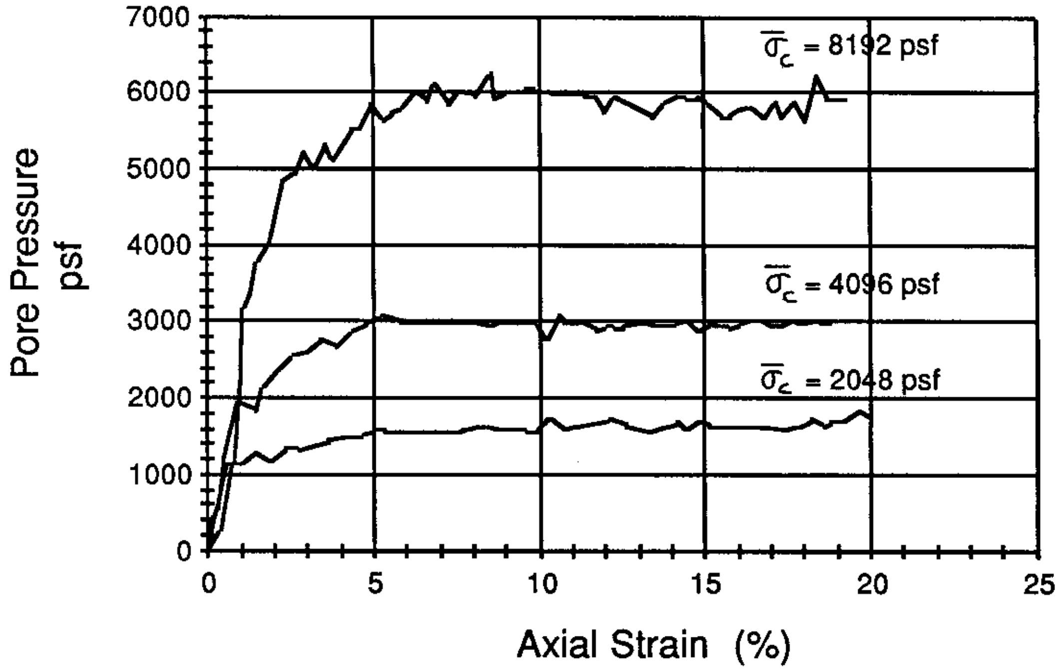
Boring: TB-2
Depth: 45-47 ft.
Sample: ST-3

Figure 18. Effective stress paths for CIU triaxial tests



Borng: TB-2
Depth: 45-47 ft.
Sample: ST-3

Figure 19. Stress vs. strain for CIU triaxial tests



Boring: TB-2
Depth: 45-47 ft.
Sample: ST-3

Figure 20. Pore pressure vs. strain for CIU triaxial tests

straining, are obtained from the field and laboratory vane tests. The range of remolded shear strength measured by the field vane was 36 psf to 1005 psf. Eliminating the sample near the bottom of the strata in TB-2 and TB-3 gives a range of 36 psf to 144 psf. The laboratory vane measured only 12 psf remolded shear strength. It was done in the sampling tube, and the lower value may reflect less confining stresses in the tube than at depths for the field vane. However, it is noteworthy that the remolded shear strengths are significantly less than the undisturbed strengths. The ratio of the undisturbed strength to the remolded strength, i.e. the sensitivity , measured by the field vane tests ranged from 3 to 15, which puts the soil in the very sensitive to slightly quick category.

Slope Stability The strengths obtained in the field investigations can be used to estimate the heights of bluffs on the verge of failure (Navfac, 1982). For a soil total unit weight of 118 lb/cf, a vertical face and no open cracks, the height is given by:

$$\text{Height (feet)} = N_0 C / \gamma = \text{Shear Strength (psf)}/30.8$$

where N_0 = Stability Number
C = Undrained shear strength (psf)
γ = Total unit weight (lb/cf)

For the undisturbed strength range of the gray clay of 215 psf to 538 psf, the maximum free standing height is 7 ft to 17 ft. Using the triaxial strength, the maximum height is 24 feet. For the remolded strength of 36 psf to 144 psf, the free standing height is 1.2 ft to 5 ft. For a sloping bluff the stability number will be higher, and thus a higher bluff can exist for the same strength. These values indicate that slopes were likely existing prior to the slide at a factor of safety close to 1.0. With only an incremental change in the loading, failure could well have begun. The highly sensitive to slightly quick soil reduced drastically in strength with disturbance. This is the property that caused the failure to be progressive. At this particular site, the bedrock surface is considerably higher in the direction of ground-failure propagation. The headward expansion of the landslide apparently continued until the failure surface began to encounter higher strength material near bedrock, and then the failure ceased. From TB-1 this would put the depth of the failure surface close to 30 feet which appears to be the level of maximum sensitivity in TB-2 and TB-3.

Relation of Gorham Strengths to Historical Correlations The Atterberg limit classification properties for the gray Presumpscot in Appendix A show liquid limits ranging from 32 to 52 and plasticity indices ranging from 16 to 29. These are similar to the ranges of samples summarized in Table 3 and are within the ranges found by others. This level of plasticity index indicates the presence of clay minerals.

The c/p ratios determined from field vane tests for the Gorham site do not correlate well with the plasticity index (Figure 21). They are also inconsistent with those found for other similar glacial marine sediments.

The sensitivity at the Gorham site increases with increasing liquidity index (Figure 22). Some of the scatter in Figure 22 may be caused by vertical variability of the Atterberg limits. If Atterberg limits were not conducted at the location of the field vane, then the next lower series of Atterberg limits were used for correlation. Despite the scatter the natural water content and the Atterberg limits appear to be a useful indicator for the level of sensitivity. Compared to Norwegian clays, the sensitivity at Gorham is consistently lower for a given liquidity index.

Conclusion

Two distinguishing features of the shear strength appear to account for the differences in the nature of the slide at Gorham compared to Bunganuc. At Gorham, the undisturbed strengths measured in the field vane tests were lower (215 -538 psf in all except maximum-depth samples) than that backfigured for the slide at Bunganuc (840 psf). This accounts for higher bluffs being able to exist at Bunganuc than at Gorham.

The other feature which was significantly different was the much higher soil sensitivity at Gorham. The sensitivity was visually assessed at Bunganuc. Indications of the sensitivity at Bunganuc can be obtained from the liquidity index of the materials (Figure 22). At Bunganuc, the liquidity index was near 0.5, and thus the soil was only slightly sensitive. At Gorham, the liquidity index was greater than one, and the soil was very sensitive to slightly quick. The high sensitivity was

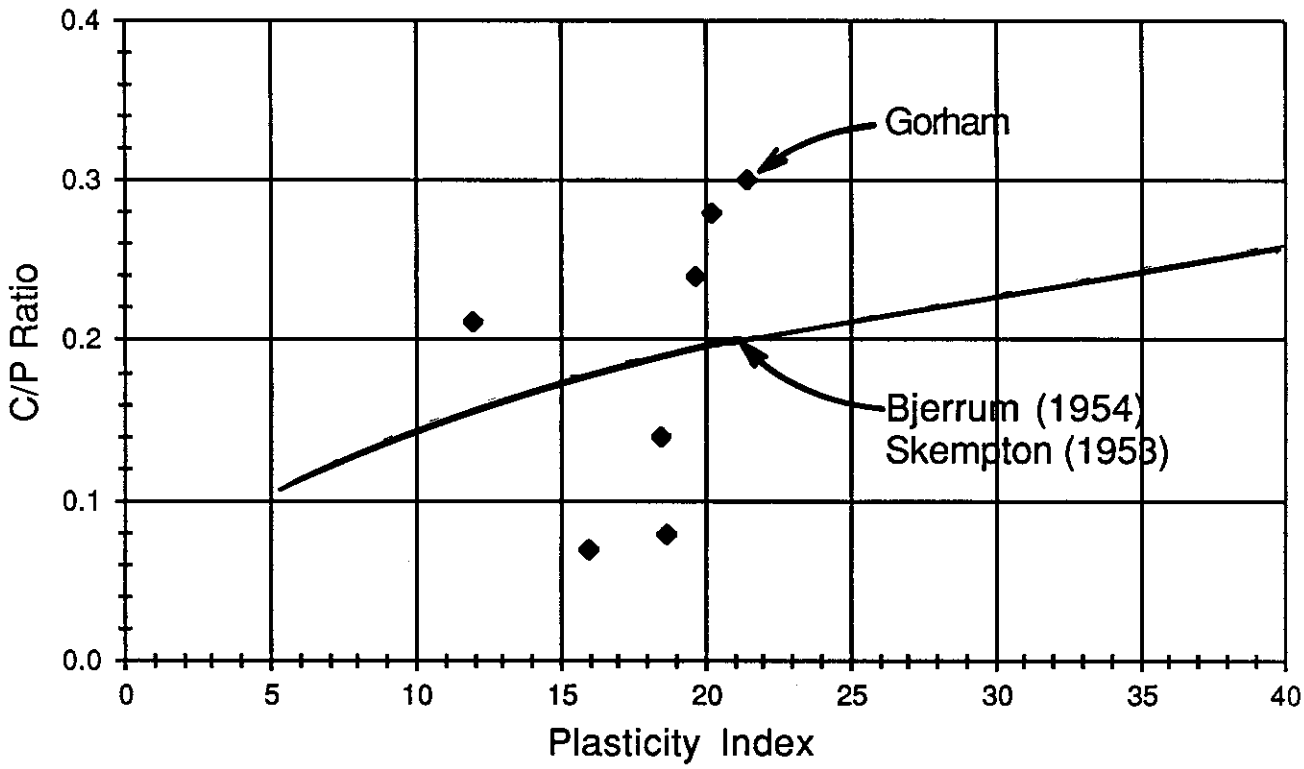


Figure 21. Relationship between c/p ratio and plasticity index

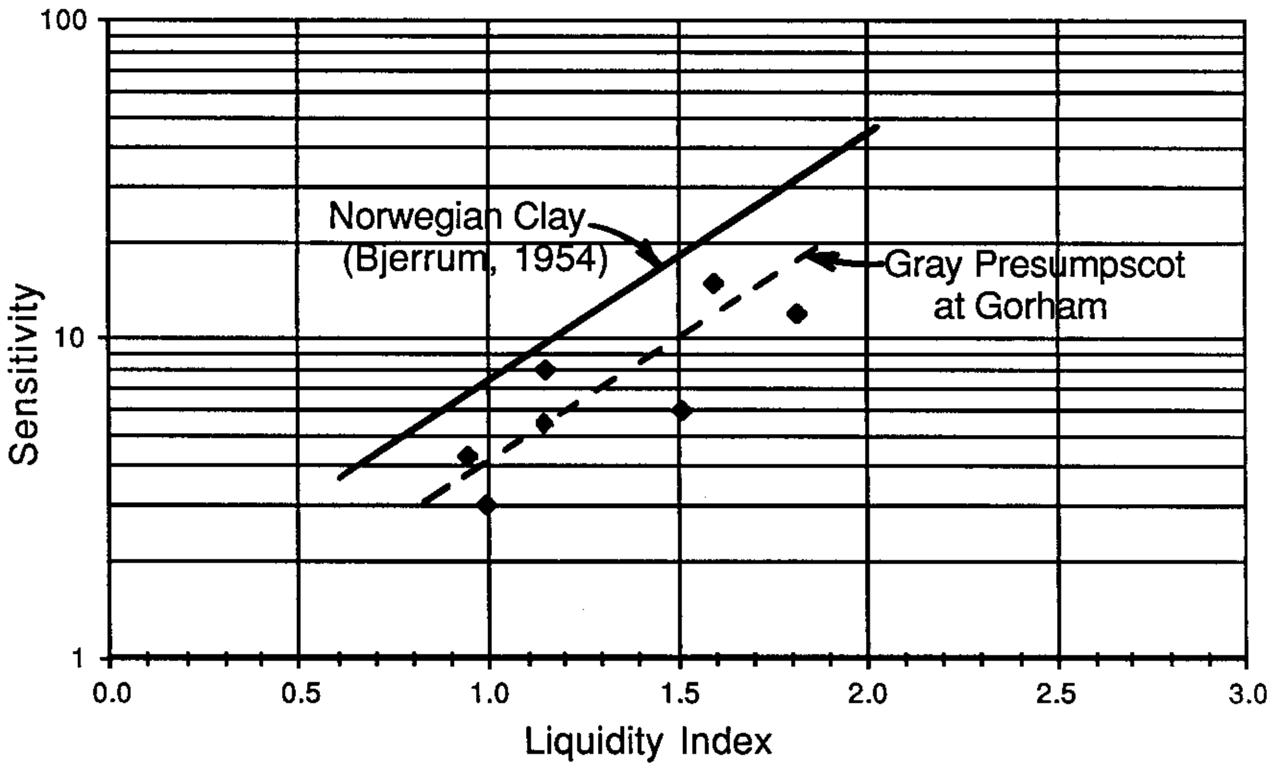


Figure 22. Sensitivity vs liquidity index

likely responsible for the Gorham slide being retrogressive, while at Bunganuc only a single slide formed.

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APPENDIX A

Final Logs of Compiled Field and Laboratory Results for Gorham Landslide

BORING LOG SYMBOLS AND ABBREVIATIONS

Symbol	Abbreviation	Description
□	SS	split spoon
□	ST	shelby tube 2" o.d.
v		field vane 2" x 7"
■	CB	core barrel

WOH - weight of hammer

WOM - weight of man

WOR - weight of rod

HYD. PUSH - hydraulic push

RQD - rock quality designation

med. - medium

DEFINITION OF TERMS:

trace	0-10% by weight
some	10-20% by weight
adjective (-y)	20-35% by weight
and	35-50% by weight
name	> 50% by weight

FINAL LOG - SUBSURFACE EXPLORATION

Boring No. TB-1
Sheet 1 of 2

Job Title Gorham Landslide
Location Longfellow Rd. Gorham, Maine
Date Start 11/19/85 Date Finish 11/19/85
Drilling Contractor Maine Test Boring, Inc.
Driller G. Rudnicki Inspector J. Amos

	Sampler	Casing	Core Barrel
Type	SS	AW	BWM4
Size (I.d.)	1 3/8"	2 3/8"	1 5/8"

Sample Hammer: wt 140 drop 30"
Casing Hammer: wt 300 drop 16"

Depth (Elevation) in feet	Blows per 6 inches on sampler (% recovery)	Unified Soil Classification Group Symbol	Sample Number	Description of Material	water content %	liquid limit %	plasticity index %	grain size	triaxial test	Remarks
0 (81.6)	1,2,3	OH	SS-1	Soft to firm brown fine sandy silt, some organics.	33.2	53.3	18.3			
5	7,12,15	CL	SS-2	Firm brown fine sandy, silty clay with gray mottling.	27.8	41.4	18.2			
10	3,4,5	CL	SS-3	Soft gray and brown silty clay.	35.4	42.1	19.8			
15	WOM (100%)	CL	ST-1	Very soft gray silty clay.	43.1					
20	WOH	CL	SS-4	Very soft gray silty clay with black streaks (organics).	43.5	43.5	21.5			
25	1,WOH, WOH	CL	SS-5	Very soft gray silty clay with black streaks (organics), trace fine sand, trace fine gravel to coarse sand size rock fragments.	42.1	37.7	16.8			
30	WOM.HYD. PUSH (100%)		ST-2	Gray fine sandy silt, trace gray clay, trace fine gravel to coarse sand size rock fragments.	22.0					
	RUN 1 (98%) RQD=.81	SCH	CB-1							Hit rock at 32.1'.

FINAL LOG - SUBSURFACE EXPLORATION

Boring No. TR-1
Sheet 2 of 2

Job Title Gorham Landslide		Sampler	Casing	Core Barrel
Location Longfellow Rd. Gorham, Maine	Type	SS	BW	BW04
Date Start 11/19/85 Date Finish 11/19/85	Size (I.d.)	1 3/8"	2 3/8"	1 5/8"
Drilling Contractor Maine Test Boring, Inc.	Sample Hammer:	wt 140	drop 30"	
Driller G. Rudnicki Inspector J. Amos	Casing Hammer:	wt 300	drop 16"	

Depth (Elevation) in feet	Blows per 6 inches on sampler (% recovery)	Unified Soil Classification Group Symbol	Sample Number and Description of Material	water content %	liquid limit %	plasticity index %	grain size	triaxial test	Remarks
35	RUN 1 (cont.)	SCH	CB-1 (cont.) *Hard dark gray mica schist with quartz veins.*						
			Bottom of boring at 37.1'.						
40									

(Summary of Test Results: water content %, liquid limit %, plasticity index %, grain size, triaxial test)

FINAL LOG - SUBSURFACE EXPLORATION

Boring No. TB-2
Sheet 1 of 3

Job Title Gorham Landslide
Location Longfellow Rd. Gorham, Maine
Date Start 11/19/85 Date Finish 11/20/85
Drilling Contractor Maine Test Boring, Inc.
Driller G. Rudnicki Inspector J. Amos

	Sampler	Casing	Core Barrel
Type	SS	BW	BWD4
Size (I.d.)	1 3/8"	2 3/8"	1 5/8"

Sample Hammer: wt 140 drop 30"
Casing Hammer: wt 300 drop 16"

Depth (Elevation) in feet	Blows per 6 inches on sampler (% recovery)	Unified Soil Classification Group Symbol	Sample Number	Description of Material	water content %	liquid limit %	plasticity index %	grain size	triaxial test	Remarks
0 (73.3)	1,1,1	OH	SS-1	Soft brown fine sandy silt, some organics.	69.6					
5	3,3,1	OL	SS-2	Soft gray and brown with orange spots fine sandy silt, some wood chips.	23.0	24.6	1.4			
		ML		Soft gray and brown fine sandy silt with organics, trace coarse to med. sand.						
10	4,1,1	SC	SS-3	Brown clayey coarse to fine sand, trace silt,, trace fine gravel.	37.2	24.7	9.3	✓		
15	WOM (100%)	CL	ST-1		53.7					
20	WOR, WOR, WOM	CL	SS-4	Very soft gray silty clay with dark gray to black streaks (organics).	46.4	43.3	20.3			
25	WOM	CL	SS-5		50.2	39.2	16.3			
30	WOR (100%)	CL	ST-2		60.0					

FINAL LOG - SUBSURFACE EXPLORATION

Boring No. TB-2
Sheet 2 of 3

Job Title Gorham Landslide		Sampler	Casing	Core Barrel
Location Longfellow Rd. Gorham, Maine	Type	SS	BW	BWD4
Date Start 11/19/85 Date Finish 11/20/85	Size (i.d.)	1 3/8"	2 3/8"	1 5/8"
Drilling Contractor Maine Test Boring, Inc.	Sample Hammer:	wt 140	drop 30"	
Driller G. Rudnicki Inspector J. Amos	Casing Hammer:	wt 300	drop 16"	

Depth (Elevation) in feet	Blows per 6 inches on sampler (% recovery)	Unified Soil Classification Group Symbol	Sample Number and Description of Material	water content %	liquid limit %	plasticity index %	grain size	triaxial test	Remarks
35	WOR		SS-6	53.9	42.8	19.7			
40	WOR		SS-7	52.2	48.0	25.5			
45	WOR (100%)		ST-3	45.7	36.6	10.9		✓	
50	WOR	CL	SS-8 *Very soft gray silty clay with dark gray to black streaks (organics).*	45.4	37.1	16.0			
55	WOR (100%)		ST-4	44.3					
60	WOR		SS-9	43.8	40.0	18.7			
65	WOR		SS-10	41.2	39.3	18.3			

FINAL LOG - SUBSURFACE EXPLORATION

Boring No. TB-2
Sheet 3 of 3

Job Title: Gorham Landslide		Sampler	Casing	Core Barrel
Location: Longfellow Rd. Gorham, Maine	Type	SS	BW	BWN4
Date Start: 11/19/85 Date Finish: 11/20/85	Size (I.d.)	1 3/8"	2 3/8"	1 5/8"
Drilling Contractor: Maine Test Boring, Inc.	Sample Hammer:	wt 140	drop 30"	
Driller: G. Rudnicki Inspector: J. Amos	Casing Hammer:	wt 300	drop 16"	

Depth (Elevation) in feet	Blows per 6 inches on sampler (% recovery)	Unified Soil Classification Group Symbol	Sample Number and Description of Material	water content %	liquid limit %	plasticity index %	grain size	triaxial test	Remarks
70	WOR (100%)	CL	ST-5	47.9					
75	WOR	CL	SS-11 Very soft gray silty clay with dark gray to black streaks (organics).	38.6	39.5	18.5			
80	WOR	CL	SS-12	37.1	31.9	13.2			
85	6,100/.2'	SM	SS-13 Gray silty med. to fine sand	18.8			✓		
			Bottom of boring at 85.7'.						
90									

FINAL LOG - SUBSURFACE EXPLORATION

Boring No. TB-3
Sheet 1 of 2

Job Title Gorham Landslide		Sampler	Casing	Core Barrel
Location Longfellow Rd. Gorham, Maine	Type	SS	BW	BWD4
Date Start 11/20/85 Date Finish 11/20/85	Size (I.d.)	1 3/8"	2 3/8"	1 5/8"
Drilling Contractor Maine Test Boring, Inc.	Sample Hammer:	wt 140	drop 30"	
Driller G. Rudnicki Inspector J. Amos	Casing Hammer:	wt 300	drop 16"	

Depth (Elevation) in feet	Blows per 6 inches on sampler (% recovery)	Unified Soil Classification Group Symbol	Sample Number	Description of Material	water content %	liquid limit %	plasticity index %	grain size	triaxial test	Remarks
0 (75.7)	1,3,5	CL	SS-1	Firm brown fine sandy, silty clay, trace gray silty clay.	19.3	33.8	13.7			
5	3,3,3	CL	SS-2	Firm brown gray silty clay with red brown stains.	29.3	42.5	18.6			
10	2,2,2	CL	SS-3	Soft to firm brown silty clay.	41.0	48.9	26.5			
		CL		Very soft gray silty clay.						
15	WOH	CH	SS-4	Very soft gray silty clay.	51.1	52.1	28.9			
20	WOR	CL	SS-5	Very soft gray silty clay with black streaks (organics).	44.7	40.3	18.9			
25	WOR (100%)	CL	ST-1		48.2					
30	WOR	CL	SS-6		42.1	32.3	12.0			

FINAL LOG - SUBSURFACE EXPLORATION

Boring No. TB-3
Sheet 2 of 2

Job Title: Gorham Landslide		Sampler	Casing	Core Barrel
Location: Longfellow Rd. Gorham, Maine	Type	SS	BW	BWD4
Date Start: 11/20/85 Date Finish: 11/20/85	Size (i.d.)	1 3/8"	2 3/8"	1 5/8"
Drilling Contractor: Maine Test Boring, Inc.	Sample Hammer:	wt 140	drop 30"	
Driller: G. Rudnicki Inspector: J. Amos	Casing Hammer:	wt 300	drop 16"	

Depth (Elevation) in feet	Blows per 6 inches on sampler (% recovery)	Unified Soil Classification Group Symbol	Sample Number and Description of Material	water content %	liquid limit %	plasticity index %	grain size	triaxial test	Remarks
35	WOR, WOR, WOH	CL	SS-7	45.5	34.4	14.2			
			Very soft gray silty clay with black streaks (organics).						
40	WOR		SS-8	41.6	34.2	14.8			
45	WOR, WOH, WOH	CL	SS-9 *Very soft gray silty clay with black streaks (organics), trace fine gravel to coarse sand size rock fragments.*	34.5	32.1	13.1			
50	6,100/0.0'	SM	SS-10 *Gray and brown silty med. to fine sand, trace fine gravel to coarse sand size rock fragments.*	19.6			✓		
			Bottom of boring at 50.5'.						
55									

APPENDIX B

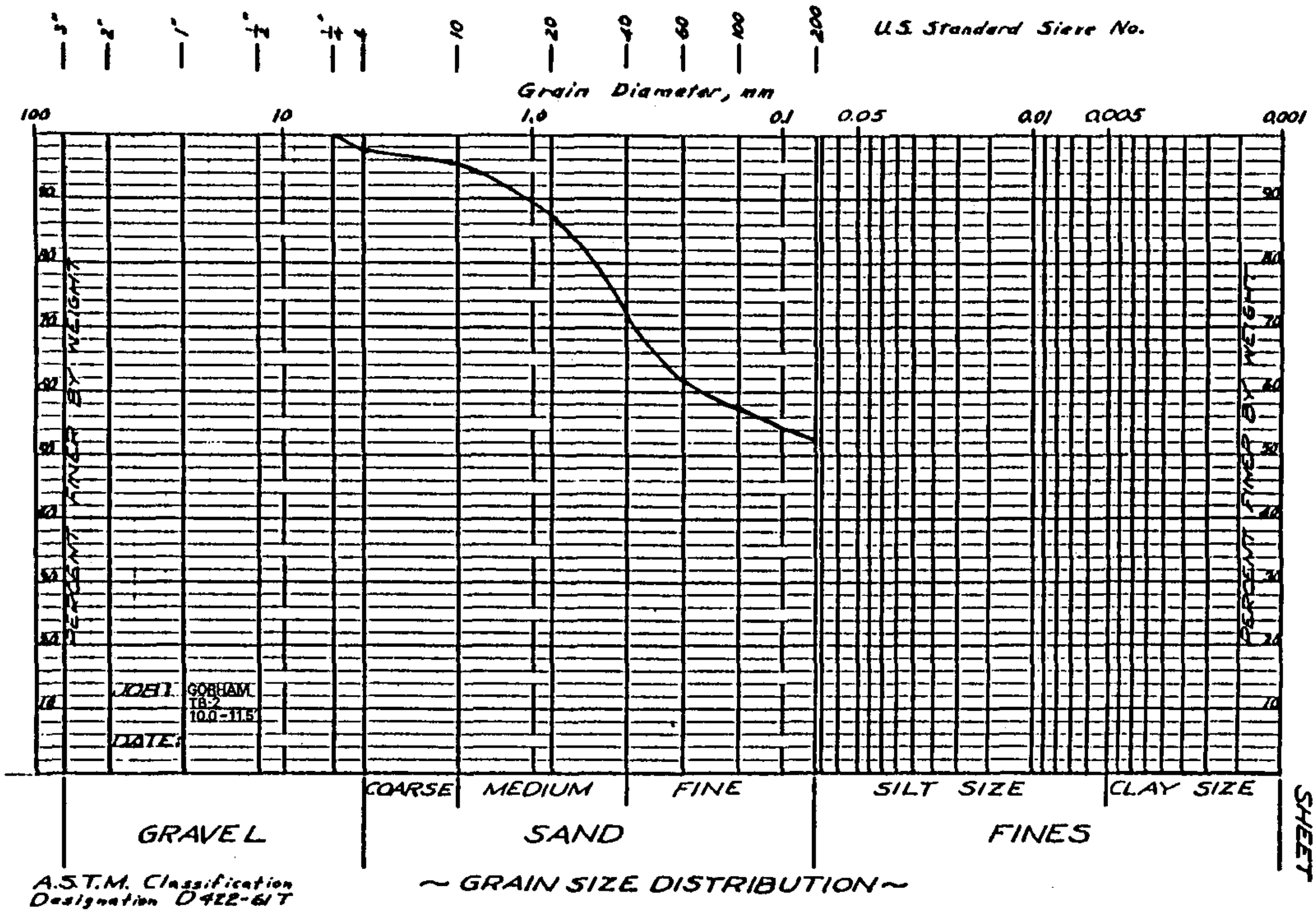
Sieve Analysis Results

STANDARD SIEVE SIZES (ASTM)

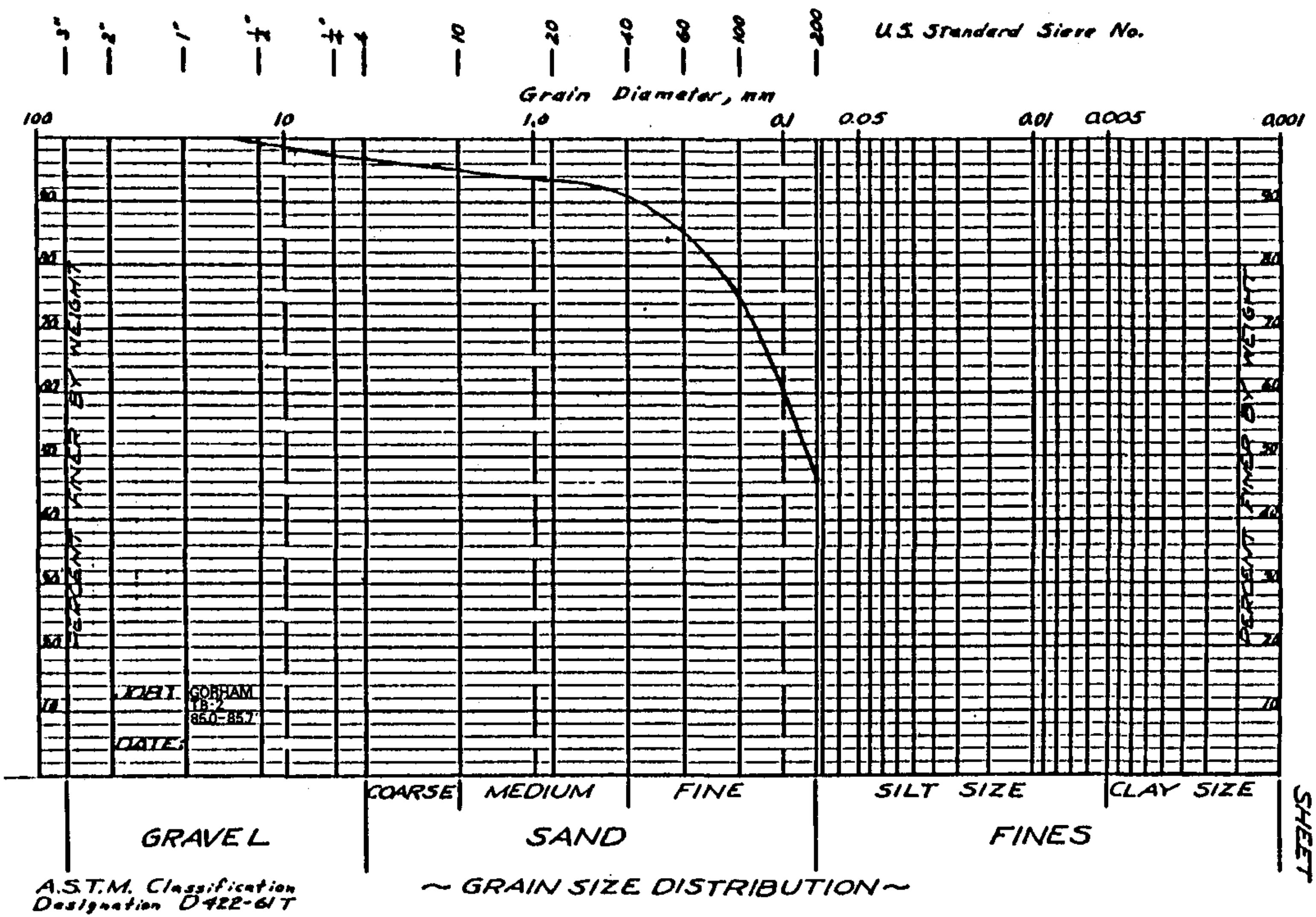
Size (in.)		Opening (mm)	Size No.		Opening (mm)	Size No.		Opening (mm)
4		100				*40		0.425
3	(1) (2)	75	*4	(1) (2)	4.75	50	(2)	0.300
*2	(1)	50	8	(2)	2.36	*60	(1)	0.250
$1\frac{1}{2}$	(1) (2)	37.5	*10	(1)	2.00	70		0.212
*1	(1)	25	16	(2)	1.18	*100	(2)	0.150
$\frac{3}{4}$	(1) (2)	19	*20	(1)	0.850	140	(1)	0.106
*$\frac{1}{2}$		12.5	30	(2)	0.600	*200	(1) (2)	0.075
$\frac{3}{8}$	(1) (2)	9.5						

(1) A standard series for ASTM D422 "Grain size test."
(2) Alternate series for uniformly spaced points on log diameter graph.

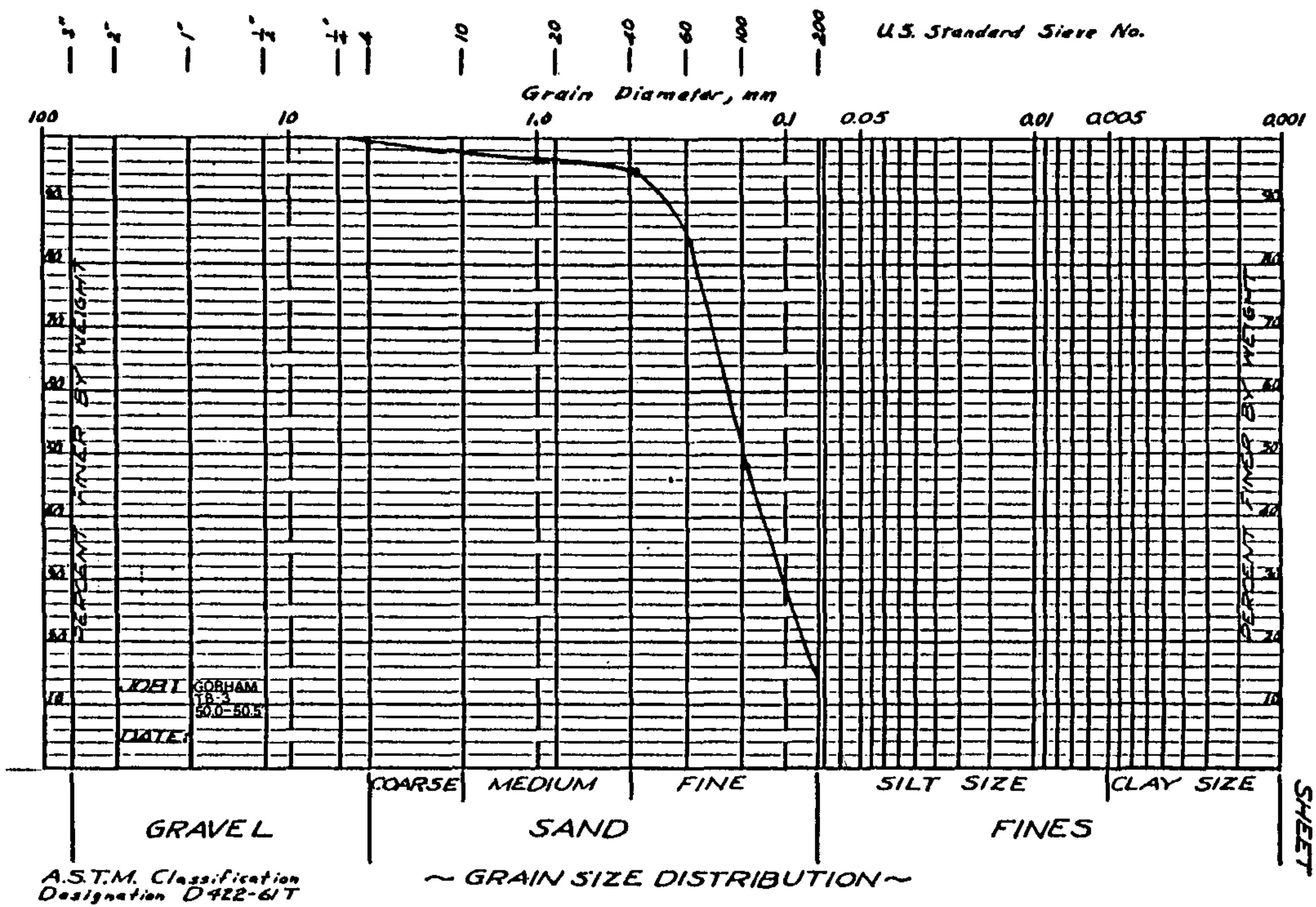
* Sieves used in grain size analysis of Gorham Samples



Grain size distribution of Gorham material taken from TB-2 at 10.0 to 11.5 ft depth.



Grain size distribution of Gorham material taken from TB-2 at 85.0 to 85.7 ft depth.



Grain size distribution of Gorham material taken from TB-3 at 50.0 to 50.5 ft depth.

APPENDIX C

Field Logs of Subsurface Exploration Drilling Program

MAINE TEST BORINGS, INC.
BREWER, MAINE 04412

CLIENT: Dept. of Conservation

SHEET 1 OF 1
HOLE NO. B-1

DRILLER: Gerry Rudnicki
PROJECT NAME: Gorham Landslide
LINE & STATION:

M.T.B. JOB NUMBER: 85-237
LOCATION: Gorham, Maine
OFFSET:

GROUND WATER OBSERVATIONS
AT ____ FT. AFTER ____ HOURS
AT ____ FT. AFTER ____ HOURS

	CASING	SAMPLER	CORE BARREL
TYPE	BW	SS	BWD4
SIZE I.D.	2 3/8"	1 3/8"	1 5/8"
HAMMER WT.	300	140	
HAMMER FALL	16"	30"	

DATE START 11-19-85 DATE FIN 11-19-85
SURFACE ELEV.
GROUND WATER ELEV.

CASING BLOWS PER FOOT	SAMPLE NO.	O.D.	PEN.	REC.	DEPTH @ BOT.	BLOWS PER 6" ON SAMPLER 0-6	6-12	12-18	VANE READING	DEPTH	STRATUM DESCRIPTION
1										1.5	~~Brown fine sandy silt w/organics.~~
8	1D	2"	18"		1.5	1	2	3		2.5	Brown silty fine sandy mottled clay.
27											
35											
40											Brown silty mottled clay.
46											
56	2D	2"	18"		6.5	7	12	15			
65										8.0	
60											
55											Brown silty clay.
51											
48	3D	2"	18'		11.5	3	4	5			
52										13.5	
49											
45											
58											Gray silty clay.
72	1C	2"	24"		17.0	Wt.	of man				
67	2 x 1 vane				17'7"				12/4		
68										19.0	
60											
58											Gray silty clay w/black spots.
53	4D	2"	18"		21.5	Wt.	of hammer				
48										23.0	
44											
41											
40											Gray silty clay w/trace of fine sand layers.
37	5D	2"	18"		26.5	1	WoH	WoH			
42											
36											
37											
35										31.0	
39	2C	2"	18"		31.5	WoM	Hydraulic	push		32.1	Gray fine sandy silt w/trace of med. to coarse sand.
100											
											Rock.
										37.1	
	1R	*	5.0	4.8	37.1	96%					
											Bottom of boring @ 37.1'

SAMPLES
D = Splite Spoon
C = 2" Shelby Tube
U = 3½" Shelby Tube

SOIL CLASSIFIED BY:
[✓] Driller - Visually
[ ] Soil Technican - Visually
[ ] Laboratory Tests

REMARKS
* 2 3/8"

HOLE NO. B-1

MTB-14

MAINE TEST BORINGS, INC. BREWER, MAINE 04412	CLIENT: Dept. of Conservation	SHEET 1 OF 3 HOLE NO. B-2
DRILLER: Gerry Rudnicki	PROJECT NAME: Gorham landslide	LINE & STATION
M.T.B. JOB NUMBER: 85-237	LOCATION: Gorham, Maine	OFFSET

GROUND WATER OBSERVATIONS		CASING	SAMPLER	CORE BARREL	
AT ___ FT. AFTER ___ HOURS	TYPE	BW	SS		DATE START 11-19-85 DATE FIN. 11-20-85
AT ___ FT. AFTER ___ HOURS	SIZE I.D.	2 3/8"	1 3/8"		SURFACE ELEV.
	HAMMER WT.	300	140		GROUND WATER ELEV.
	HAMMER FALL	16"	30"		

CASING BLOWS PER FOOT	SAMPLE NO.	O.D.	PEN.	REC.	DEPTH @ BOT.	BLOWS PER 6" ON SAMPLER 0-6	6-12	12-18	VANE READING	DEPTH	STRATUM DESCRIPTION
1											
1	1D	2"	18"		1.5	1	1	1			Brown fine sandy silt w/organics.
1										3.5	
2											
4											Brown fine sandy silt.
2										5.5	
										6.0	Gray fine sandy silt - silty fine sand.
1	2D	2"	18"		6.5	3	3	1			
1											
3											Brown fine sandy silt w/organics, trace of med. to coarse sand.
4										10.5	
5										10.8	Brown fine to coarse sand w/trace of silt.
3	3D	2"	18"		11.5	4	1	1			
3											
1											
3											
6											Gray silty clay w/black spots.
5	1C	2"	24"		17.0	Wt. of man					
4	2 x 4 vane				17'11"				11/2		
4											
2											
WoH											
WoH	4D	2"	18"		21.5	WoR	WoR	WoH			
WoH											
2											
5											
8											
5	5D	2"	18"		26.5	Wt. of rods.					
5											
5											
3											
6	2C	2"	2"		30.2	Wt. of rods.					
6	2 x 4 vane				33'7"				15/1		
5											
3											
2											
9											
6	6D	2"	18"		36.5	Wt. of rods					
6											
4											
2											

SAMPLES
D = Split Spoon
C = 2" Shelby Tube
U = 3½" Shelby Tube

SOIL CLASSIFIED BY:
[X] Driller - Visually
[ ] Soil Technician - Visually
[ ] Laboratory Tests

REMARKS:

HOLE NO. B-2

MTB-14

MAINE TEST BORINGS, INC.
BREWER, MAINE 04412

CLIENT: Dept. of Conservation

SHEET 2 OF 3
HOLE NO. B-2

DRILLER	PROJECT NAME	LINE & STATION
Gerry Rudnicki	Gorham landslide	

M.T.B. JOB NUMBER	LOCATION	OFFSET
85-237	Gorham, Maine	

GROUND WATER OBSERVATIONS

AT ____ FT. AFTER ____ HOURS

AT ____ FT. AFTER ____ HOURS

	CASING	SAMPLER	CORE BARREL
TYPE	BW	SS	
SIZE I.D.	2 3/8"	1 3/8"	
HAMMER WT.	300	140	
HAMMER FALL	16"	30"	

DATE START 11-19-85 DATE FIN. 11-20-85

SURFACE ELEV. ____

GROUND WATER ELEV. ____

CASING BLOWS PER FOOT	SAMPLE NO.	O.D.	PEN.	REC.	DEPTH @ BOT.	BLOWS PER 6" ON SAMPLER 0-6	6-12	12-18	VANE READING	DEPTH	STRATUM DESCRIPTION
4											
5	C	2"	24"	0.0	42.0	Wt. of rods					
4	7D	2"	18"		41.5	Wt. of rods					Gray silty clay w/black spots.
4											
1											
WoH											
WoH	3C	2"	24"		47.0	Wt. of rods					
3	2 x 7 vane				47'7"				6/1		
5											
4											
4											
5	8D	2"	18"		51.5	Wt. of rods					
WoH											
WoH											
WoH											
4											
3	4C	2"	24"		57.0	Wt. of rods					
WoH	2 x 7 vane				57'7"				8/1		
"											
"											
"											
"	9D	2"	18"		61.5	Wt. of rods					
"											
"											
WoC											
"											
"	10D	2"	18"		66.5	Wt. of rods					
"											
"											
"											
"											
"	5C	2"	24"		72.0	Wt. of rods					
"	2 x 7 vane				72'7"				17/4		
"											
"											
"											
"	11D	2"	18"		76.5	Wt. of rods					
"											
"											
"											

SAMPLES
D = Splits Spoon
C - 2" Shelby Tube
U = 3½" Shelby Tube

SOIL CLASSIFIED BY:
[X] Driller - Visually
[ ] Soil Technician - Visually
[ ] Laboratory Tests

REMARKS

HOLE NO. B-2

MTB-14

MAINE TEST BORINGS, INC. BREWER, MAINE 04412	CLIENT Dept. of Conservation	SHEET 3 OF 3 HOLE NO. B-2
DRILLER Gerry Rudnicki	PROJECT NAME Gorham landslide	LINE & STATION
M.T.B. JOB NUMBER 85-237	LOCATION Gorham, Maine	OFFSET

GROUND WATER OBSERVATIONS		CASING	SAMPLER	CORE BARREL	
AT ___ FT. AFTER ___ HOURS	TYPE	BW	SS		DATE START 11-19-85 DATE FIN. 11-20-85
AT ___ FT. AFTER ___ HOURS	SIZE I.D.	2 3/8"	1 3/8"		SURFACE ELEV.
	HAMMER WT.	300	140		GROUND WATER ELEV.
	HAMMER FALL	16"	30"		

CASING BLOWS PER FOOT	SAMPLE NO.	O.D.	PEN.	REC.	DEPTH @ BOT	BLOWS PER 6" ON SAMPLER 0-6	6-12	12-18	VANE READING	DEPTH	STRATUM DESCRIPTION
WoC											Gray silty clay w/black spots
"	12D	2"	18"		81.5	Wt. of rods				82.0	
10											Gray silty fine sand w/trace of coarse sand.
6											
										85.7	
	13D	2"	8"		85.7	6	100				
											Refusal @ 85.7'

SAMPLES
D = Splite Spoon
C = 2" Shelby Tube
U = 3½" Shelby Tube

SOIL CLASSIFIED BY:
[X] Driller Visually
[ ] Soil Technican - Visually
[ ] Laboratory Tests

REMARKS:

HOLE NO. B-2

MTB-14

MAINE TEST BORINGS, INC. BREWER, MAINE 04412	CLIENT: Dept. of Conservation	SHEET 1 OF 2 HOLE NO. B-3
DRILLER: Gerry Rudnicki	PROJECT NAME: Gorham landslide	LINE & STATION
M.T.B. JOB NUMBER: 85-237	LOCATION: Gorham, Maine	OFFSET

GROUND WATER OBSERVATIONS

AT ______ FT. AFTER ______ HOURS

AT ______ FT. AFTER ______ HOURS

	CASING	SAMPLER	CORE BARREL
TYPE	BW	SS	
SIZE I.D.	2 3/8"	1 3/8"	
HAMMER WT.	300	140	
HAMMER FALL	16"	30"	

DATE START 11-20-85 DATE FIN. 11-20-85

SURFACE ELEV. ______

GROUND WATER ELEV. ______

CASING BLOWS PER FOOT	SAMPLE NO.	O.D.	PEN.	REC.	DEPTH @ BOT.	BLOWS PER 6" ON SAMPLER 0-6	6-12	12-18	VANE READING	DEPTH	STRATUM DESCRIPTION
1											Brown fine sandy silt w/trace of clay.
7	1D	2"	18"		1.5	1	3	5		2.0	
8											
11											
16											Brown silty mottled clay.
7											
10	2D	2"	18"		6.5	3	3	3			
7										8.0	
7											
10											Brown silty clay.
13										10.5	
13	3D	2"	18"		11.5	2	2	2			Gray silty clay.
15											
14										14.0	
13											
14											
13	4D	2"	18"		16.5	Wt. of hammer					Gray silty clay w/black spots.
12											
10											
9											
27											
23	5D	2"	18"		21.5	Wt. of rods					
26											
19											
17											
19											
17	1C	2"	24"		27.0	Wt. of rods					
15	2 x 4 vane				28'7"				12/1		
17											
16											
15											
14	6D	2"	18"		31.5	Wt. of rods					
13											
11											
9											
8											
6	7D	2"	18"		36.5	WoR	WoR	WoH			
4											
2											
WoH											

SAMPLES
D = Split Spoon
C = 2" Shelby Tube
U = 3½" Shelby Tube

SOIL CLASSIFIED BY:
[X] Driller - Visually
[ ] Soil Technician - Visually
[ ] Laboratory Tests

REMARKS:

HOLE NO. B-3

MTB-14

MAINE TEST BORINGS, INC. BREWER, MAINE 04412	CLIENT Dept. of Conservation	SHEET 2 OF 2 HOLE NO. B-3
DRILLER Gerry Rudnicki	PROJECT NAME Gorham landslide	LINE & STATION
M.T.B. JOB NUMBER 85-237	LOCATION Gorham, Maine	OFFSET

GROUND WATER OBSERVATIONS

AT ____ FT. AFTER ____ HOURS

AT ____ FT. AFTER ____ HOURS

	CASING	SAMPLER	CORE BARREL
TYPE	BW	SS	
SIZE I.D.	2 3/8"	1 3/8"	
HAMMER WT.	300	140	
HAMMER FALL	16"	30"	

DATE START 11-20-85 DATE FIN. 11-20-85

SURFACE ELEV. ____

GROUND WATER ELEV. ____

CASING BLOWS PER FOOT	SAMPLE NO.	O.D.	PEN.	REC.	DEPTH @ BOT.	BLOWS PER 6" ON SAMPLER 0-6	6-12	12-18	VANE READING	DEPTH	STRATUM DESCRIPTION
8											
4	C	2"	24"	0.0	42.0	Wt.	of man				Gray silty clay w/black spots
WoH	8D	2"	24"		42.0	Wt.	of rods			43.0	
3	2 x 7 vane				43'9"				42/28	44.0	Gray silty clay w/coarse sand & fine gravel.
WoH											
6											Gray silty clay w/black spots, trace of coarse sand.
6	9D	2"	18"		46.5	WoR	WoH	WoH			
6											
5										49.0	
8											
	10D	2"	6"		50.5	16	100			50.5	Brown fine to med. sand w/coarse sand.
											Refusal @ 50.5'

SAMPLES
D = Split Spoon
C = 2" Shelby Tube
U = 3½" Shelby Tube

SOIL CLASSIFIED BY:
[X] Driller - Visually
[ ] Soil Technican - Visually
[ ] Laboratory Tests

REMARKS:

HOLE NO. B-3

MTB-14 43

MAINE TEST BORINGS, INC.
P.O. BOX A. BREWER, MAINE 04412 (207) 989-7820

DONALD B. WISWELL
CLARENCE W. WELTI, PhD

Client: Dept. of Conservation
Project: Gorham landslide
Location: Gorham, Maine
Driller: Gerry Rudnicki
Job # 85-237

11-19-85

GROUND WATER OBSERVATIONS

Bor #	Time	Depth to Water	Depth of Casing	Depth of Hole	Remarks
B-1	1:00pm	4.8'	32.1'	32.1'	
B-1	1:15pm	7.0'	0.0'	36.0'	Caved
11-20-85					
B-2	2:45pm	18.2'	84.0'	85.7'	
B-2	3:15pm	4.7'	0.0'	10.2'	Caved
B-3	10:20am	11.0'	50.0'	50.5'	
B-3	10:30am	9.0'	0.0'	0.0'	
P-4	11:55am	6.4'	0.0'	6.7'	Caved

COMPLETE TEST BORING SERVICE

MTB-12

MAINE TEST BORINGS, INC.
P.O. BOX A. BREWER, MAINE 04412 (207) 989-7820

DONALD B. WISWELL
CLARENCE W. WELTI, PhD

Client: Dept. of Conservation
Project: Gorham landslide
Location: Gorham, Maine
Driller: Gerry Rudnicki
Job # 85-237
Hammer: 300 lbs.
Fall: 16"
Rods: 1 3/4"

ROD PROBES

P-4

Intvl	Blows
0 - 5	Probe auger
5 - 6	1
6-7	1
7-8	WoH
8-9	WoH
9-10	1
10-11	3
11-12	4
12-13	6
13-14	5
14-15	5
15-16	4
16-17	7
17-18	7
18-19	7
19-20	8
20-21	7
21-22	8
22-23	9
23-24	7
24-25	6
25-26	5
26-27	8
27-28	6
28-29	6
29-30	4
30-31	4
31-32	4
32-33	3
33-34	4
34-35	3
35-36	2
36-37	3

P-4 cont.

Intvl	Blows
37-38	3
38-39	2
39-40	3
40-41	3
41-42	3
42-43	4
43-44	3
44-45	3
45-46	2
46-47	4
47-48	3
48-49	4
49-50	3
50-51	2
51-52	3
52-53	3
53-54	3
54-55	3
55-56	3
56-57	3
57-58	3
58-59	3
59-60	3
60-61	3
61-62	2
62-63	3
63-64	3
64-65	3
65-66	11
66-67	17
67-68	20
68-68.8	100

Refusal @ 68.8'

COMPLETE TEST BORING SERVICE

MTB-12