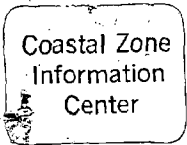


10702



## **SHORE EROSION STUDY**

**COASTAL ZONE  
INFORMATION CENTER**

### **TECHNICAL REPORT**

**JUN 22 1977**

### **APPENDIX 6**

**SHORELINE EROSION AND BLUFF STABILITY ALONG LAKE MICHIGAN  
AND LAKE SUPERIOR SHORELINES OF WISCONSIN**

### **SOUTHERN AND CENTRAL MANITOWOC COUNTY**

D. Hadley

C. Fricke

T. Edil

B. Haas

**APRIL 1977**

Wisconsin Coastal Zone Management Program



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459.5  
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S5  
appendix 6



This report has been prepared through the cooperative efforts of the Wisconsin Geological and Natural History Survey, the University of Wisconsin (Madison, Milwaukee, Parkside and Extension), the Wisconsin Department of Natural Resources and the Office of State Planning and Energy. Assistance was further provided by Owen-Ayres and Associates.

This report is being reproduced quickly and in a limited quantity for dissemination to local governments and interested parties. The report will be broadly available when reproduced in the fall of 1977 as an information circular from the Wisconsin Geological and Natural History Survey.

Financial assistance for this study has been provided by the Coastal Zone Management Act of 1972 administered by the federal Office of Coastal Zone Management, National Oceanic and Atmospheric Administration.

10702

W.P.

SHORE EROSION STUDY  
TECHNICAL REPORT

Appendix 6

Southern and Central  
Manitowoc County  
Wisconsin

**COASTAL ZONE  
INFORMATION CENTER**

D. Hadley, C. Fricke  
(Geology)

T. Edil, B. Haas  
(Geotechnical Study)

**US Department of Commerce  
NOAA Coastal Services Center Library  
2234 South Hobson Avenue  
Charleston, SC 29405-2413**

Wisconsin Coastal Zone Management Program  
GB 454.5, M 5 S 5  
Appendix 6

## INTRODUCTION

This Appendix provides detailed information on shoreline conditions within much of the county. The order of materials in the Appendix is from south to north. Parts of the shoreline are broken down by reach (see County Map) and geographic section within each reach. There is a text which describes the characteristics of shoreline conditions at the beginning of each reach section. This is accompanied by a map of the whole reach which shows the sections, public perception of erosion hazards, shore damage in 1952, short- and long-term recession rates, bluff height, shore protection structures, houses per mile, and boat ramps.

Location of geotechnical borings is indicated on the county map at the beginning of the Appendix. Logs for geotechnical holes and detailed location maps are given at the end of all of the maps in the reach containing that geotechnical site. For each geographic section (one mile long) a map showing the location of shore protection structures which are numbered and described in reports on file with the Department of Natural Resources. Also on the map, locations of measured profiles are shown along the shoreline. A running description of bluff characteristics, materials making up the toe of the slope, and beach characteristics is also given. Engineering data such as safety factor, the confidence level on this safety factor, and the distance the slope must retreat to attain a stable slope angle is also given. It should be noted that this distance assumes no wave cutting at the base of the bluff. This distance is referred to in the text as a stable slope distance. Also included with each section is a set of profiles from the water's edge to the bluff top. These profiles show stratigraphy, slope angles, circles of failure, and calculated safety factors along the shoreline. The dis-

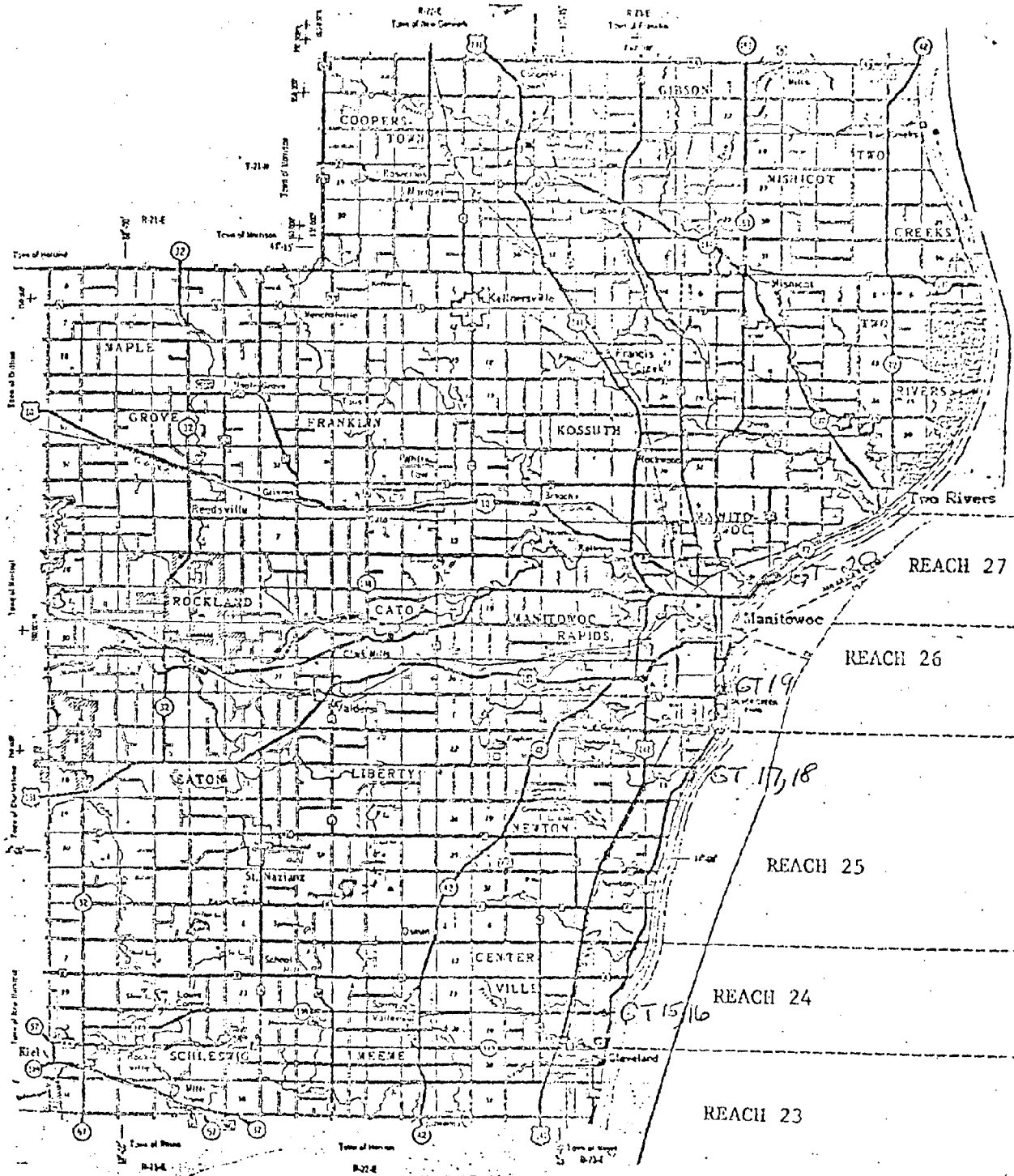
tance to a 5 foot depth of water is also given. The date when the profile was measured is also given. Remember that the bluff profile could have changed since the profiles were measured.

The meaning of abbreviations used in the Appendix is given on this page. For more detailed description of the methods used in compiling the data, regional interpretations, and conclusions about the engineering characteristics and types of slope failure taking place refer to the main report (Shoreline Erosion and Bluff Stability Along Lake Michigan and Lake Superior Shorelines of Wisconsin) available from the State Planning Office and the Wisconsin Geological Natural History Survey.

#### Symbols Used

(used as nouns and adjectives)

b	boulders
c	clay or clayey
co	coarse
f	fine
g	gravel
m	medium
p	pebbles
s	sand
si	silt
t	till
y	cobbles
t(1A)	till name
SF	Factor of Safety
	A - unsatisfactory ( 1.00)
	B - questionable (1.00-1.25)
	C - satisfactory ( 1.25)
CL	Confidence Level
	A - high confidence - at borehole
	B - medium confidence - near borehole, stratigraphy visible
	C - low confidence - away from borehole, stratigraphy questionable
SL	Stability line - the distance slope must retreat to attain a stable slope angle. This assumes no erosion at toe and unchanged conditions of nature of material and water table.



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## FIELD REPORT - REACH 23

Location and General Description

Reach 23 lies in Sheboygan and Manitowoc Counties, and includes the shoreline in Sections 3, 10, and 15 in T.16N., and Section 34 in T.17N., R.23E. Of these, only Section 34 lies in Manitowoc County. Readers interested in the southern sections in the reach are referred to the report on Sheboygan County.

(Appendix 5)

Section 34, T.17N.

From the Manitowoc-Sheboygan County line, which is the southern boundary of this section, to 0.07 the stratigraphy of the bluffs was completely obscured by large scale sequential slumping. From 0.07 to 0.39 the mode of slope failure changed to relatively minor high angle slumping and some flows. In this area there was relatively good exposure of the upper beds in the sequence. Profile #1, which is located at 0.3, was taken within this zone. The exposed units at the top of the bluff consisted of about 10 feet of lacustrine sand, silts, and clays containing a lens of till 3C about 2 feet thick. This bed was traced laterally and was found to be one of a number of thin, discontinuous lenses of till which were contained in the upper lacustrine sequence. At the base of this sequence, about 3 feet of a massive gray silt was exposed. The base of this unit was obscured by minor slumping which covered the lower 40 feet of the bluff. The contact between this massive silt and the overlying mixed lacustrine sediments was a major seepage zone. This seepage greatly facilitated tracing the contact, even in those areas where it was covered by a coating of materials washed down from above. Till 3A was exposed at beach level at the base of Profile #1 and was present in discontinuous exposures along the beach throughout the section. At 0.39 the mode of slope failure once again changed and large scale sequential slumping again was dominant. As was the case near the county line, exposures were

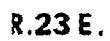
found only along the scarps at the bluff top and in discontinuous exposures along the beach level.

At the county line, the bluffs were about 60 feet high. The level of the bluffs drops steadily to the north, and at the northern section line they are only about 45 feet high. This lowering of the bluff height seems to be largely at the expense of the thickness of the lacustrine sand, silts, and clays that overlie the gray silt. The upper lacustrine unit was found to thin to about 2 feet at the northern section line.

Beaches along the section were of mixed sand and cobbles and ranged from 20 to 35 feet in width.

Housing density within the section was listed as 3 houses per mile. There was one long term recession measurement made at about the northern section line which showed a long term average of 1 foot/year. There were no protective structures described in the section. Water depth at Profile 1 was found to be 2.5 feet at a distance of 50 feet from the shoreline.





A-less than 1.00  
B-1.00 to 1.25  
C-greater than 1.25

A-boreholes  
(high confidence)  
B-near boreholes  
stratigraphy visible  
C-no stratigraphy  
visible (low  
confidence)

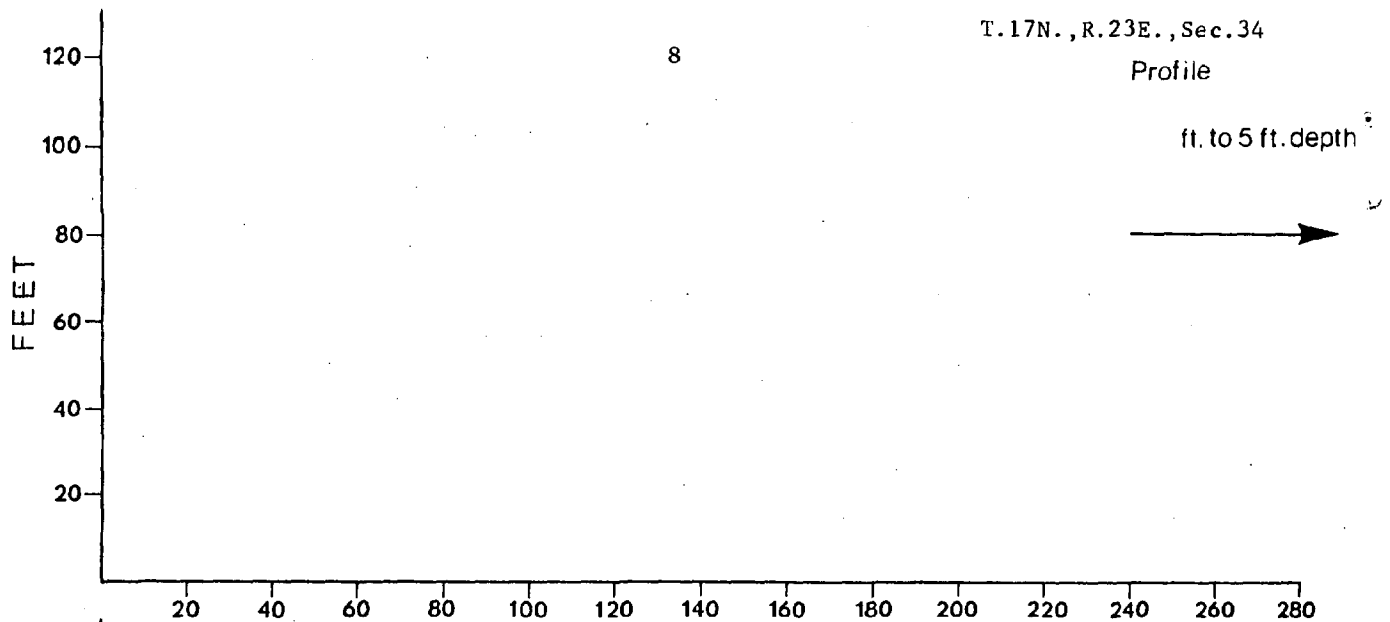
1. BLUFF	a-large scale sequential slumping	b-minor high angle slumping, some flows	c-large scale sequential slumping
2. TOE	a-slumped till '3C' and lacustrines, some exposures of till '3A'		
3. BEACH	a-20-35 ft. sand and cobbles		

T. 17N., R. 23E., Sec. 34

8

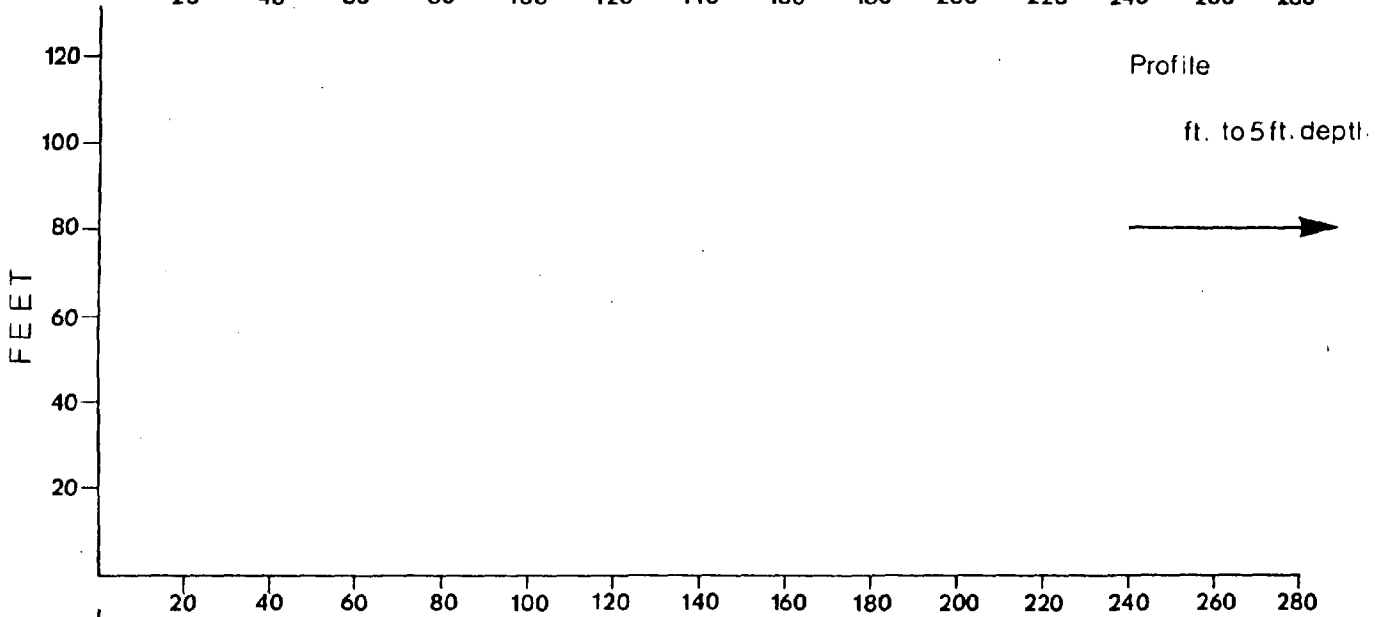
Profile

ft. to 5 ft. depth



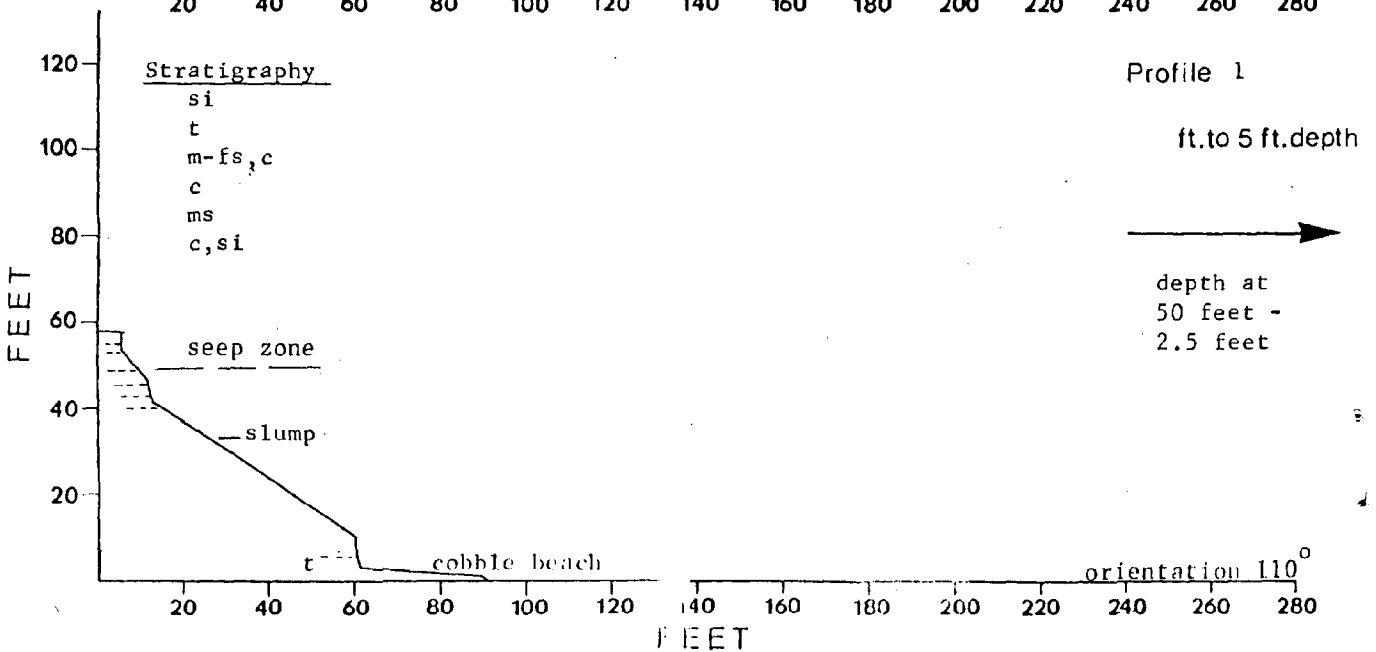
Profile

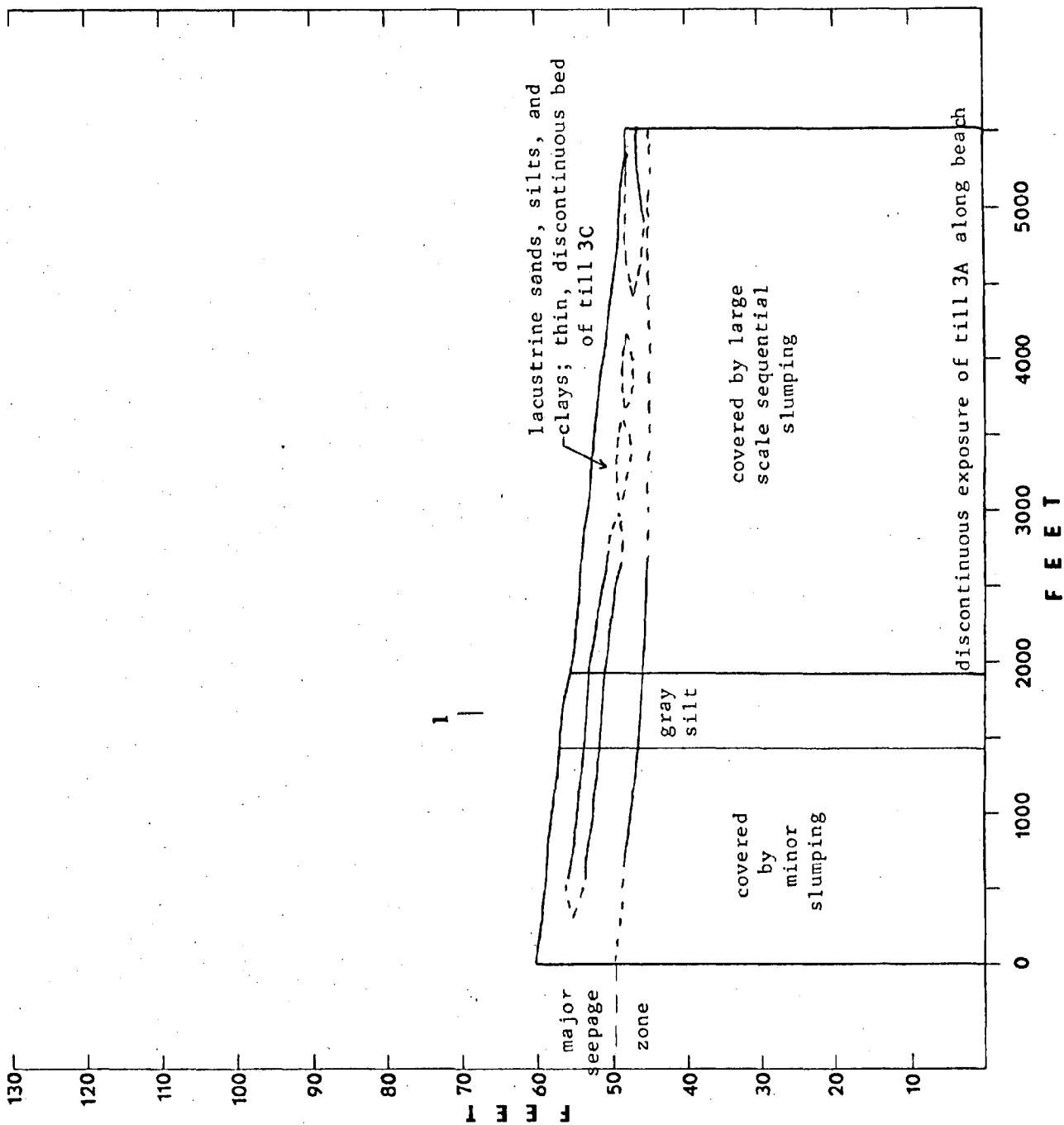
ft. to 5 ft. depth



Profile 1

ft. to 5 ft. depth





## FIELD REPORT - REACH 24

Location and General Description

Reach 24 includes the shoreline of Sections 27, 22, 14, and 11 of T.17N., R.23E. The reach has a priority rating of 17 and is the third highest ranked of those reaches lying north of the Ozaukee-Sheboygan County line.

The reach includes an area of substantial residential development at its southern end associated with the town of Cleveland, and large portions of the remainder will probably see considerable residential development in the future.

The shoreline in the extreme southern portion of the reach consists of the remnants of an ancient terrace.

No short term recession rate data were available for this reach. Long term averages range from 0.3 foot/year in the southern portions of the reach to 2 feet per year in the north.

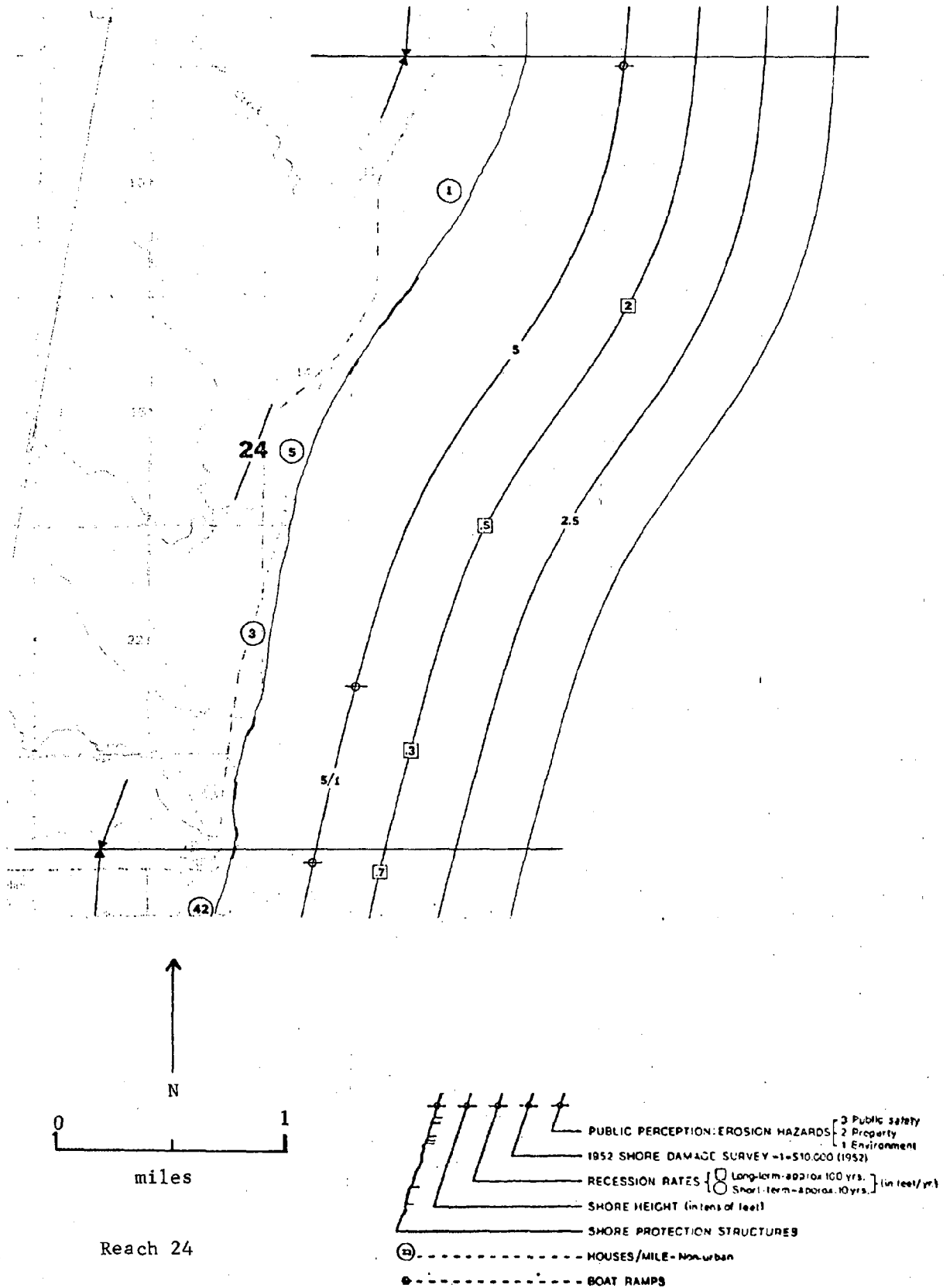
The boundary between Reach 23 and Reach 24 lies about halfway up the shoreline of section 27. For the sake of convenience, that portion of the section that lies within Reach 23 will be included in the text for Reach 24.

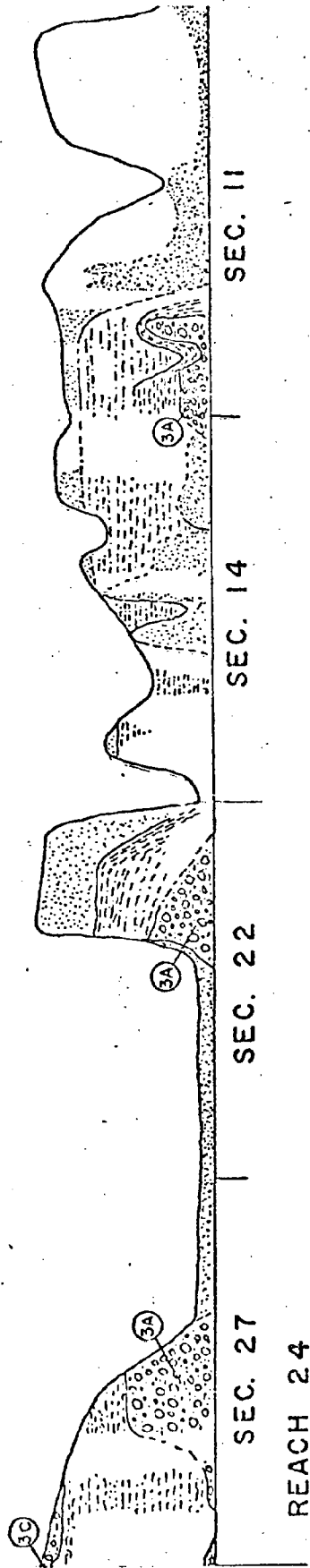
Section 27

At the southern boundary of Section 27 the bluffs are about 50 feet high. Moving north from this point the bluff height decreases rapidly and at about the mid-point of the section the bluff gives way to a terrace lying about four feet above the modern beaches.

From the southern section line to 0.15, the stratigraphy of the bluff is almost completely obscured by large scale sequential slumping. Exposures are limited to the scarp zone at the top of the bluff and in this area a four foot thick bed of till 3C is exposed overlying lacustrine silts. At scattered locations along the beach wave action has cut through the slumped material and exposed till 3A along the beach.

Between 0.15 and 0.23 the mode of slope failure changes and soil fall and





1000 ft.

Vertical Exaggeration = 50 X

## LEGEND

	SAND		SILT		COVERED OR INACCESSIBLE
	GRAVEL		CLAY		TILL
	SAND AND GRAVEL		CLAYEY SILT, SILTY CLAY		MIXED SEDIMENTS

high angle slumping become the principle mechanisms. Rapid erosion in this area provides numerous good exposures in which the stratigraphy of the bluff can be observed. In this area it was found that a thin surficial bed of till 3C was underlain by interbedded lacustrine sands, silts, and clays almost to the level of the beaches where 1 or 2 feet of till 3A were exposed.

From point 0.23 to 0.36 large scale slumping once more occurs and the entire face of the bluff is covered.

From 0.36 to 0.5 steep rapidly eroding bluffs once again occur with undercutting and soil fall being the primary mode of slope failure. Exposures are good in this segment of the shoreline and the stratigraphy of the bluff was found to be an upper lacustrine unit of interbedded sands, silts and clays resting on 25 feet of till 3A.

From 0.5 north to the terrace, which begins at about 0.64, slopes are for the most part gentle and fully vegetated and exposures were limited to low cut faces along the beaches. These cuts expose a sand that is probably simply a veneer along the base of the bluffs and represents a remnant of the same terrace that is found immediately to the north.

Beaches between the southern section line and the beginning of the terrace are primarily of cobbles and range from 10 to 40 feet in width. Along the terrace the beaches are normally between 10 and 30 feet in width and combination sand and cobble beaches are the rule.

Four structures were described in this section. All were either low bulkheads or revetments protecting homes built along the terrace in the northern half of the section. A water depth measurement taken near the beginning of the terrace showed a depth 50 feet offshore to be less than 1 foot.

Land use in the southern half of the section is primarily agricultural. From 0.4 north however, the shoreline is highly developed as this area contains the village of Hika Bay. A housing density of 42 houses per mile was given for this



section. One long term recession rate determination was made at Hika Bay and gave a result of 0.7 foot/year.

#### Section 22

At the south section line of Section 22 the true bluff lies some 800 feet back from the lakeshore and is separated from the shoreline by a terrace. This terrace, which was first encountered about one-half mile south of the section line, is made up of beach and dune sand and is about 4 feet higher than the current beach level along the shoreline. The bluffs swing back to the shoreline at about 0.59. At this point the bluffs are about 50 feet high and are fully vegetated above a very steep face that has been cut into till 3A at beach level. This face varies between 2 and 15 feet in height. The erosion surface on the top of till 3A is well exposed. From 2 to 5 feet of very coarse sand are exposed above the contact with the basal till and the till-sand contact rises steadily to the north up to 0.67. From this point north to the northern section line the bluffs display closely spaced areas of slumping. Most of these slumps involve only the lower two-thirds of the slope, leaving the upper third vegetated. Scattered full face slumps also occur in this area.

There are enough exposures along the bluff face to allow the stratigraphy of this section to be determined. The bluff consists of about 16 feet of sand overlying a similar thickness of silts and clayey silts which in turn rest upon the surface of till 3A. The stratigraphy as worked out in the bluffs was confirmed in boring GT-15 which was drilled close to the edge of the bluff at about 0.9.

North of 0.9 the bluffs plunge steeply into the valley of Fisher Creek. Exposures along the bluff indicate that the bedding in the silts that overlie the basal till also dip steeply into the valley.

Beaches along this section show considerable variation, with both cobble and sand beaches present. Beach widths also show a great deal of variation,

with beach widths of up to 50 feet in some segments of the shore and essentially no beach in adjacent sections.

Water depths were obtained at the site of two profiles. At Profile #1 which was taken at about 0.67, the lake was found to be 5 feet deep 97 feet from the shoreline.

There were four structures described in this section. Three of these were revetments protecting private residences along the terrace in the southern portion of the section. The fourth was a 1600 foot long stone revetment built along the northern section of the high bluff area. In a number of places this revetment was found to consist of a single course of dolomite blocks and ranged in height from one to three feet. In many areas considerable active erosion was going on behind the revetment which had undoubtedly been over topped by storm waves.

This section is currently at a low level of development, having a housing density of only 3 houses per mile. Much of the land in the section is, however, owned by a private development corporation and considerable construction in this region should probably be expected in the future.

One recession rate determination was available for this section. This gave a long term average of 0.3 foot per year at a point near the southern section line.

#### Section 14 (C.F.)

Marking the start of the southernmost portion of Section 14 is a low lying floodplain (terrace?) formed at the mouth of Fisher Creek. Yellow silty sand is exposed in a number of places along the 4 foot high bluff.

North of Fisher Creek the bluffs are considerably higher, ranging from 18 to 45 feet in height. The bluff reaches the maximum height at 0.8 and then descends to a height of 40 feet at the north section line.

Sand less than 10 feet thick overlies silt and clay in the bluff in the southern four-tenths of the section. The silt and clay exhibits massive to rhythmic bedding and contains smaller seams of fine sand or silt. The wet, less permeable silt and clay is conducive to unstable slope conditions and failure.

Interbedded red clays and yellow silts occupy the upper portion of the bluff profile immediately north of mile 0.5. Clays form an intermediate position while sand is exposed near the toe of the slope. A wedge of red clay (till?) lies at the top of the bluff but tapers out near mile 0.6 as one proceeds north.

North of mile 0.6, a thin, discontinuous layer of surficial sand overlies highly contorted interbedded red clays and gray silts. These materials in turn overlie massive and laminated clays. Near the base of the bluff, sand emerges from below lake level to a height of ten feet just south of mile 0.8.

North of mile 0.7, a thin finger of brown, pebbly, clayey silt till emerges from below lake level, replacing the sand at the toe. The till continues for only a short (23 feet) distance before pinching out to the north. Where the stratigraphy is exposed, sand lies below the till while laminated lacustrine clays are draped over the top of the till. Seeps occur within the silt and clay.

Proceeding toward the lake from the bluff near Fisher Creek, the beach consists of 36 feet of sand, 12 feet of gravel, and 15 feet of sand and gravel. In front of the revetment along the lower four-tenths of the section, beaches approximately 20 feet wide and composed of sand with small amounts of gravel sized material abut the toe of the bluff.

The beach reaches a width of 43 feet near mile 0.4. North of this point to the top of the section, the beach tapers down to a width of between 20 to 25 feet and is composed of greater than 80% sand. Gravel and cobbles form the remaining portion.

A stone revetment ranging from 5 to 10 feet in height protects a road ramp leading down from the bluff to the north side of Fisher Creek. There is no beach in front of this structure. This quarry stone revetment continues as a low-lying (2-3 feet high) structure, recessed a shore distance back from the shoreline, north of this point through the half mile mark.

A second structure, largely composed of stone with smaller amounts of steel

and timber, protects the bluff in front of the houses just south of mile 0.6.

No beach is present in front of the structure.

Seeps occur at the base of the surficial sand where the sand is in contact with the less permeable silts and clay below. The sand maintains a steep face because of a vegetative cover. Slumping and soil fall occurs in the silts and clays. The northern two-tenths of the section is vegetated and no recent failures have occurred.

#### Section 11 (C.F.)

Section 11 of Reach 24 covers the area between 2 and 3 miles south of the town of Northeim. The bluffs in this region are relatively high, ranging from approximately 45-55 feet above lake level. Sags in the bluff occur at mile 0.6 and again at the northernmost end of the section where Point Creek cuts down through the bluff. The stratigraphy in the southern three-tenths of the mile section consists of a complex sequence of sand, silt, clay and till. North of this area, the bluff appears to be composed entirely of sand. Vegetative cover obscures portions of the stratigraphy.

In the southern portion, sand occurs at the top of the bluff. It is divisible into two sub-units. The uppermost portion consists of soft, yellow sands while the lower part contains compacted, medium grained sand, contorted and interbedded with red clays. Silts and clays lie below the sand and are often interbedded with seams of fine sand. In places, this material is also highly contorted.

At the base of the bluff between mile 0.2 and 0.3, a red-brown silty clay till is exposed. The upper surface of this till dips below lake level in several places. Slump covers a large portion of the lower half of the bluff in the area. Pebbles in the slumped material suggest that the till may be present beneath the surficial slump in the southern portion.

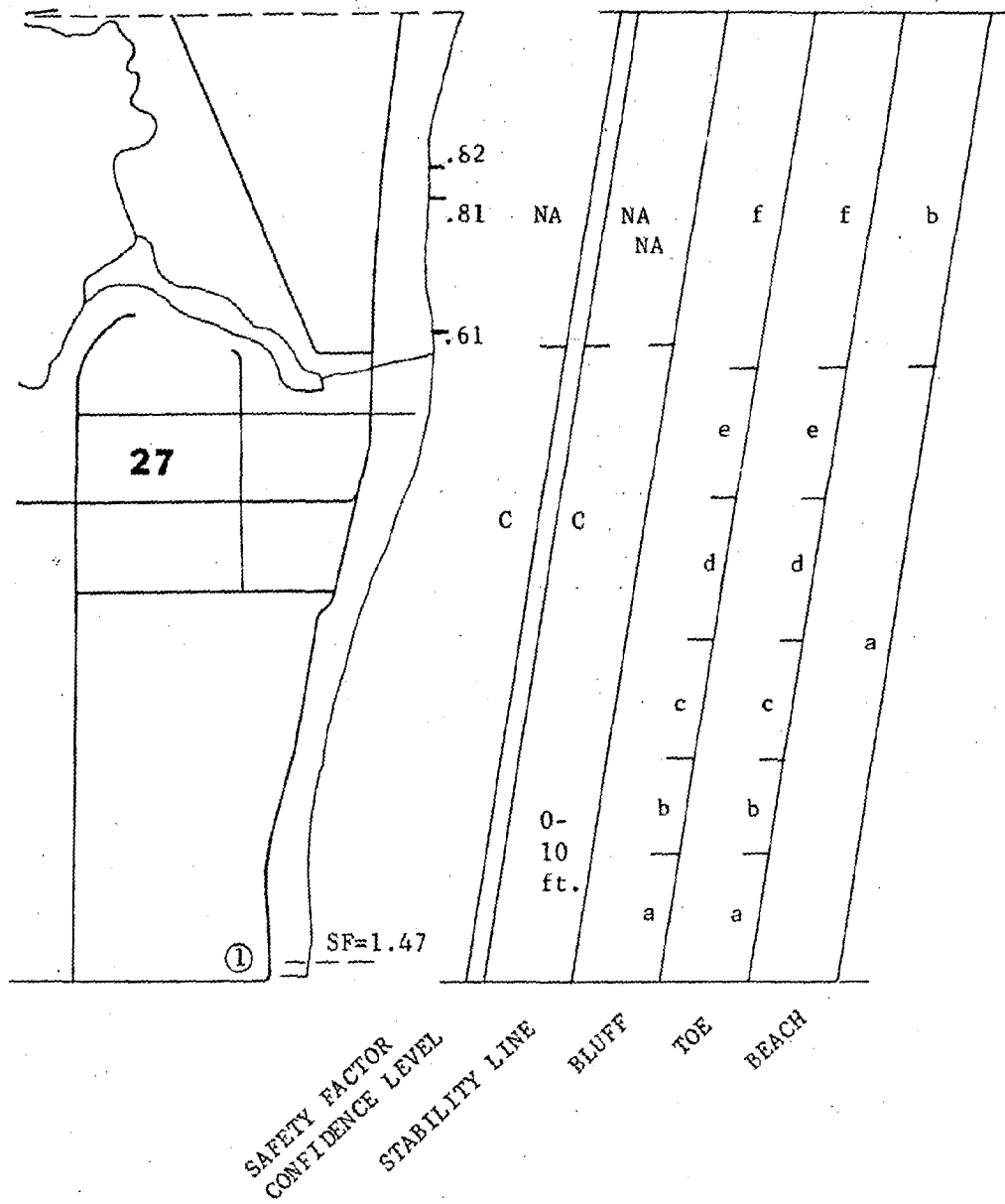
There are no extensive exposures of materials immediately north of mile 0.4,

but bluffs to the south of this point and those to the north of this vegetated section suggest that the bluff is probably composed chiefly of coarse-grained material. Massive medium-grained sands are exposed between mile 0.3 and 0.4 in this section while coarse-grained sands and gravels are exposed in the southern part of Section 1, the adjacent section to the north.

The only recent slump scars occur in the southern four-tenths of the section. Between 0.3 and 0.4, where the bluff is composed of all medium-grained sand, failure occurs by undercutting the toe of the bluff, removing the vegetation, and causing slumping. In the southern three-tenths of the section, the slopes are failing by soil fall. Some sapping and small size slump blocks are also active.

Most of the beaches in this section are greater than 30 feet in width. In the northern portion, beaches are 50 to 80 feet wide. The beaches consist almost entirely of sand sized material except along the immediate shoreline or in the southern third of the section where gravels predominate.

No structures are present in this section.

SAFETY FACTOR

A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

CONFIDENCE LEVEL

A-boreholes

(high confidence)

B-near boreholes

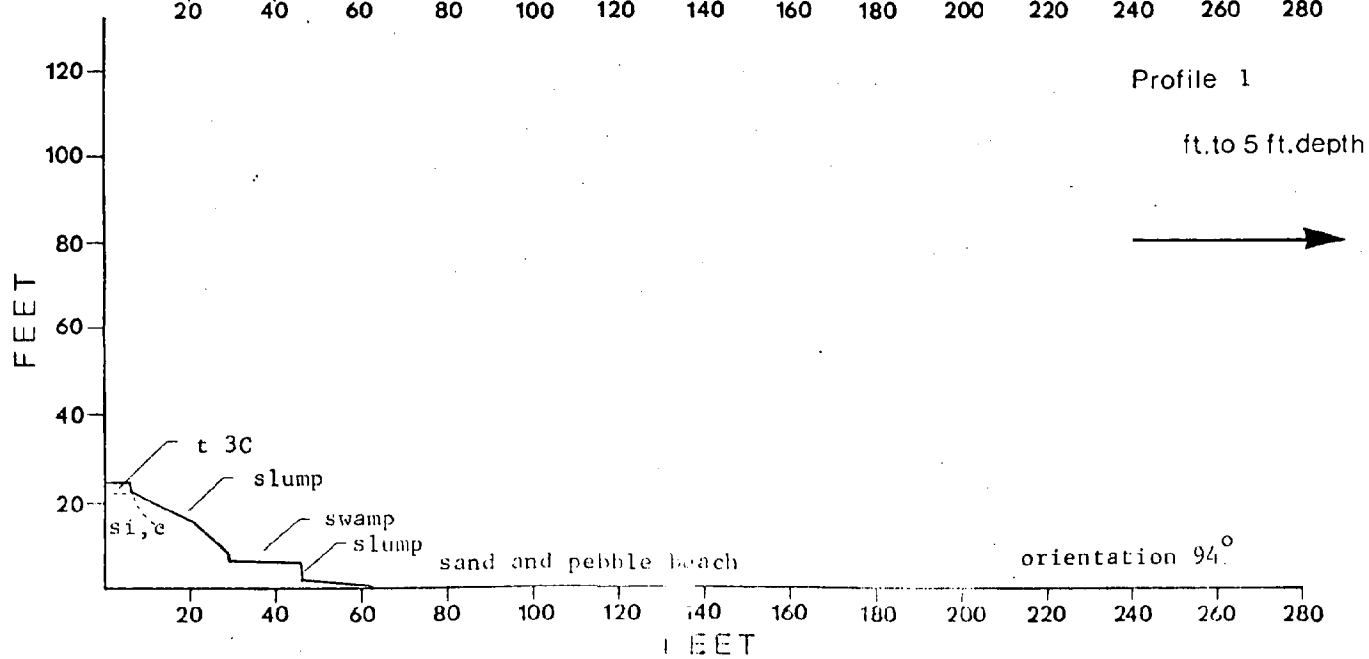
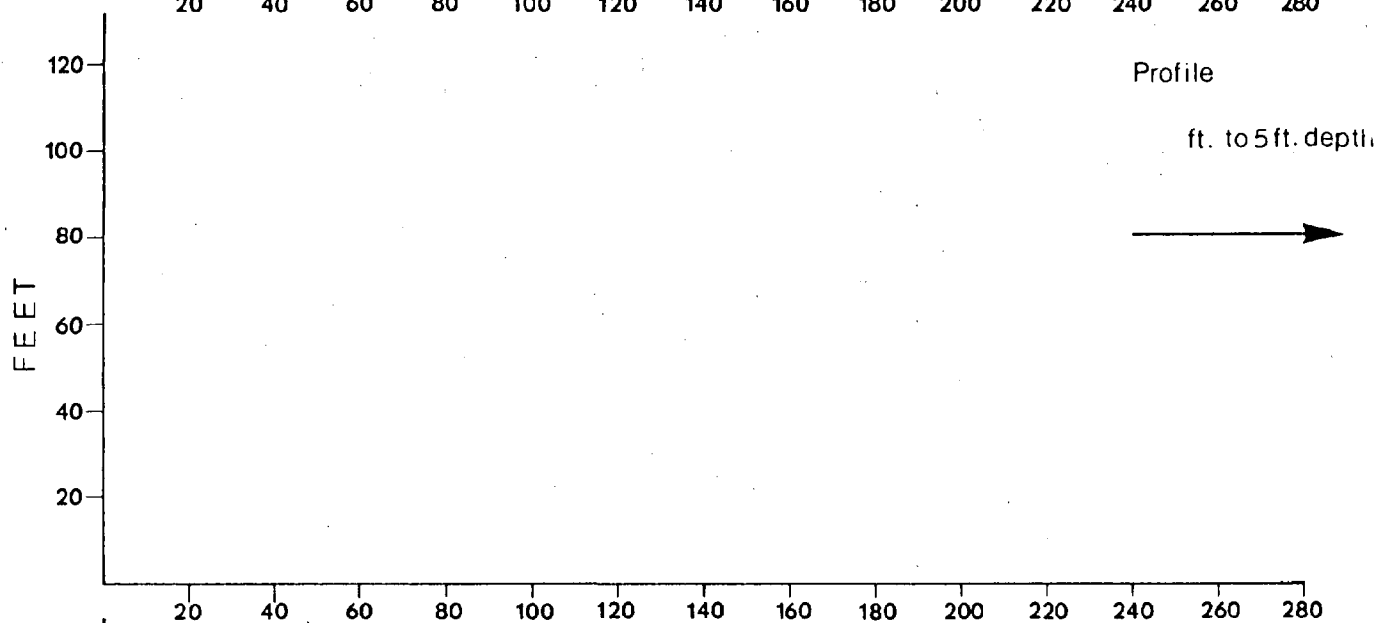
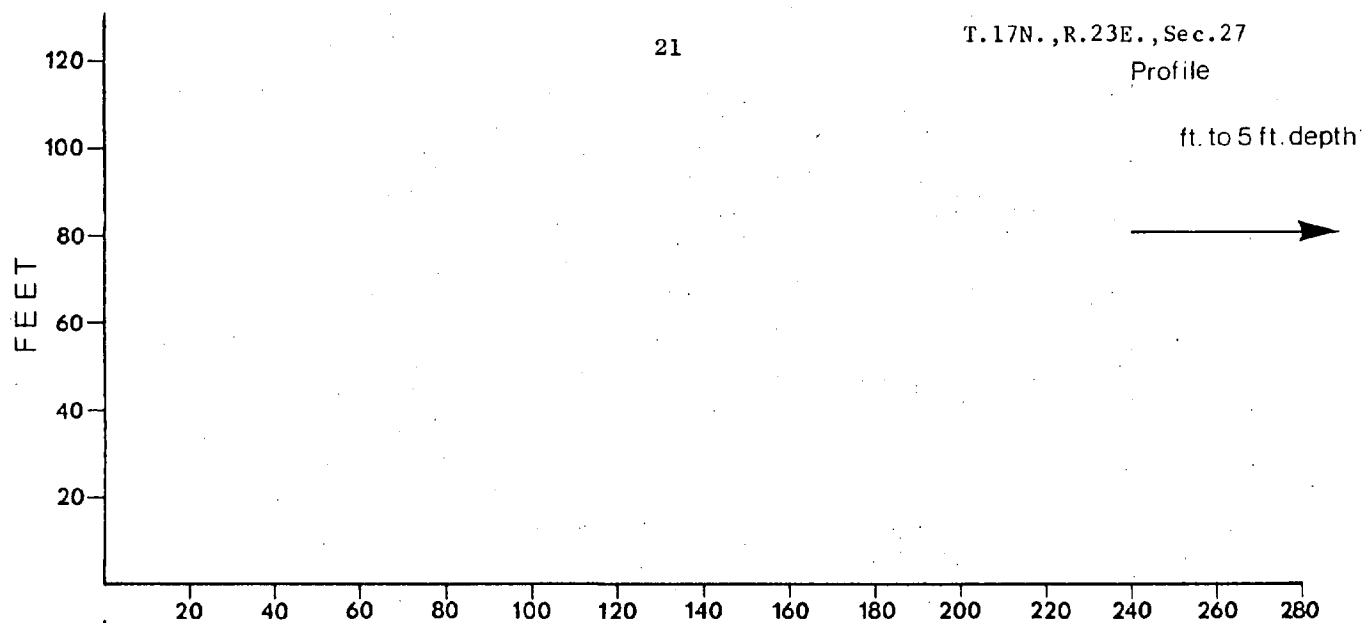
stratigraphy visible

C-no stratigraphy

visible (low

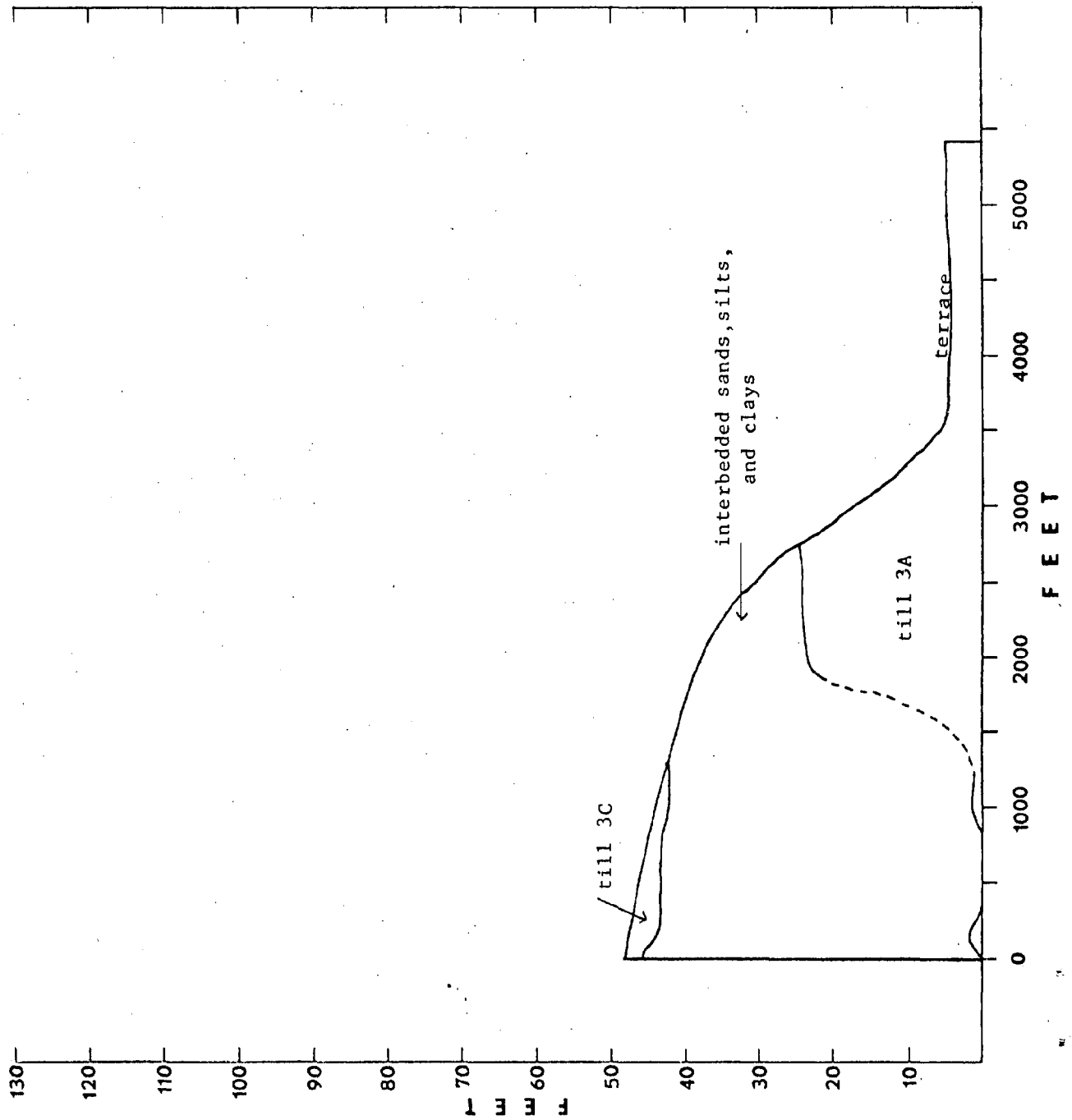
confidence)

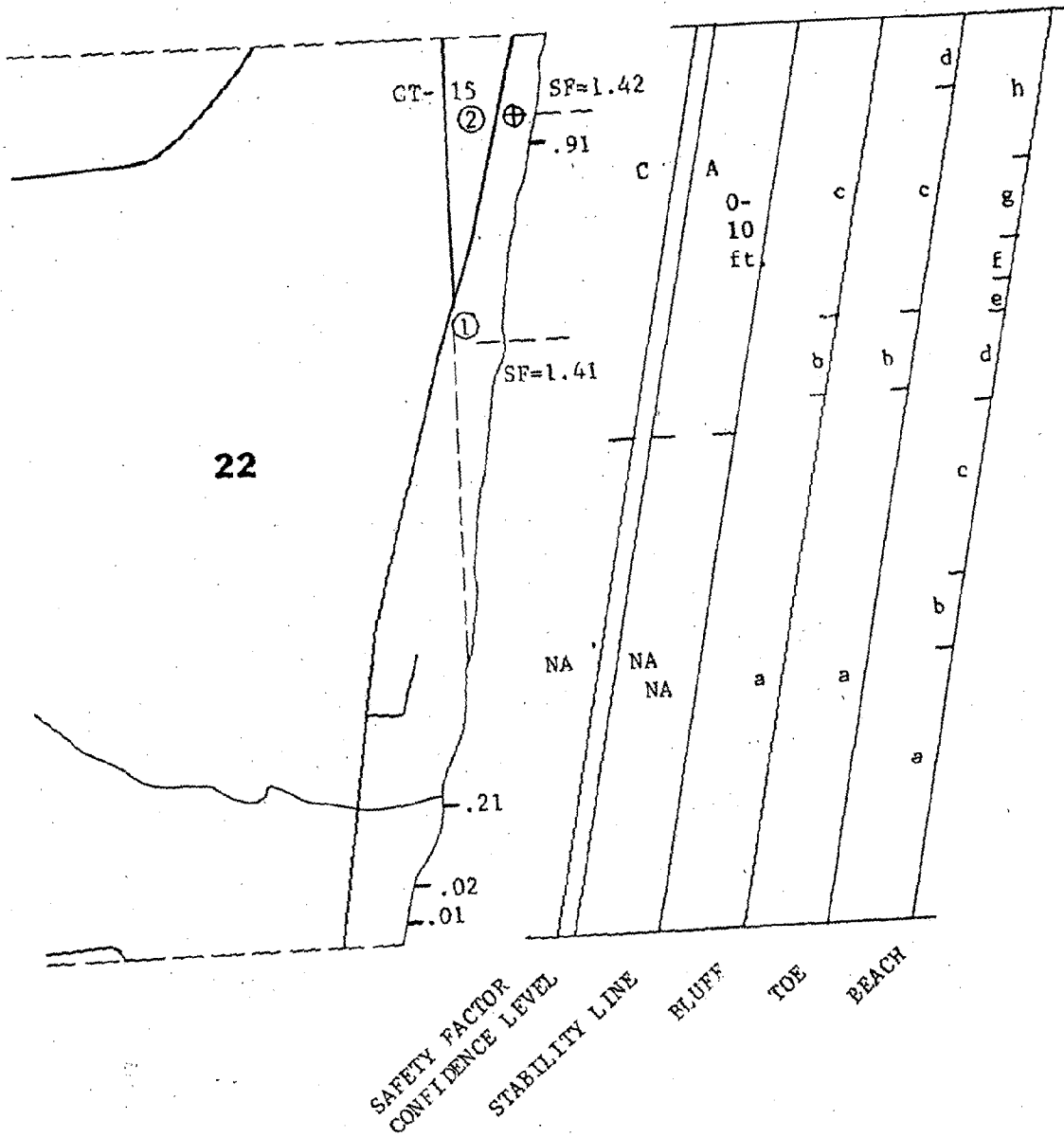
1. BLUFF	a-large scale sequential slumping; some exposures in scarp zone	b-rapid erosion, slope failures primarily by soil fall and high angle slumping	c-slumped and covered, entire bluff face involved	d-steep rapidly eroding bluffs, sapping and soil fall
	e-covered and vegetated; gentle slopes	f-terrace		
2. TOE	a-slumped till, clay, and silt	b-till 3A and slumped silts and clays	c-slumped silts and clays	d-till 3A
	e-sand	f-terrace sands		
3.BEACH	a-10-40 ft. cobbles	b-10-30 ft. sand and cobbles		





T. 17N., R. 23E., Sec. 27



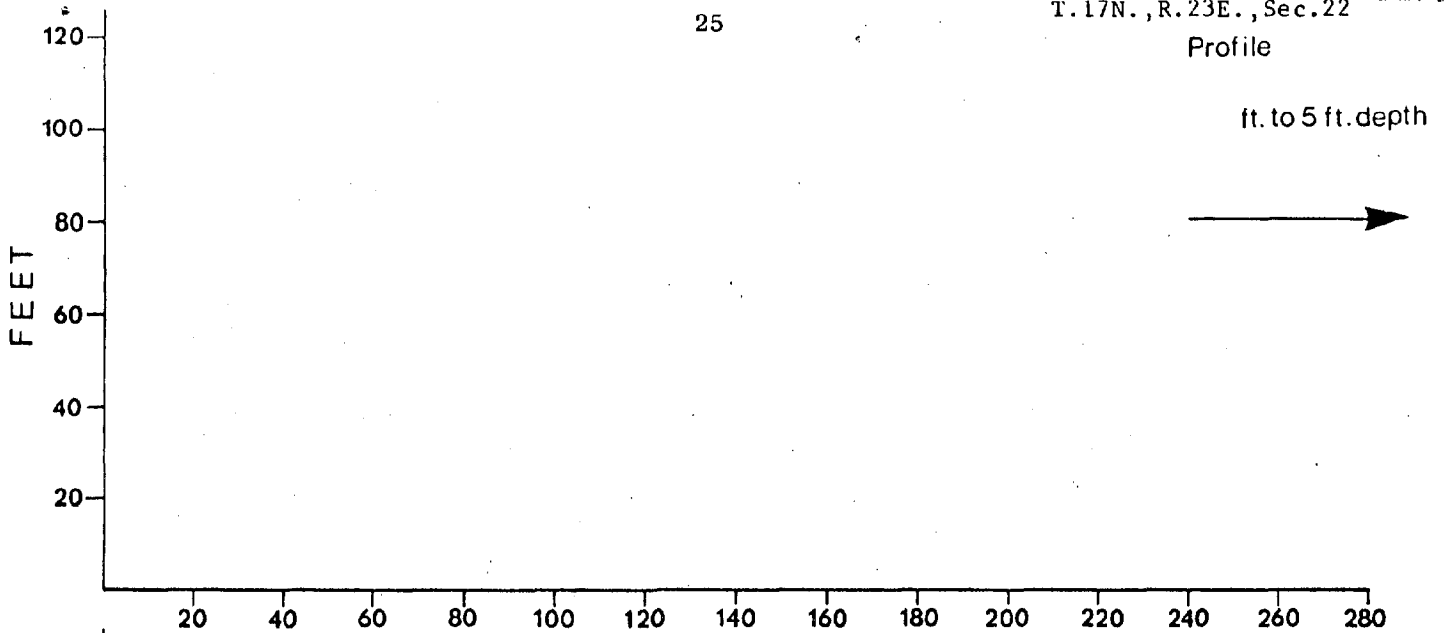


**SAFETY FACTOR**  
 A-less than 1.00  
 B-1.00 to 1.25  
 C-greater than 1.25

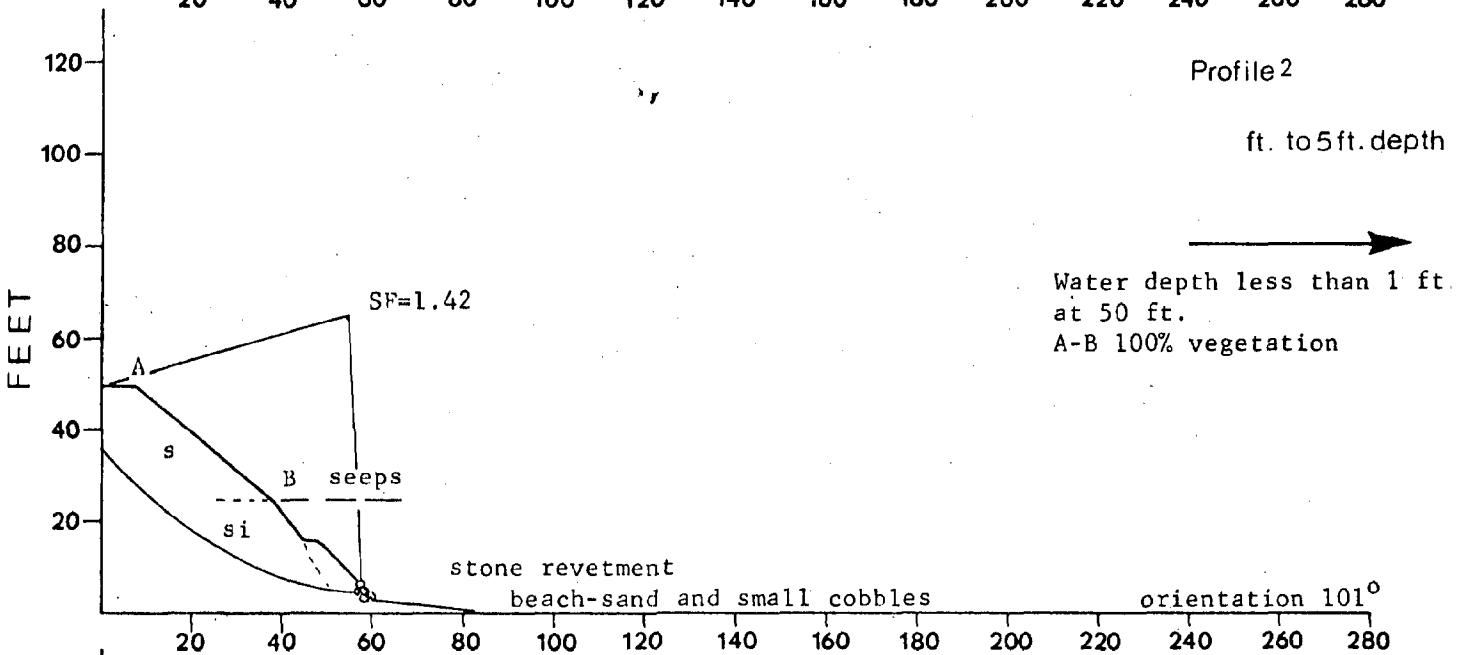
**CONFIDENCE LEVEL**  
 A-boreholes  
 (high confidence)  
 B-near boreholes  
 stratigraphy visible  
 C-no stratigraphy  
 visible (low  
 confidence)

1. BLUFF	a-stable, fully vegetated bluff protected by terrace	b-2-15 ft. near vertical cut face in very stiff till; 2-5 ft. of coarse sand above; slope fully vegetated above cut face	c-closely spaced slumped areas; some full face, but most involving only lower 2/3 of slope; significant subsequent flowage of slumped silts.	
2. TOE	a-sands of terrace	b-stiff red-brown clayey silt till, few stones.	c-primarily slumped and flowed silts; scattered till exposures.	
3. BEACH	a-30-50 ft. beach; largely sand but cobbles in shoreward portion.	b-30-50 ft. cobble beach	c-30-50 ft. m-c sand beach	d-0-15 ft. cobble beach
	e-0-20 ft. c. sand beach	f-0-15 ft. cobble beach in front of revetment	g-0-10 ft. cobble beach behind revetment	h-0-25 ft. sand and cobble beach

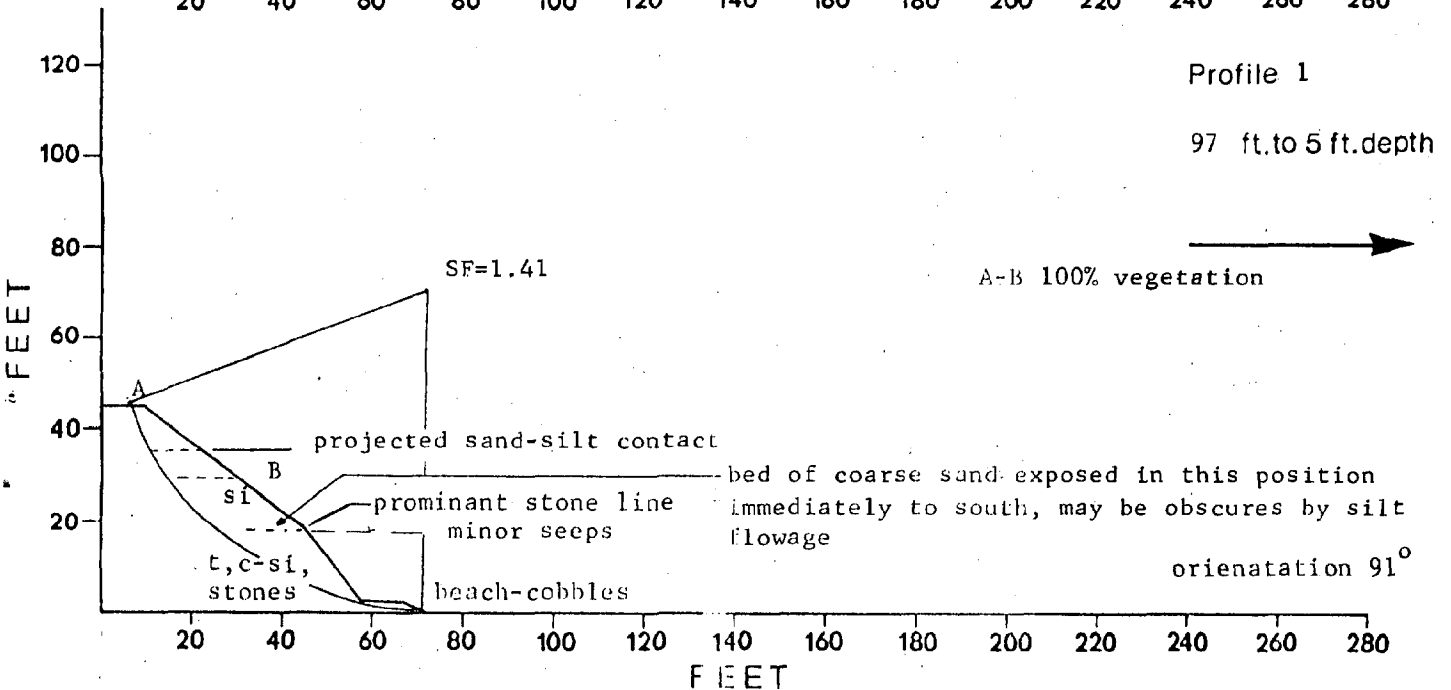
## Profile



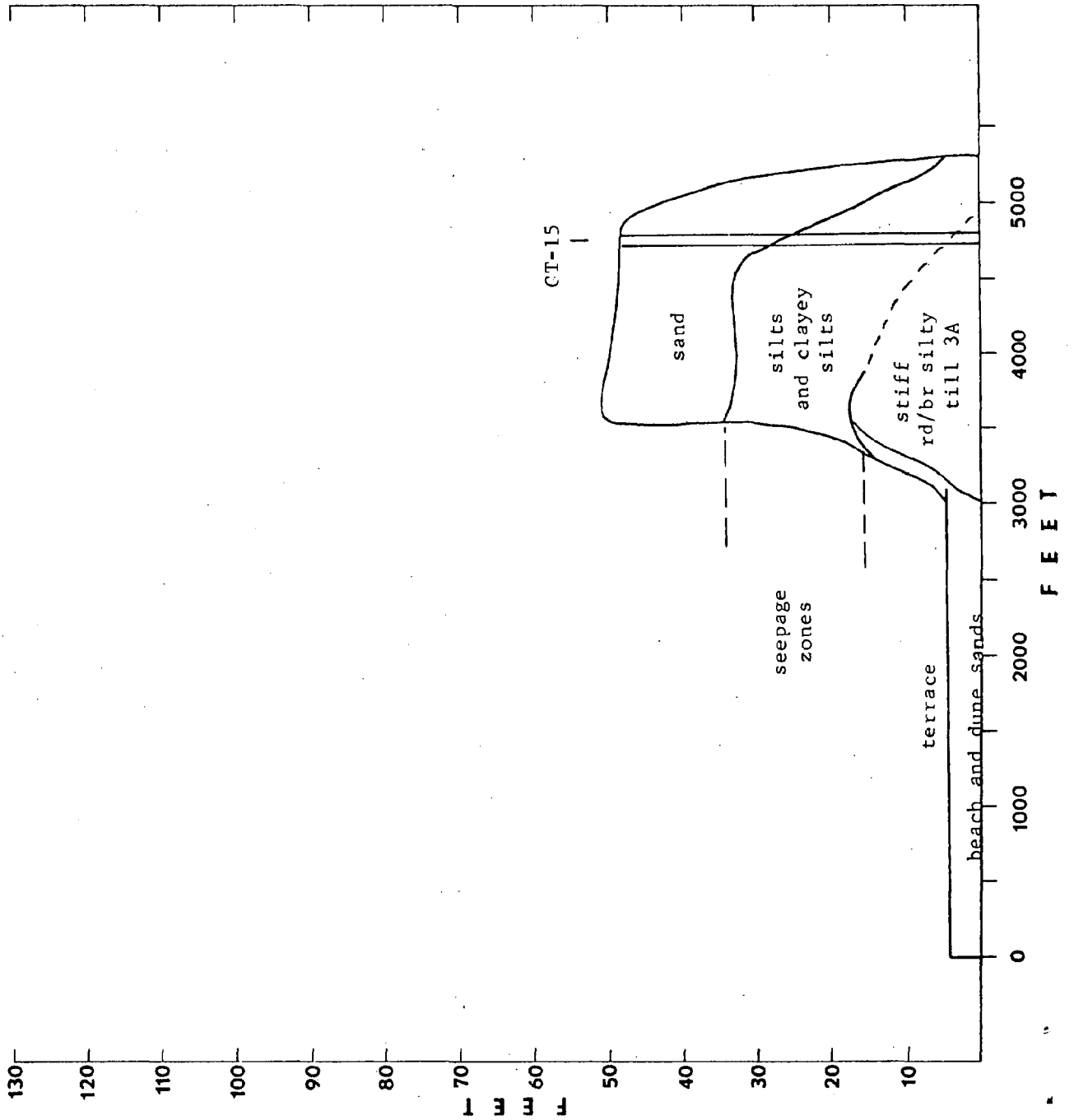
## Profile 2

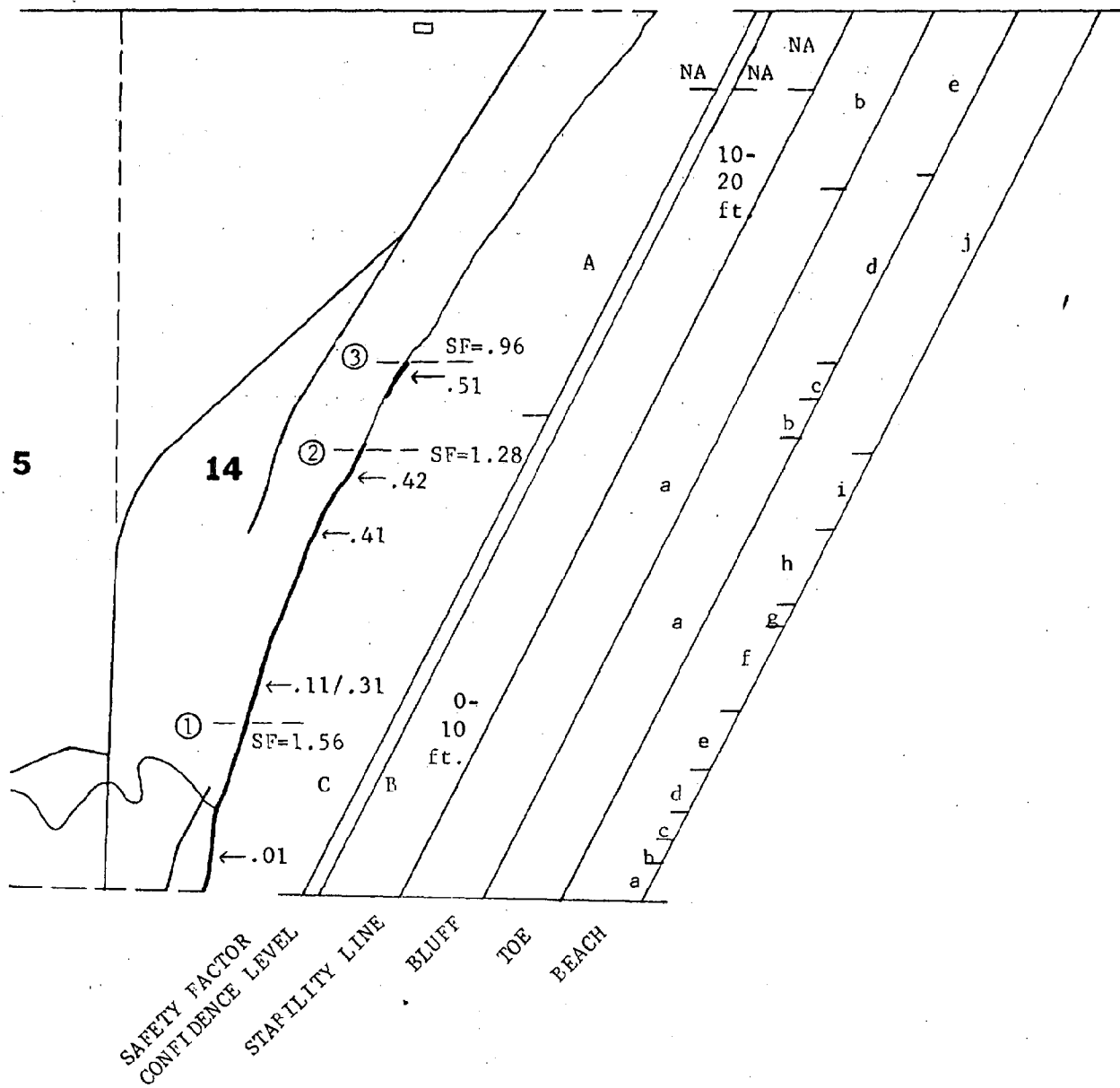


## Profile 1



T.17 N., R.23 E., Sec. 22



SAFETY FACTOR

A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

CONFIDENCE LEVEL

A-boreholes

(high confidence)

B-near boreholes

stratigraphy visible

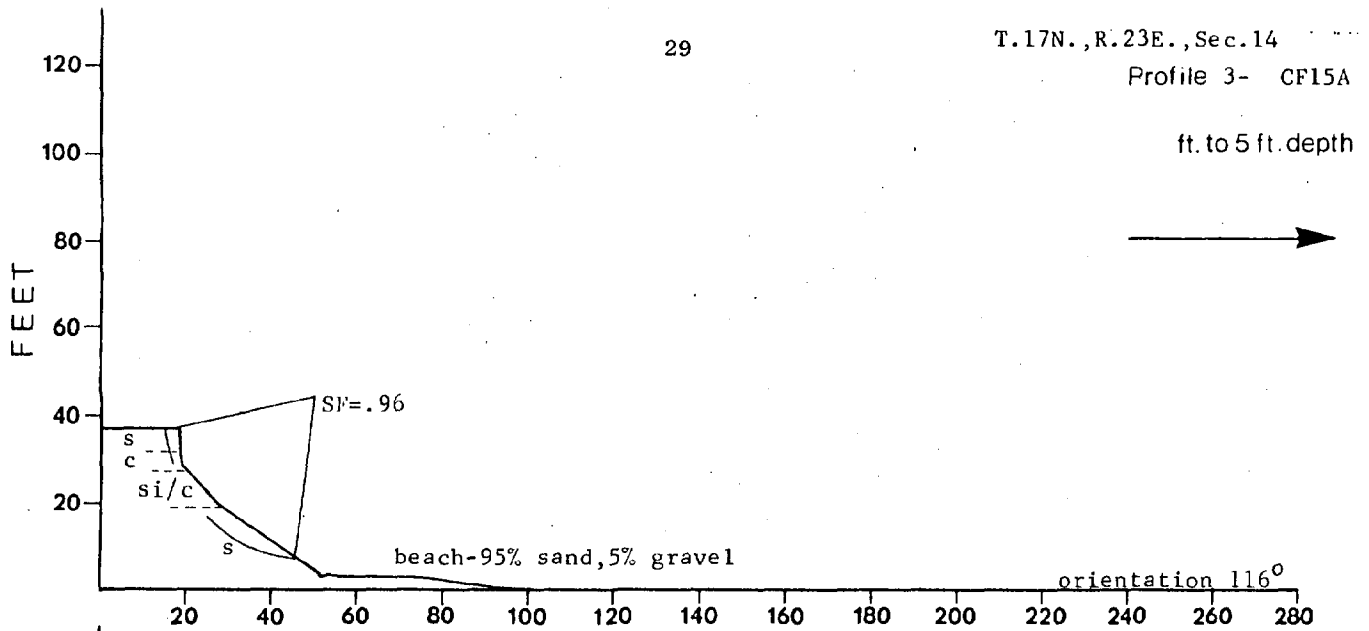
C-no stratigraphy

visible (low

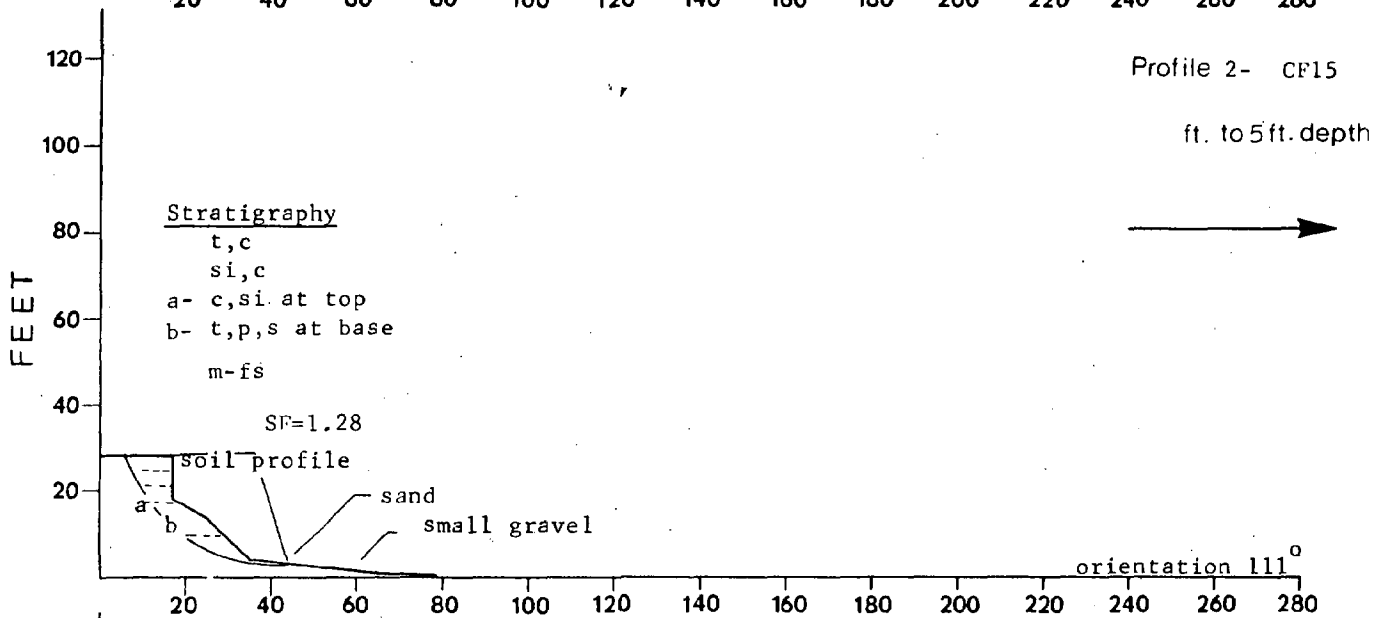
confidence)

1. BLUFF	a-slumping and soil fall	b-vegetated and stable		
2. TOE	a-rip-rap	b-sand	c-rip-rap	d-slumped clay and silt, some sand
	e-sand			
3. BEACH	a-0-65 ft. sand	b-no beach	c-0-40 ft. sand	d-no beach
	e-0-40 ft. sand	f-no beach	g-0-25 ft. sand	h-no beach
	i-0-45 ft. sand	j-0-30 ft. sand		

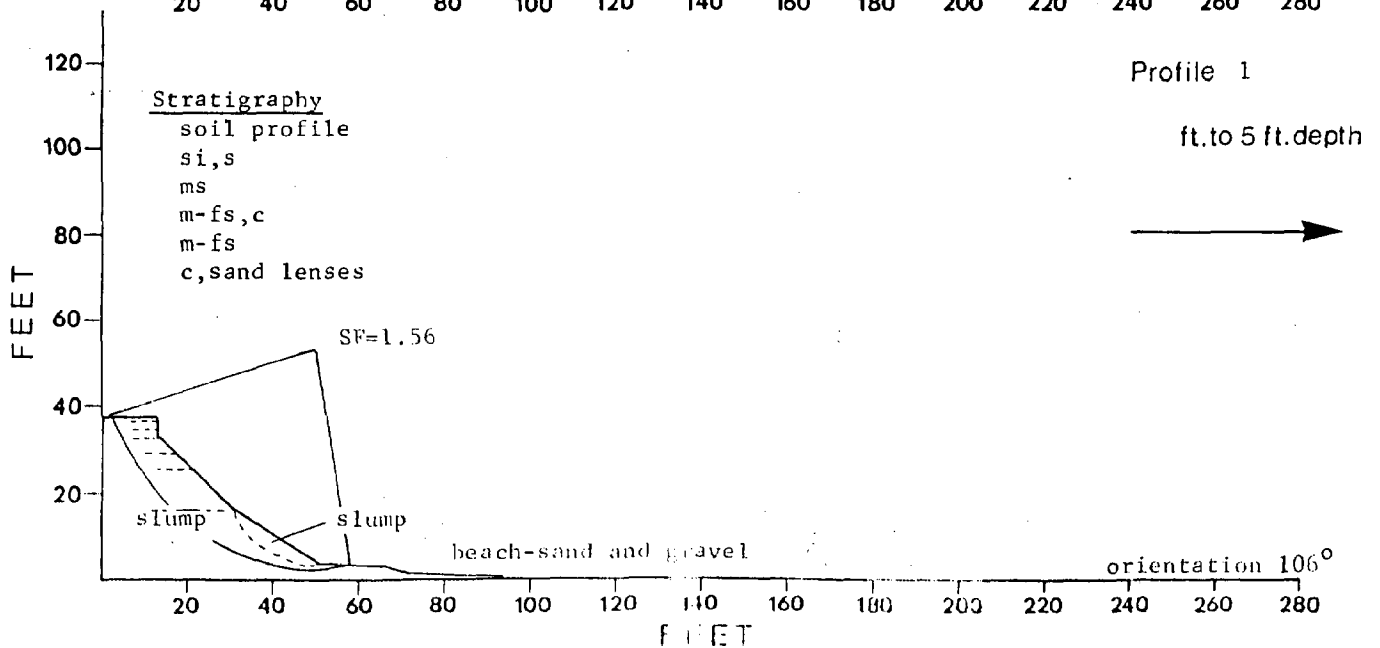
ft. to 5 ft. depth



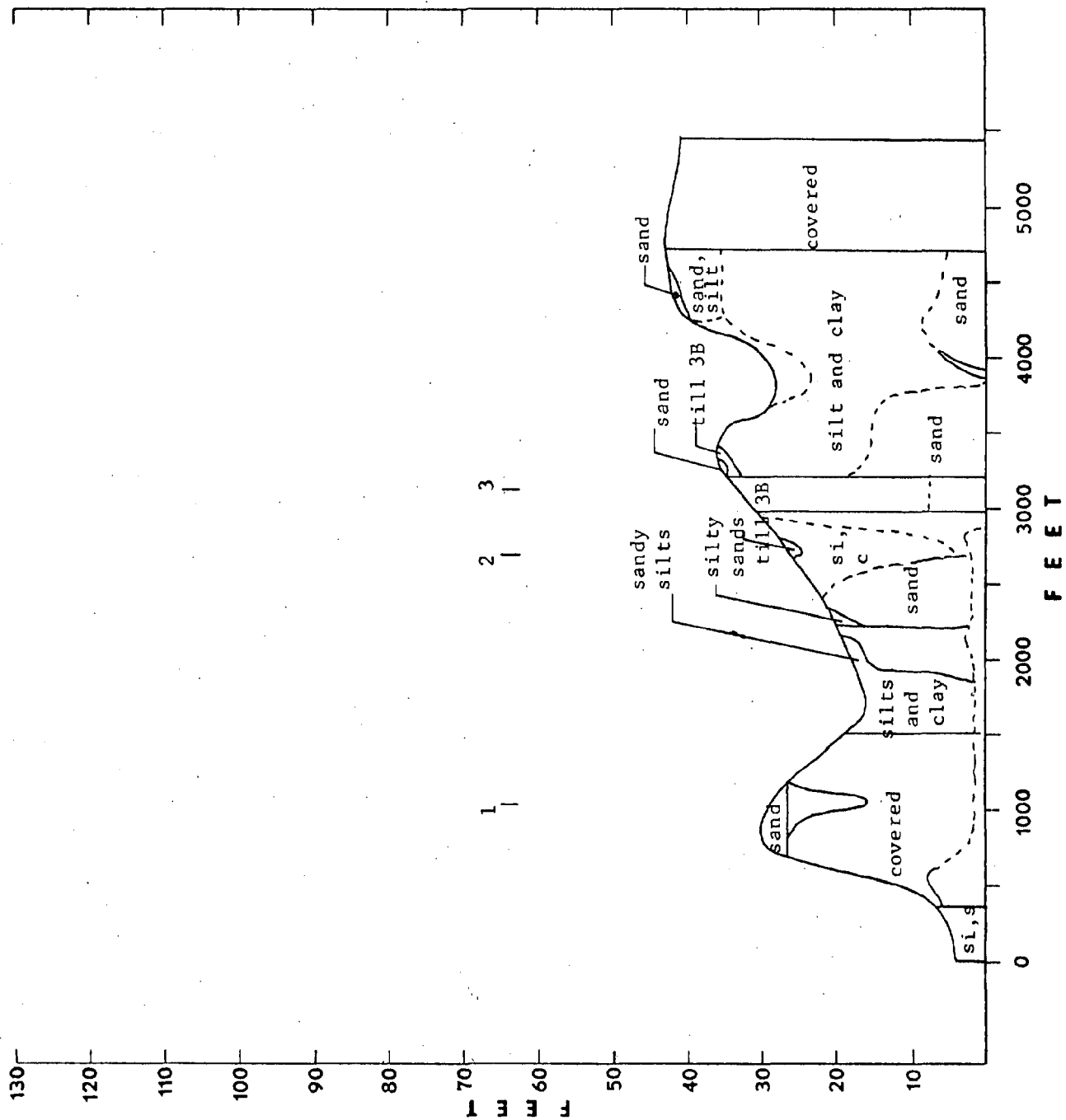
ft. to 5 ft. depth

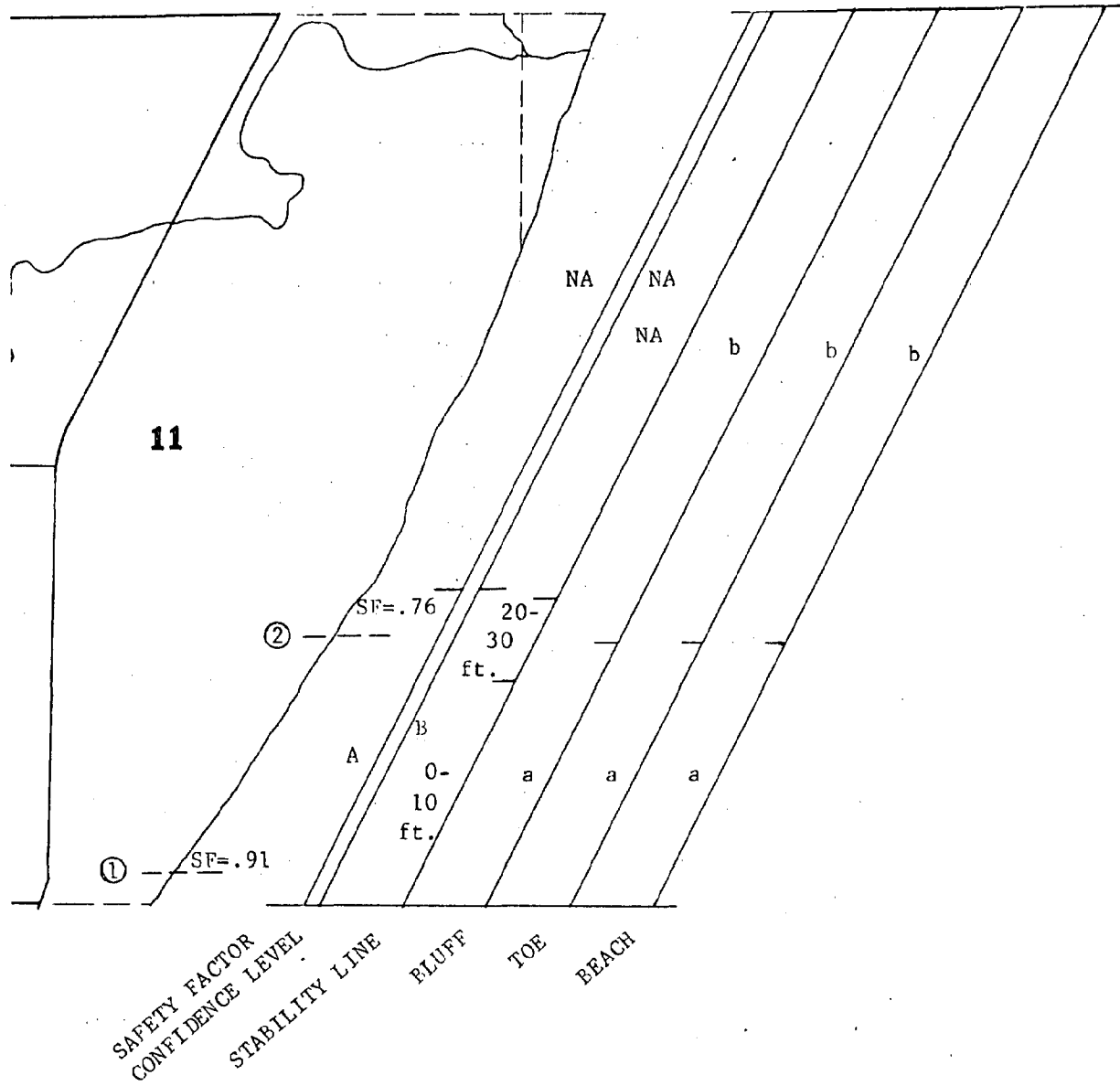


ft. to 5 ft. depth







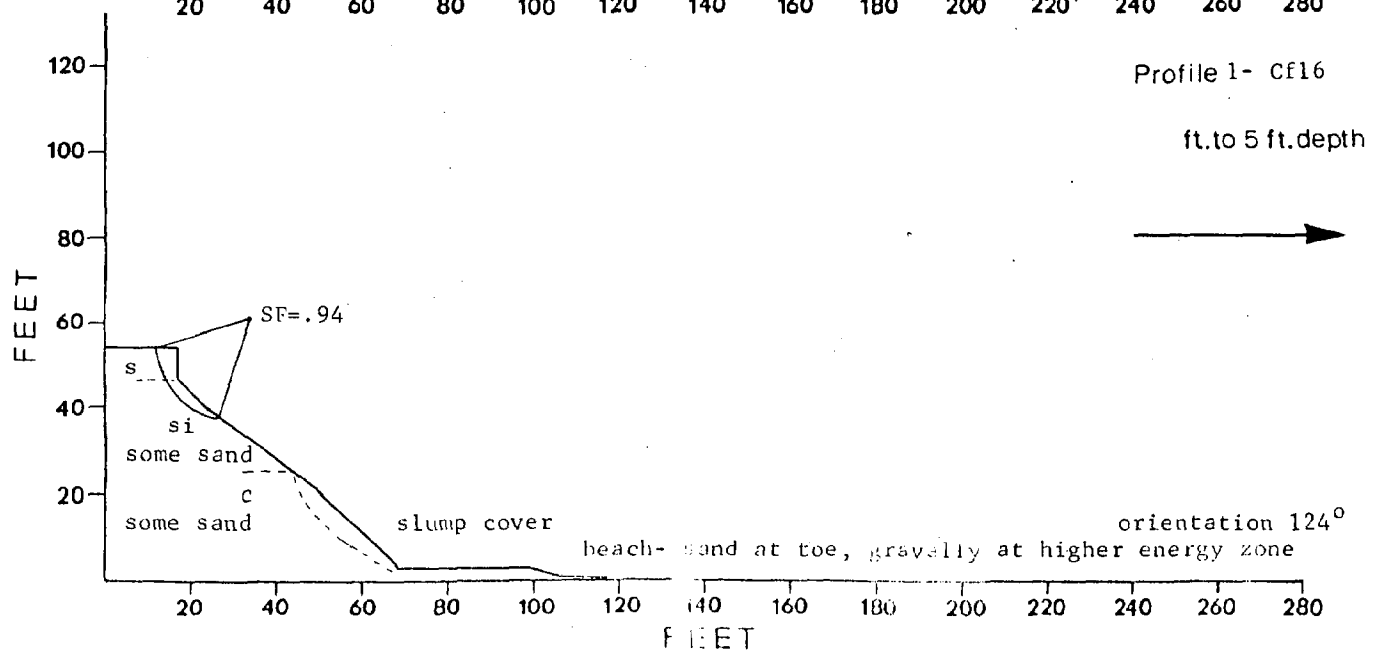
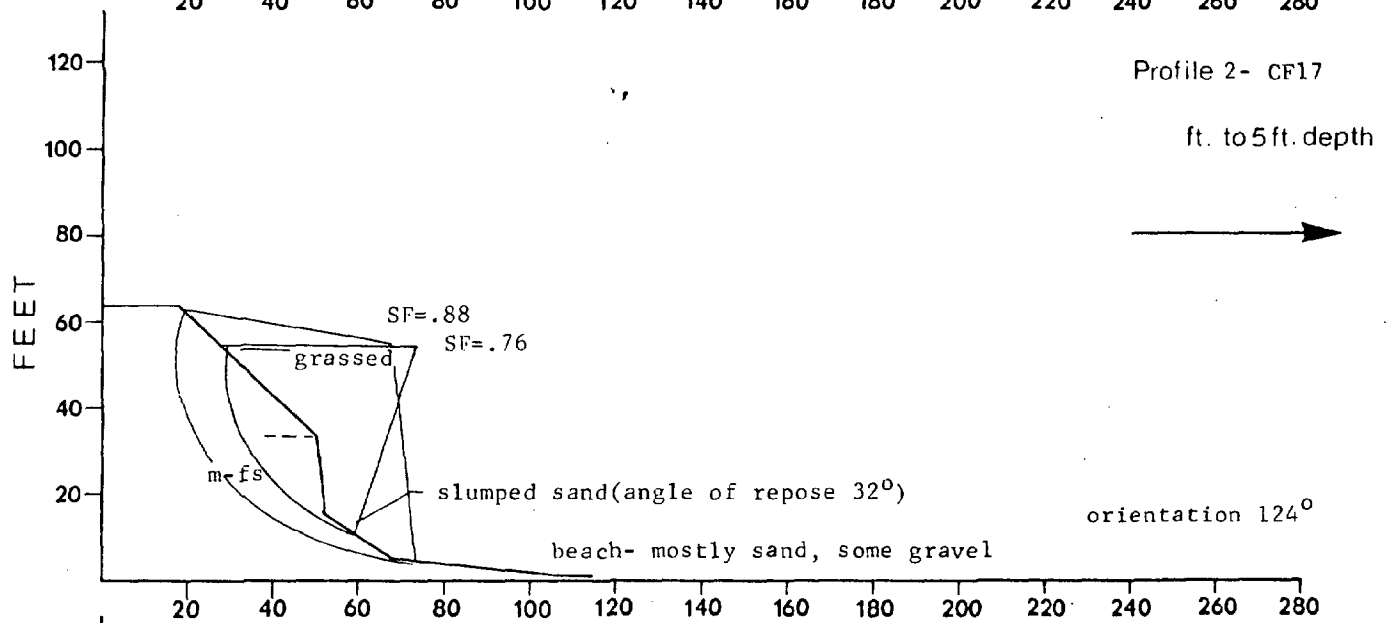
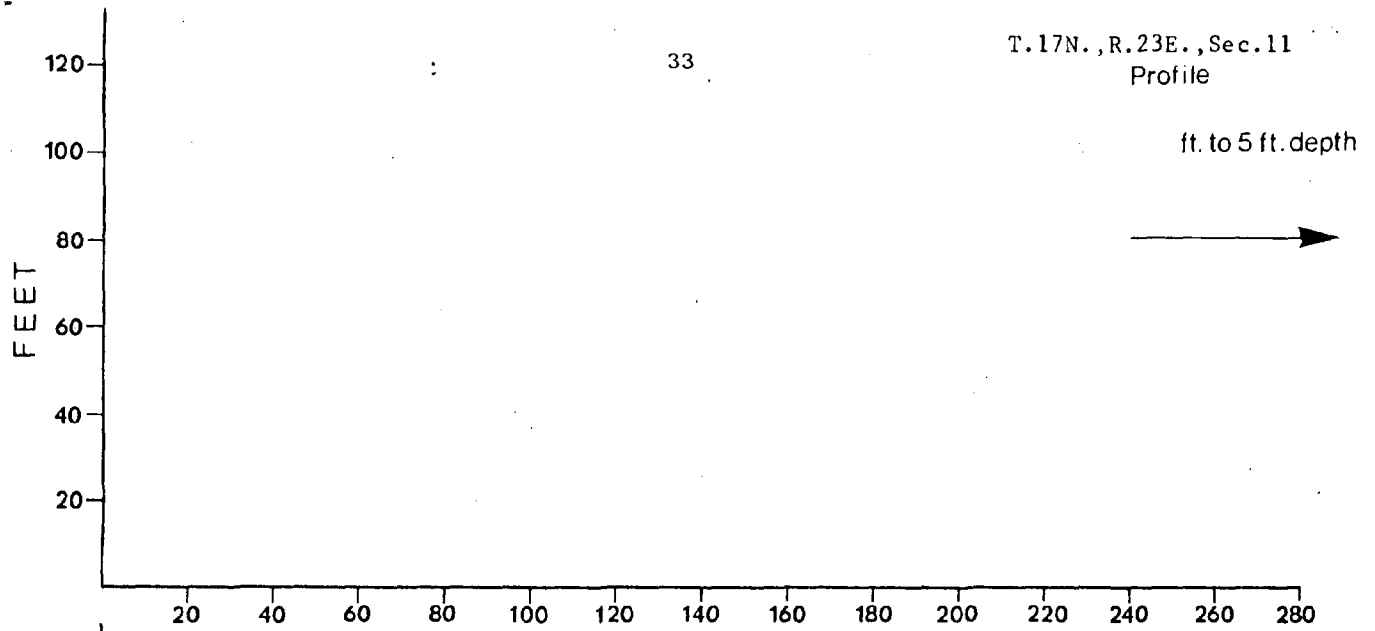
SAFETY FACTOR

- A-less than 1.00
- B-1.00 to 1.25
- C-greater than 1.25

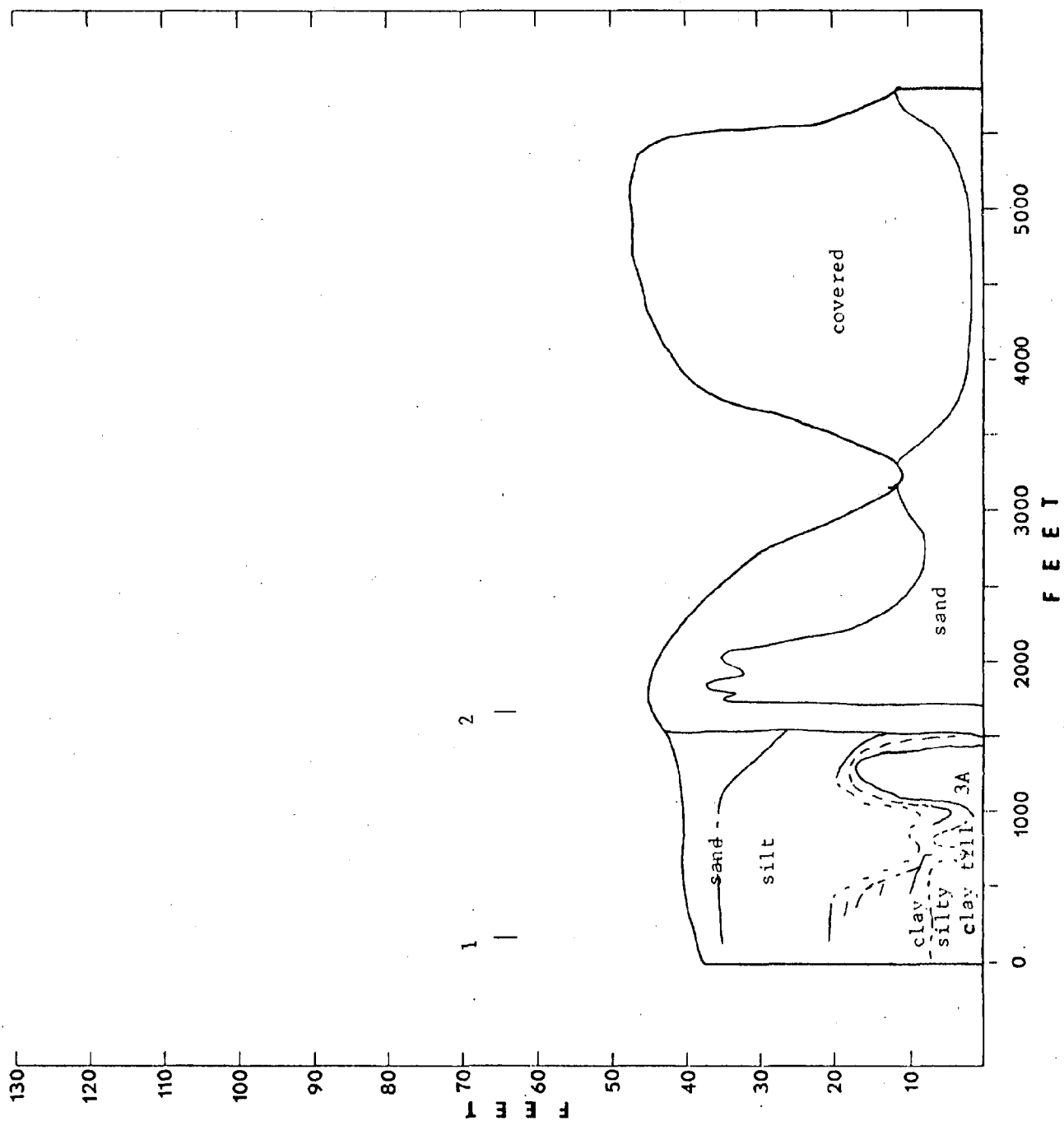
CONFIDENCE LEVEL

- A-boreholes  
(high confidence)
- B-near boreholes  
stratigraphy visible
- C-no stratigraphy  
visible (low confidence)

1. BLUFF	a-undercutting and soil fall	b-slumps and shallow slides in sand	
2. TOE	a- till 3A and slumped sand, silt and clay	b-slumped sand	
3. BEACH	a-sand and gravel, greater than 30 ft.	b-50-80 ft. sand	



I.17 N., R.23 E., Sec. 11



## FIELD REPORT - REACH 25

Location and General Description

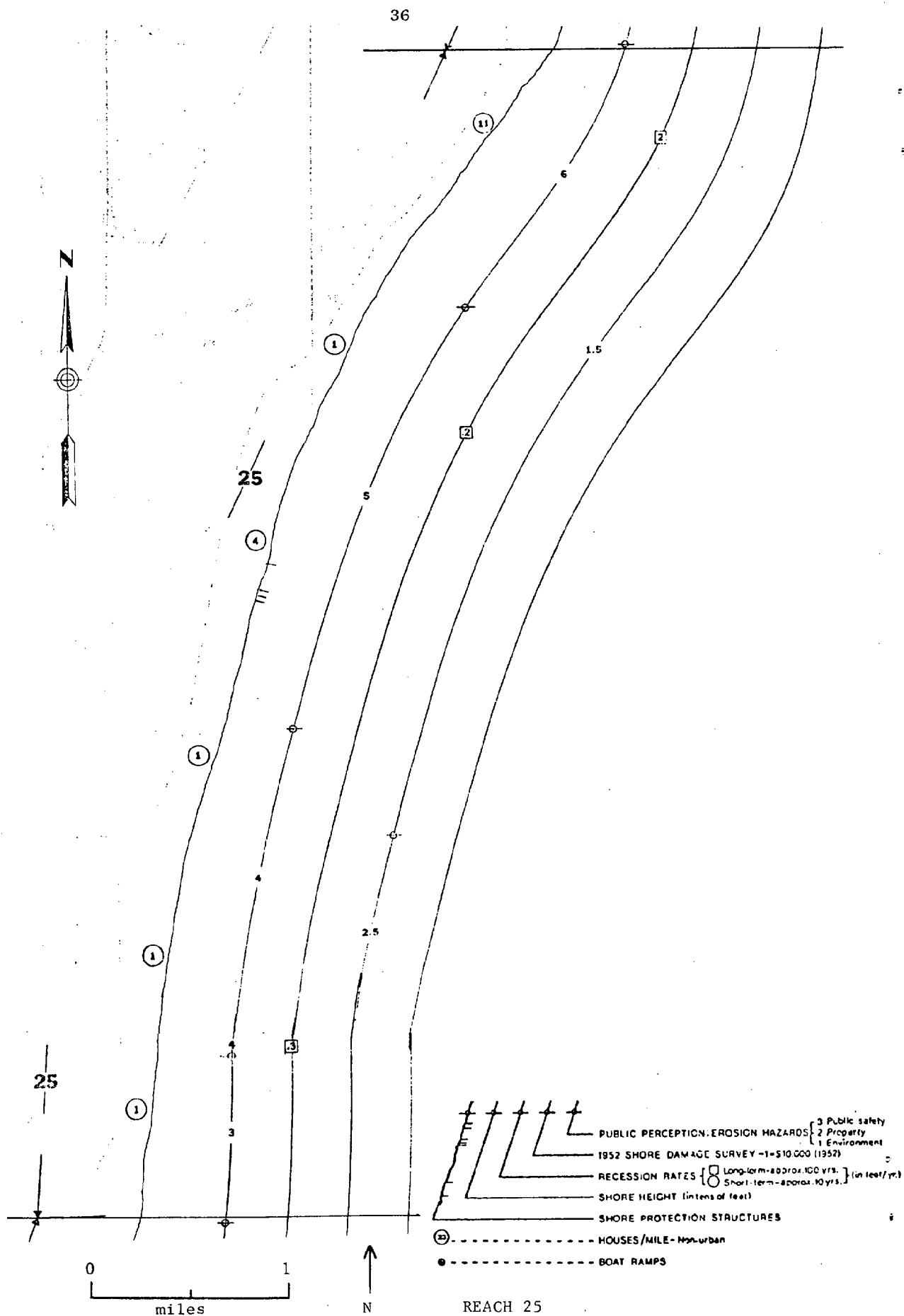
Reach 25 is located in the southern portion of Manitowoc County, covering a north-south distance of 5.9 miles. It is bounded on the north by section 5 of T.18N., R.23E., and on the south by Point Creek. Land use is predominantly agricultural with sparsely spaced rural housing. A small amount of sand and gravel extraction occurs in section 24. The reach ranks 20th on the priority list with a value per mile of seven. Erosion rates vary from 2 feet in the north to between .2 and .3 in the central and southern portions.

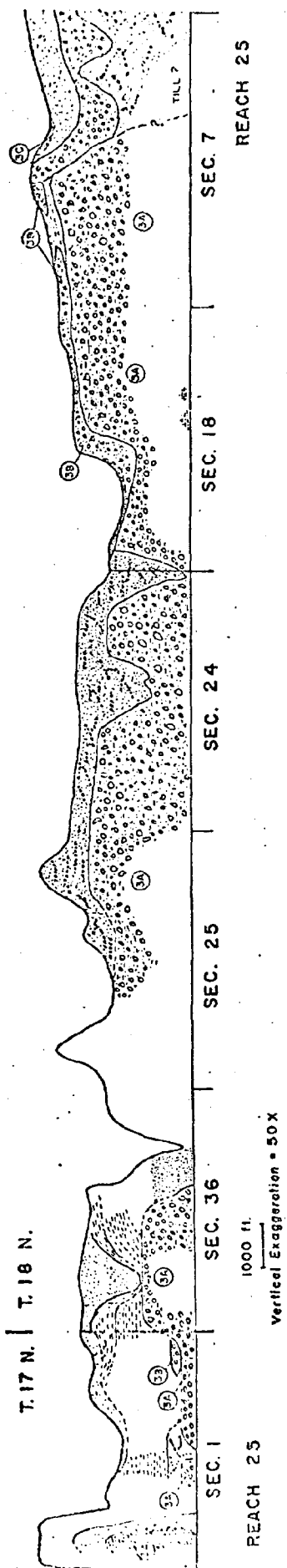
The highest bluffs in the reach are found in the far southern and the far northern portions where they obtain heights of 80 feet and 60 feet respectively. Between these two areas, the bluff generally maintains a height of between 40 and 50 feet.

A red/brown silty clay till (till 3A) up to 55 feet thick is found along nearly the entire length of the reach at the base of the bluff. Except in sections 1 and 36, the till is overlain by sand with smaller amounts of gravel. In these two sections silts and clay lie between the sand and the red/brown silty till. A second thin, sandy till (till 3B) lies in several locations above the red/brown silty clay till (sections 1, 7, 18) but it does not form a continuous unit.

Seeps are often noted at the contact of the surficial sand and the silty clay till 3A. The sand is usually dry and holds a nearly vertical face. The steepness of the face of the sand is aided by a vegetative cover and, in places, by compaction. Where sand composes a large portion of the bluff, failure occurs most often by slumping. Masses of clumped sand entangled in roots also slide down the face of the bluff (southern part of section 1, northern part of section 24).

Vegetation covers large portions of the bluff face in some sections resulting in relatively stable conditions. Slides in these vegetated areas, underlain by





# LEGEND

	SAND		SILT		COVERED OR INACCESSIBLE
	GRAVEL		CLAY		TILL
	SAND AND GRAVEL		CLAYEY SILT, SILTY CLAY		MIXED SEDIMENTS



silts, clays and fine-grained till, is by sapping, slumps and slides (Sec. 36).

Where little or no vegetation is established on the silt, clay or till, sliding and flow occurs. In places where undercutting occurs, soil fall results in steep cliffs, some measured to be as great as 56 degrees, even with a 51 foot high bluff (southern part of Section 18). Large slump blocks have been noted in this reach as well (northern portion of Section 18).

Beach width is variable, ranging from 5 to 50 feet. The predominant beach material is sand sized material although gravels do constitute a significant portion in some places, especially at the immediate lakeshore.

Very few structures exist along this length of the shoreline.

#### Section 1 (C.F.)

Section 1 of Reach 25 lies between one and two miles south of the town of Norheim. The bluffs maintain a height of between 50 and 70 feet except in the southern fifth where a higher and more hummocky topography exists.

Underlying the tall bluffs in the south are sands and gravels. These, in turn, are underlain by a red-brown silty clay till, till 3A, which dips below lake level to the north. The sands and the gravels are well sorted (i.e., a small range of grain size) and exist as two distinct grain size classes. The coarse gravel exhibit no bedding whereas the sands are stratified. The till is pebbly and well compacted.

Vegetation fully covers the slopes north of this area to the half mile mark. At this latter point, the stratigraphy in the exposed bluffs is a basal red-brown silty clay till (till 3A) overlain by sands and gravels, clays and silt in that order. The surficial yellow silts are interbedded with red clays. The clays that lie beneath the yellow silts are massive in the upper portion. In its lower part, the clay is evenly and horizontally bedded with small silt seams.

A sandy, yellow till forms a thin ( $1\frac{1}{2}$  to 2 feet thick) bed between the lacustrine clay and above the red-brown silty clay till in the northern quarter

of the section. It is not exposed for any great length because of vegetative cover. The sand and gravel, which was found in this same position to the south, no longer exists in this area.

In the southern portion of the section, slumping occurs in the unconsolidated sands. Sapping occurs in the fine-grained silts and clays along the central and northern portions of Section 1. Where slumping occurs, it is in small blocks in the middle part of the section. More minor occurrences of slumping were noted to the north. Along the immediate lakeshore, slides were common in the northern half.

The beaches consist largely of sand with minor amounts of pebble size material. Where gravels do constitute any significant proportion of the beach, they are usually found along the immediate shoreline. Along nearly the entire section the beach maintains a width of greater than or equal to 30 feet. At mile 0.2 the beach was 54 feet wide.

No structures are present along the shoreline.

#### Section 36

This section covers the shoreline south from the town of Northeim for one mile. The bluff maintains a height of between 40 and 50 feet above the lake throughout the southern six-tenths of its length. The bluff descends to near lake level between 0.7 and 0.8, rising to a height of approximately 40 feet at the town of Northeim. A vegetative cover of trees and brush mask the southern eight-tenths of the section while grasses cover the northern two-tenths.

Where windows do exist in the vegetation, surficial sands overlies silts and clays in the upper half of the bluff, while red-brown silty clay till 3A extends along the lower portion of the bluff.

Between mile 0.6 and 0.7, where the top of the bluff descends to near lake level, only sand is exposed in the bluff face. North of this low area, the bluff is entirely vegetated. The red-brown till is probably present at or near the

base of the bluff beneath the vegetation.

Much of Section 36 is vegetated. Where the most recent slope failures have occurred, sapping and sliding are the more prevalent failure mechanisms. Slump is common in the sands.

The southern quarter of the section contains 15 to 20 feet wide beaches composed mostly of large cobbles. Trees have fallen or lean out into the water along the shoreline. The southern middle quarter of the section contains narrow (5 to 10 feet) to wide (60 feet) beaches of sand. A gravel beach between mile 0.5 and 0.7 varies in width from between 20-35 feet.

Except near the lake, where gravels are more common, the remaining northern three-tenths of the shoreline is composed almost entirely of sand. Beach width here is between 50 and 80 feet.

No structures are developed along this mile of shoreline.

#### Section 25 (C.F.)

Section 25 extends north for one mile from the town of Northeim. Except for a slight rise in topography at mile 0.2, the southern half of the section contains 35 to 40 foot vegetated bluffs. The vegetation is largely weeds and grasses. A red-brown silty clay till probably exists near the base of the bluff under the vegetative cover.

The northern one-half mile of the section contains a number of stratigraphic windows exposing sand at the top of the bluff underlain by red-brown silty clay below. The sand ranges from very coarse gravel and boulders to fine sand. The bluff reaches a height of 65 feet near mile 0.9 where the surficial sand obtains its greatest thickness. The contact between the sand and till remains nearly horizontal.

A number of seeps occur as small streams or rivulets when they emerge from below the vegetative cover along the southern quarter of the section. These areas are often identified by clumps of trees and bushes at the base of the bluff. The stratigraphic origin of these streams could not be detected because of the dense vegetative cover. In the northern portion of the section, slumping occurs in large blocks.

The beaches are composed mostly of sand with some gravel nearest the lake. Beach widths varies from between 30 and 50 feet along the entire length of shoreline except where vegetative growth and slumps have advanced over the beach in narrow patches.

Only one structure exists along the section. This revetment protects a boat house and ramp to the beach at mile 0.3.

#### Section 24

The stratigraphy of the bluffs in Section 24 is very straight forward and exposures are numerous. The bluffs throughout the section are made up of till 3A overlain by sand and gravel. Inspection of the upland surface discloses a topography typical of pitted outwash. This interpretation as to the origin of the sand and gravel deposit is substantiated by collapse structures noted in gravel pits along the section.

The contact between the till and the overlying sand and gravel is a major seepage zone. This is especially evident in a small buried valley or sag in the surface of till 3A. Despite prolonged drought conditions prior to the time at which this section was inspected, actively flowing springs were observed along the valley bottom. Profile #1 was taken at 0.57 immediately to the south of the most active of these springs in the deepest part of the valley.

With the exception of a small slumped area which lies between 0.08 and 0.13 slope failures throughout the section are essentially the same. Wave action

against the basal till 3A leads to undercutting of the bluffs and subsequent soil falls. This eventually results in the oversteepening of the slope and high angle slumping results. In many portions of the bluff, the slumping is confined to the till unit and the overlying granular materials appear to be undisturbed and often have retained a vegetative cover of grasses.

Beach conditions throughout this section are also relatively constant with cobble beaches about 30 feet wide being characteristic. Narrowing of the beaches occurs where recent slumps have moved out into the lake and this is especially true in the area of full faced slumping that was mentioned earlier.

A single measurement of water depth was made at the boring GT-17 which lies at about 0.85. Here it was found that the water was 1.5 feet deep 50 feet from the shoreline.

Land use along the shoreline is largely either agriculture or mining of the sand and gravel deposits. A residential density of 4 houses per mile was given for this section. No recession rate data was available for Section 24. No protective structures were described.

#### Section 18 (C.F.)

This portion of Reach 25 covers one mile of shoreline north of the Radant Brothers gravel pit operations.

A red-brown silty clay till lies along the bottom of the entire length of this section. This till is the predominant material found along this section and nearly always forms the bottom of the bluff. Only between mile 0.6 and 0.8 is another material exposed at the base of the bluff. Here, brown to tan sandy silts emerge as two separate units from below lake level to a height of 4 feet.

Coarser grained materials overlie the finer grained red-brown till. Gravelly sands are found at the extreme southern end of the section while a soft, friable sand forms a thin surficial cover throughout the rest of the section to the north.

A more compact, hard, fine grained, gravelly sand till is exposed in the central part of the section. A gravelly bouldery material marks the contact between the yellow sandy till above and the red-brown silty clay till below in several places. The sandy till is not continuous but tapers out to the north.

On the north end, when the sandy till thins, a short wedge of hard, compacted, bedded sand has formed. This sand unit, too, ends abruptly near mile 0.7 and only the thin cover of soft sand continues along the top of the bluff through the rest of the section.

Where sand is the predominant bluff material, failure occurs most often by slumping. Vegetation helps hold the sand in clumped masses as they slide down the slope.

In the finer grained material such as the till, soil fall results in steep cliffs. Sliding and slump is more common in the northern portion of the section.

The beaches along the lower third of Section 18 are composed mostly of gravel and are from 20 to 30 feet in width. To the north, sand sized material makes up 75 to 100% of the beach material. Beaches in this latter portion are commonly 20 to 30 feet wide, although in a few places the beaches can be as large as 50 feet or as small as 5 feet.

No structures were found along this stretch of shoreline.

#### Section 7

The geology and stratigraphy in this section are probably the most complex encountered in the area north of Ozaukee County. The section is unique in that it is one of the few places known to the authors in which all three of the tills that have been recognized in the area are exposed.

The southern boundary of the section lies just south of the south valley wall of Calvin Creek. At the section line, the stratigraphic section consists of a bed of very sandy till, till 3B, overlying a thick exposure of till 3A. In the immediate vicinity of the south section line, the two tills are often separated by a thin sand bed. On the north side of the valley of Calvin Creek till 3B,

rather than occurring as a continuous and well developed unit, is found as prominent lenses of till within a sequence of mixed lacustrine sediments between 5 and 10 feet thick. At several locations, this lacustrine sequence was also found to contain what appeared to be a red-brown till. This material could either be highly oxidized till 3A, till 3C, or a lacustrine clayey silt with an unusually high pebble content.

At the north section line, the stratigraphy differs greatly from that in the southern portions of the section. The observed sequence is a thick bed of coarse sand overlying till 3C which in turn overlies a thick unit of sand and gravel. The widely differing stratigraphic sequences that occur at the two section boundaries can each be traced readily towards the central portion of the section. The geologic relationships where these two differing sequences meet are extremely complex and are not yet fully understood. Unfortunately, Section 7 was the last section investigated by the authors and the early advent of winter weather conditions, especially the presence of a snow cover on the high, steep bluffs that are found in this area, forced a termination of field activities in mid-December before relationships were fully worked out.

The authors' current interpretation of the geology in Section 7 is shown graphically on the longitudinal profile for the section. As can be seen from this profile, the authors now believe that till 3A represents the oldest unit exposed and that the very sandy till 3B was deposited upon the erosion surface that marks the top of this till, probably in a shallow lacustrine environment. The sand and gravel that occupied the basal position in the northern portions of the section are believed to lap up on an erosion surface that was cut on both till 3A and the overlying 3B with its accompanying lacustrine beds. Till 3C is believed to have moved across the sand and gravel and up the erosion surface on tills 3B and 3A. The bed of coarse sand that lies over till 3C in the northern portions of the section is thought to be the youngest unit present in the section.

If this interpretation is correct, it would lend support to the view that the sandy till 3B is intermediate in age between the two red-brown tills, tills 3A and 3C. An additional till body has been reported lying within the basal gravel unit in the northern part of the section. The identity of this unit, if present, has not been established.

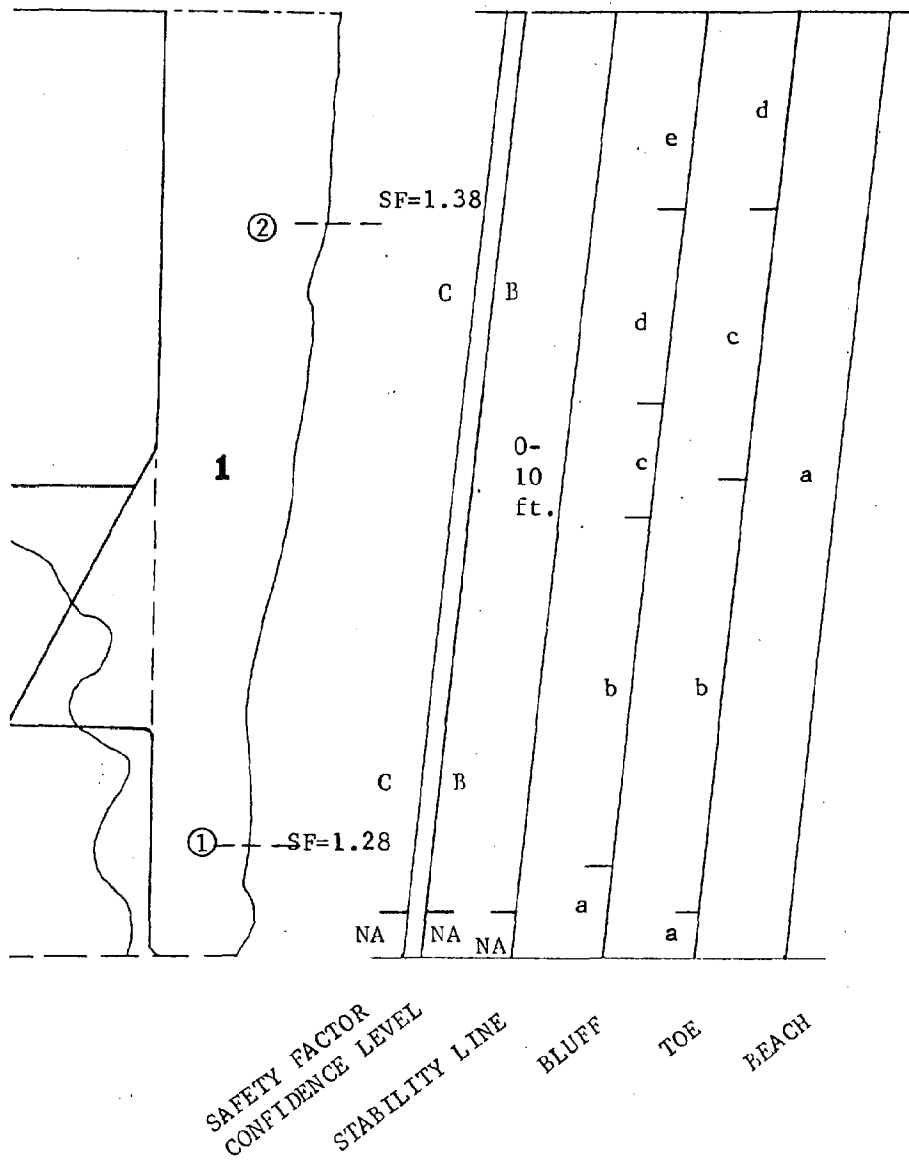
The mode of slope failure is relatively constant throughout the section and consists mainly of high angle slumps and soil falls, with the lower slopes largely covered by materials that have slumped down from above. The single exception lies in a 100 foot long segment of the shoreline lying at about 0.22 where slumping involving the entire bluff as a unit has taken place.

In contrast, beach conditions along the section are quite variable. From the southern section line to about 0.2 beaches are made up of between 20 and 30 feet of cobbles. Between 0.2 and 0.45 the beaches are once again 20 to 30 feet wide and consist of a mixture of boulders and cobbles. From 0.45 north to 0.77 the beaches are made up of 20 to 50 feet of sand and cobbles and from this point to the north section line the beaches consist of 20 to 30 feet of cobbles.

The area is relatively highly developed with a housing density of 11 houses per mile. One long term recession rate determination had been made in this section and it yielded a rate of 2 feet/year.

No structures were described in this section.



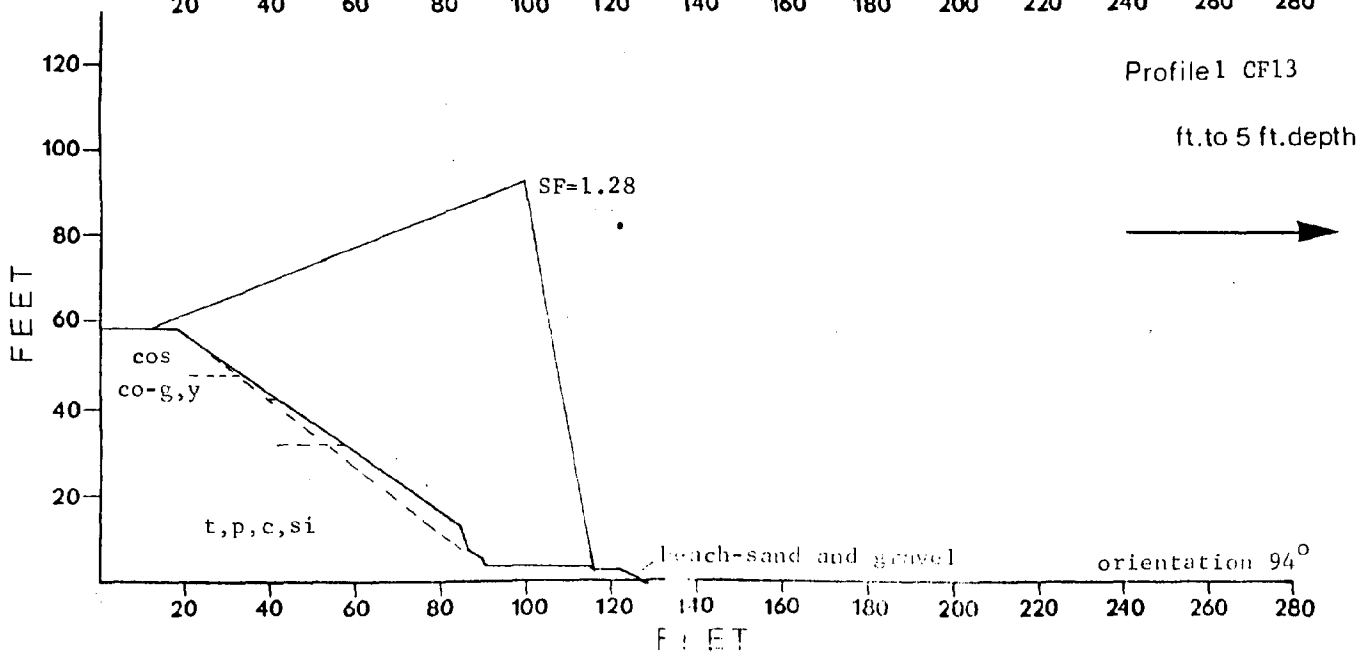
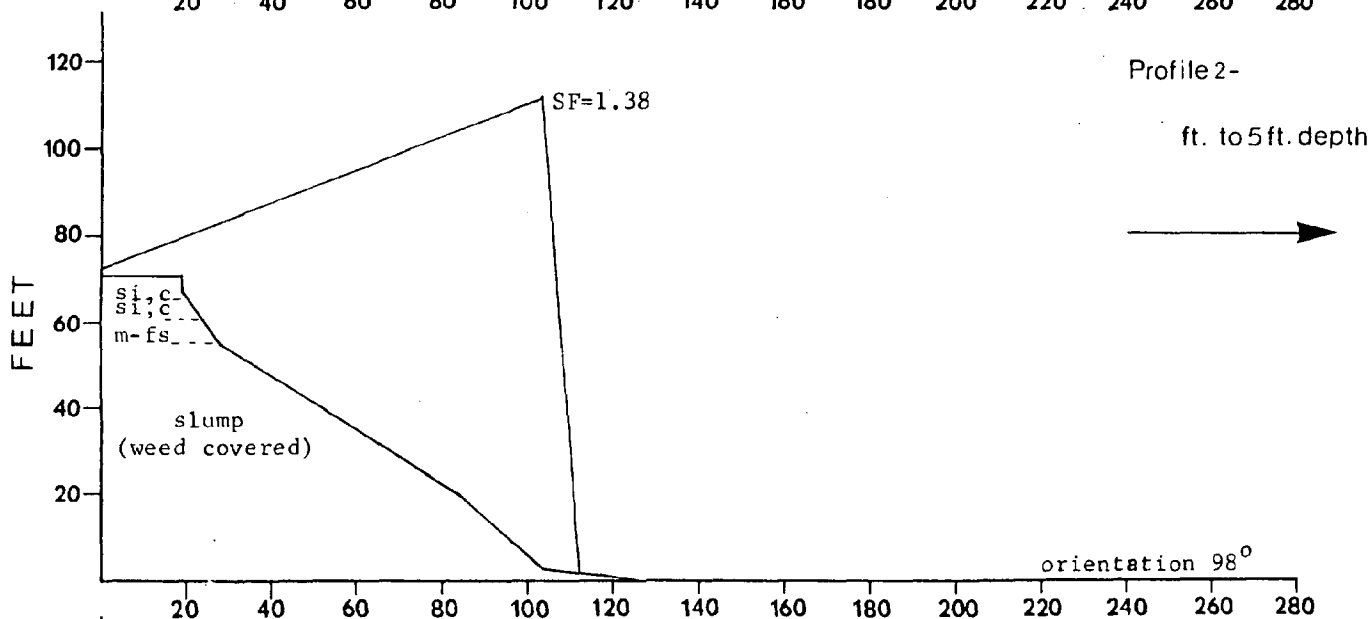
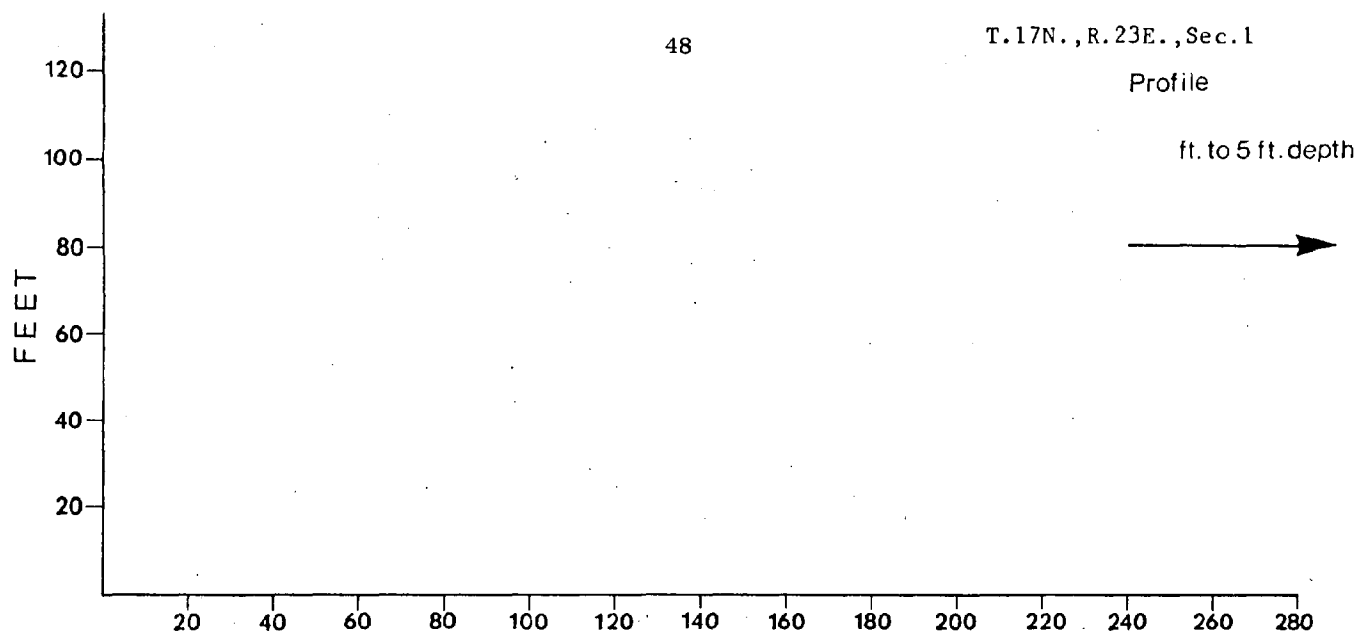
SAFETY FACTOR

- A-less than 1.00
- B-1.00 to 1.25
- C-greater than 1.25

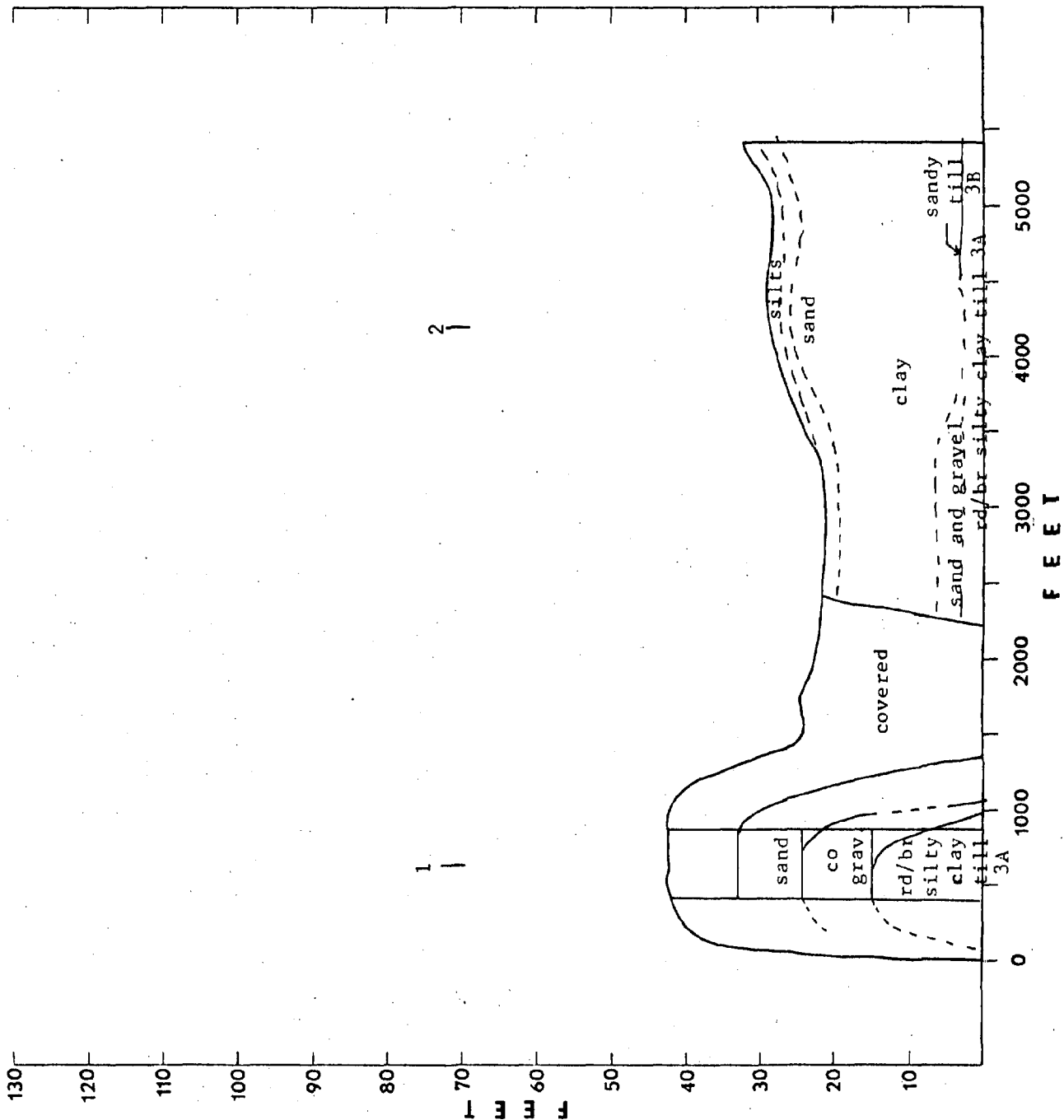
CONFIDENCE LEVEL

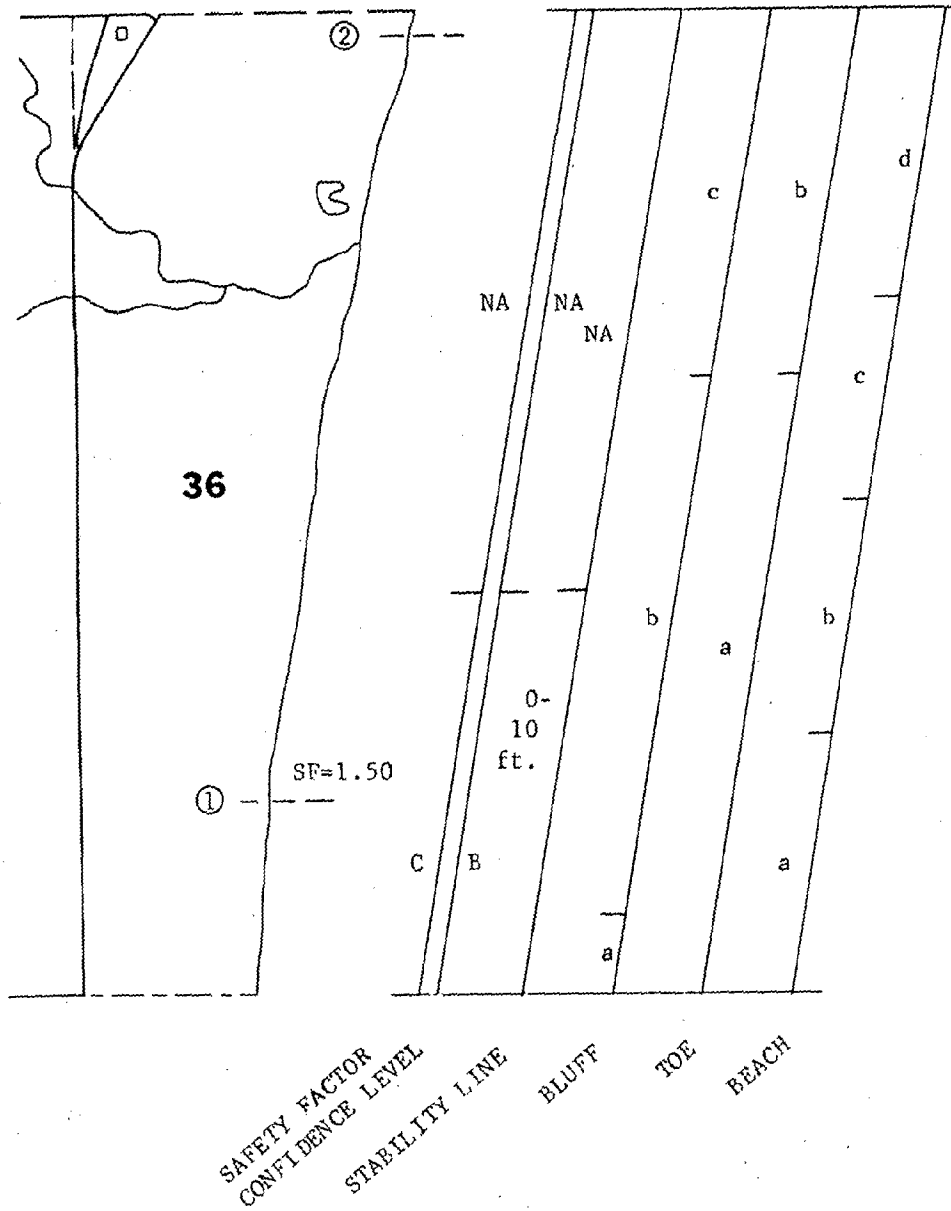
- A-boreholes  
(high confidence)
- B-near boreholes  
stratigraphy visible
- C-no stratigraphy  
visible (low  
confidence)

1. BLUFF	a-high angle slumping, upper $\frac{1}{2}$ of slope remains vegetated.	b-large scale slumping, full face involved.	c-undercutting and soil fall; full face involved.	d-undercutting and soil fall, usually involves only the lower $\frac{1}{3}$ of bluff; upper slopes remain vegetated.
2. TOE	a-till '3A'	b-sand and slumped sand	c-till '3A' and slumped sand	d-slumped till, silts, and clays
3. BEACH	a-30-55 ft. of sand, some gravel near lake margin.			



T. 17 N., R. 23 E., Sec. 1



**SAFETY FACTOR**

A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

**CONFIDENCE LEVEL**

A-boreholes

(high confidence)

B-near boreholes

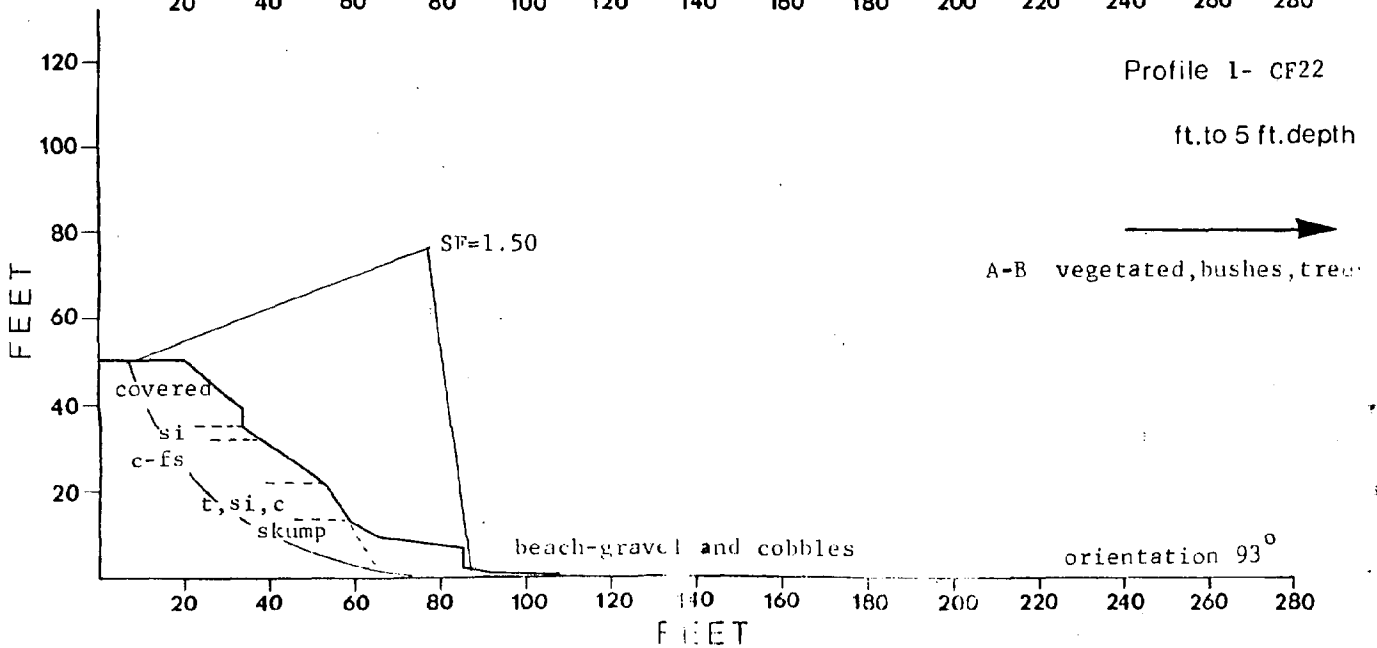
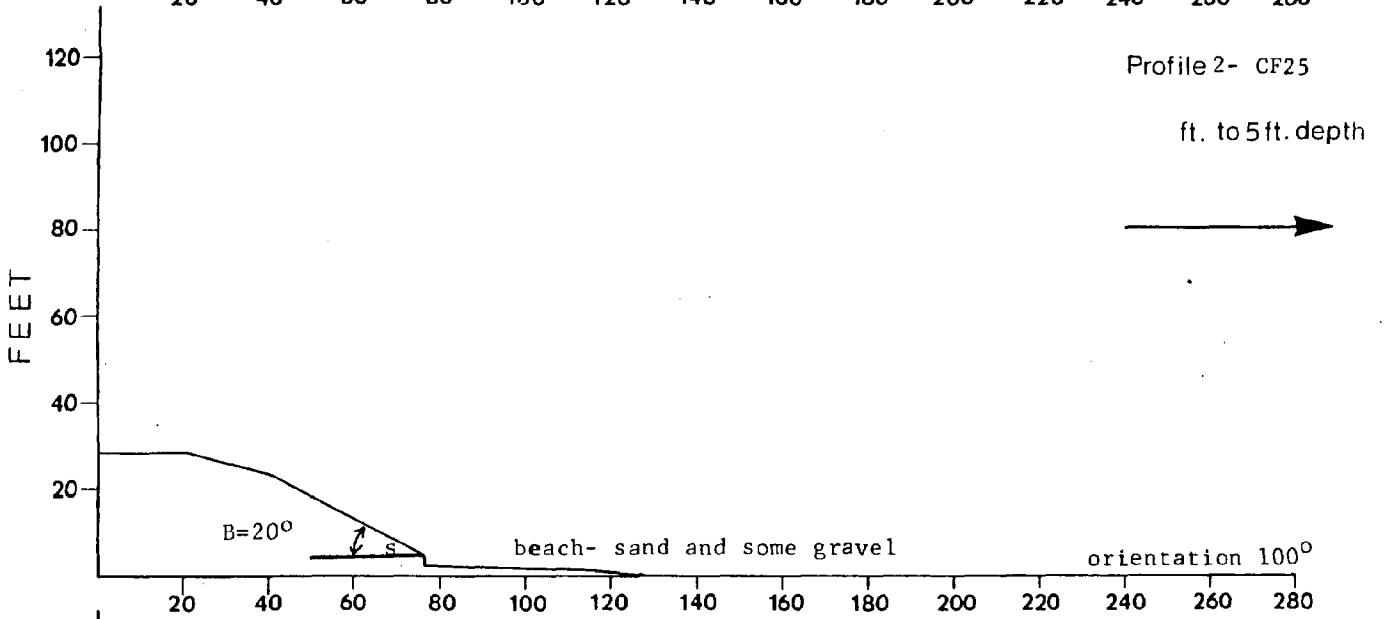
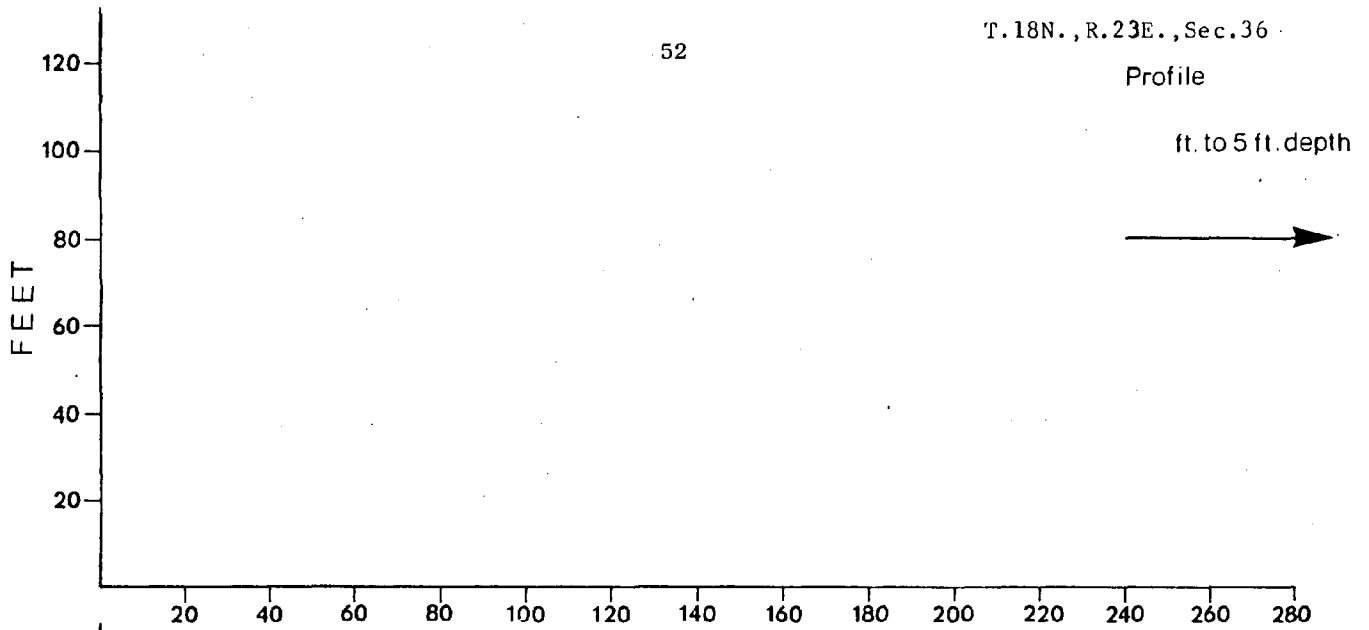
stratigraphy visible

C-no stratigraphy

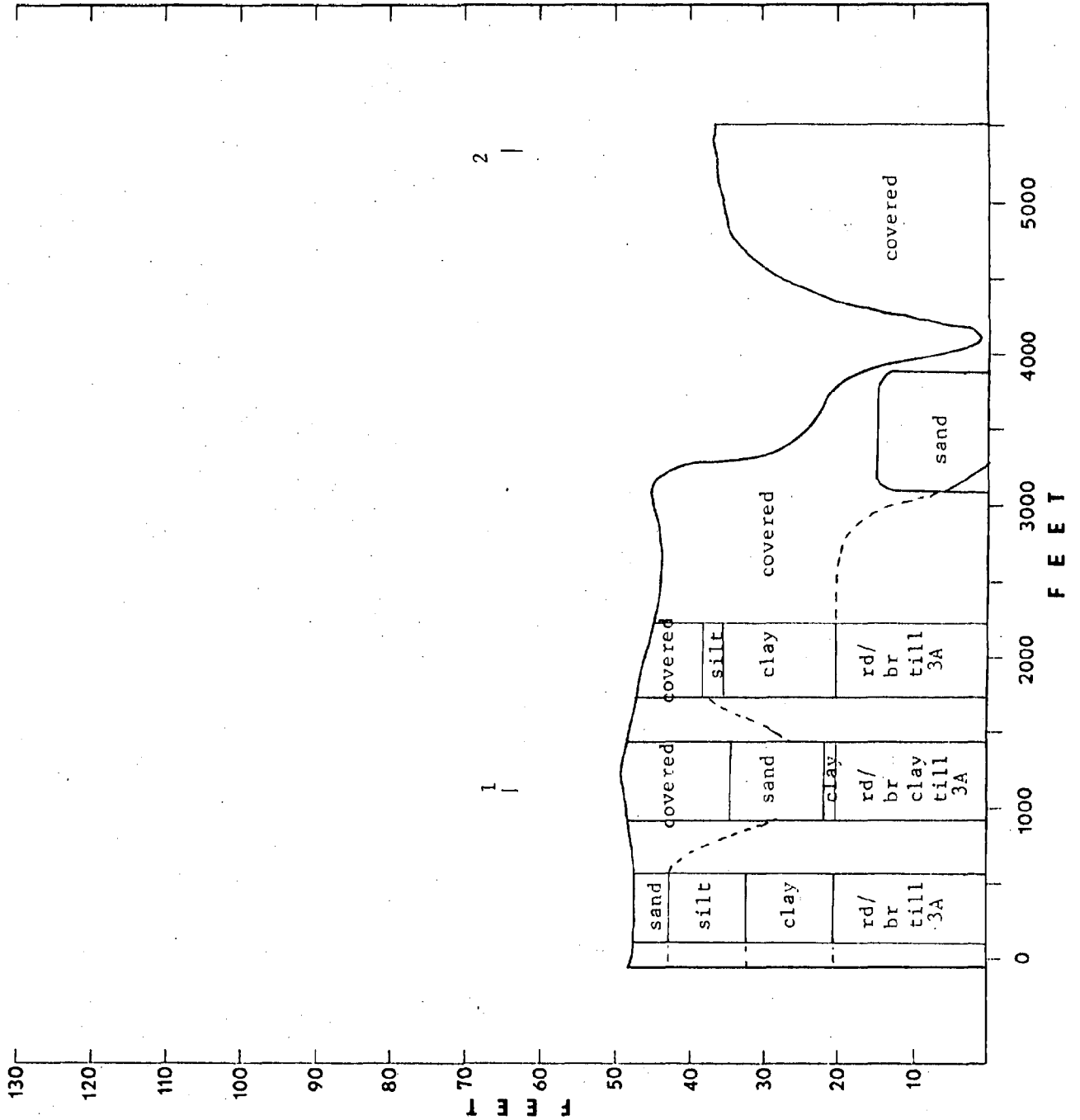
visible (low

confidence)

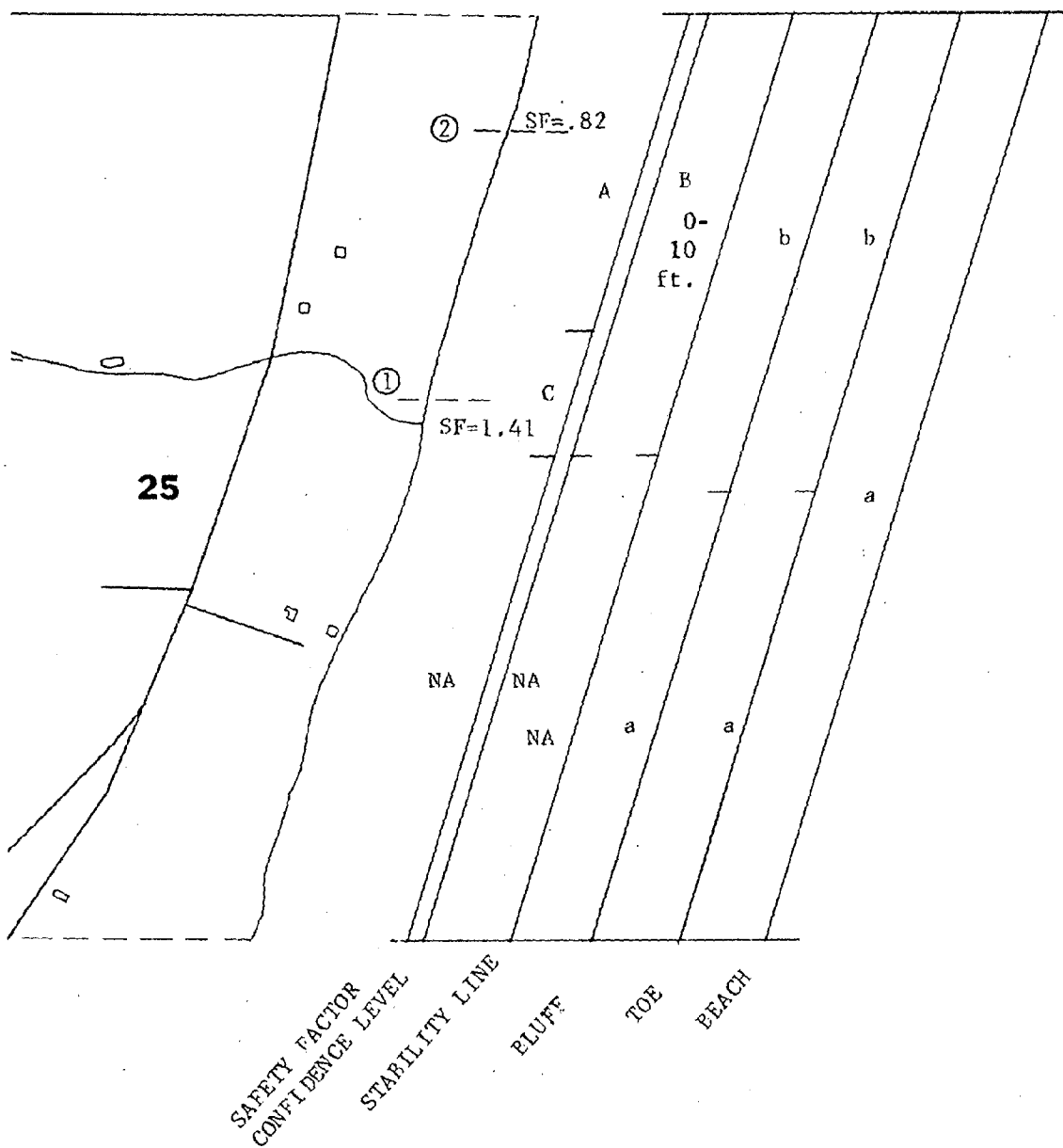
1. BLUFF	a-large scale slumping	b-minor soil fall at cut face behind beach, heavily vegetated.	c-mainly grassed slopes very minor slumping	
2. TOE	a-till 3A	b-sand		
3. BEACH	a-15-20 ft. large cobbles	b-5-60 ft. sand	c-20-35 ft. gravel	d-50-80 ft. sand



T. 18 N., R. 23 E., Sec. 36





SAFETY FACTOR

A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

CONFIDENCE LEVEL

A-boreholes

(high confidence)

B-near boreholes

stratigraphy visible

C-no stratigraphy

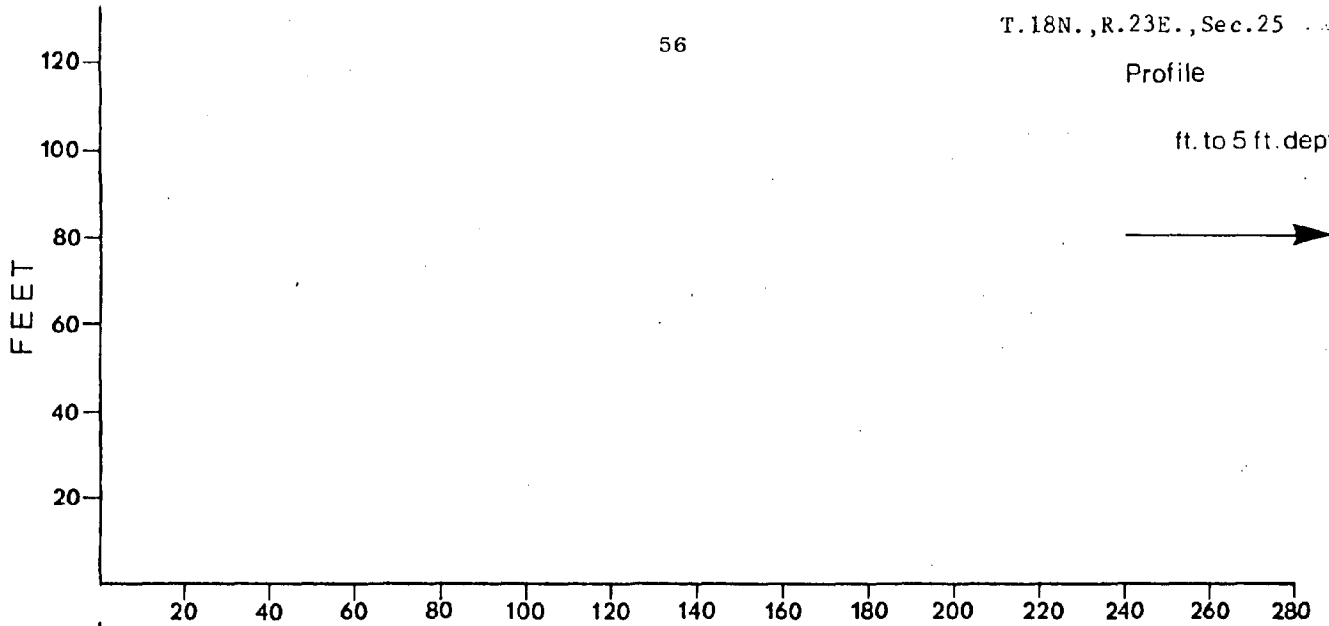
visible (low

confidence)

1. BLUFF	a-fully vegetated slopes with little or no indication of recent erosion	b-large scale slumping, some soil fall	
2. TOE	a-till 3A, in place	b-till 3A, in place and/or slumped	
3. BEACH	a-30-50 ft. sand, some gravel; locally constricted by recent slumps		

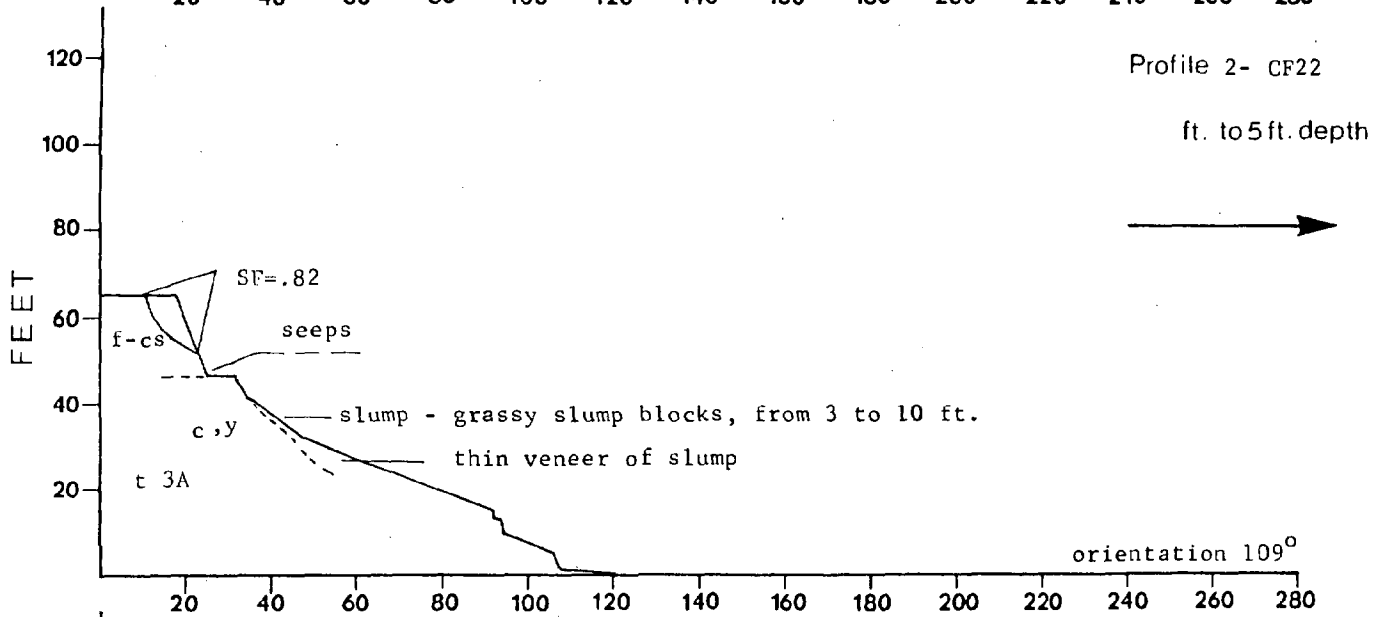
Profile

ft. to 5 ft. depth



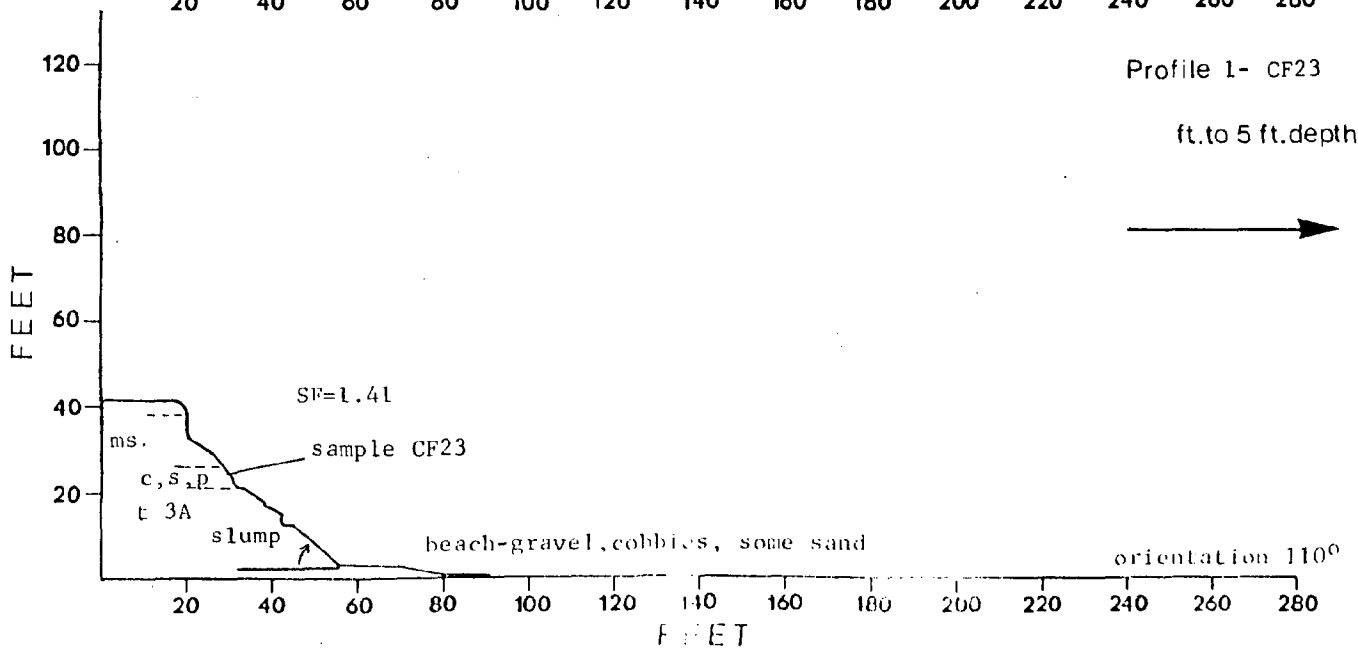
Profile 2- CF22

ft. to 5 ft. depth

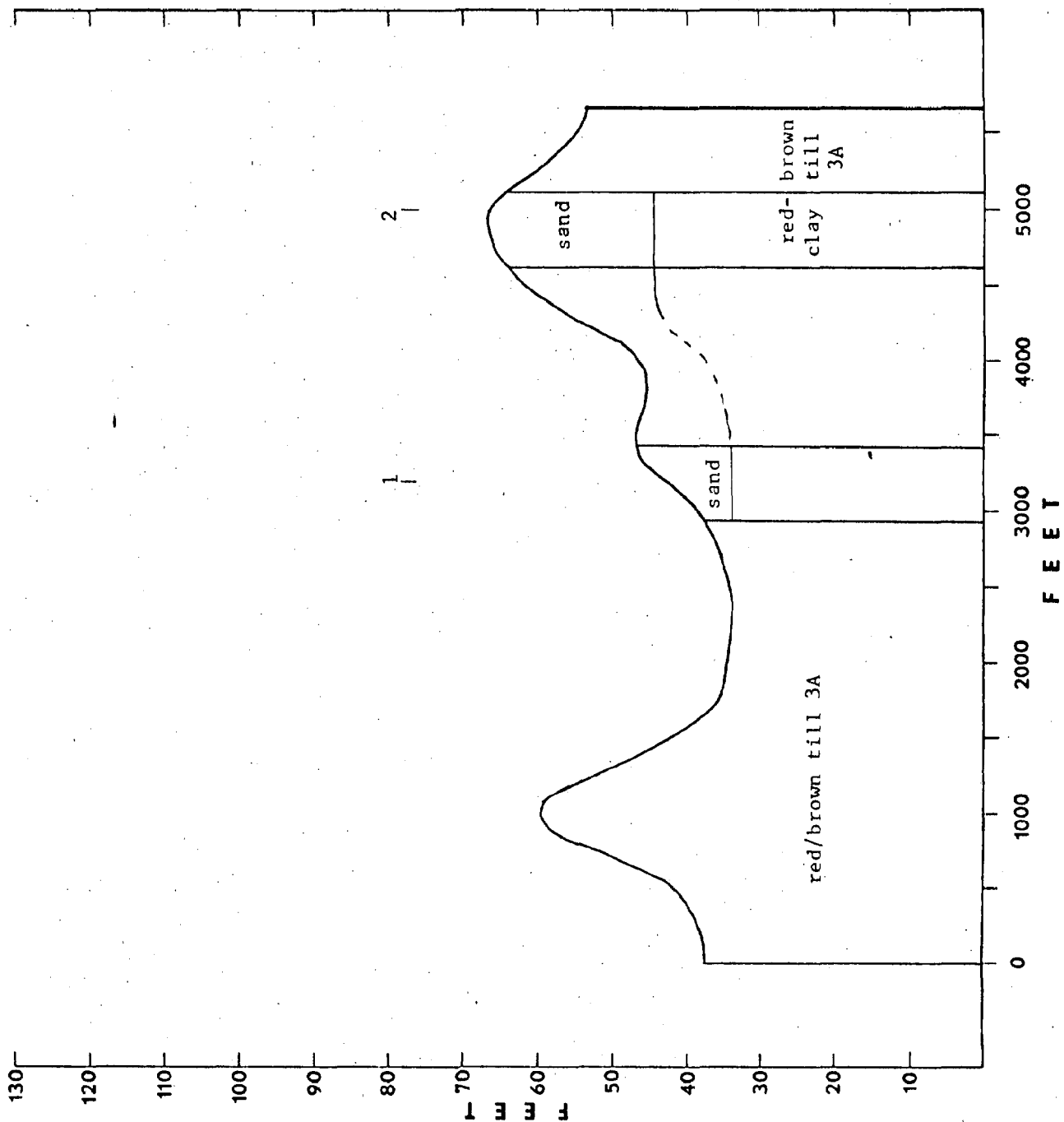


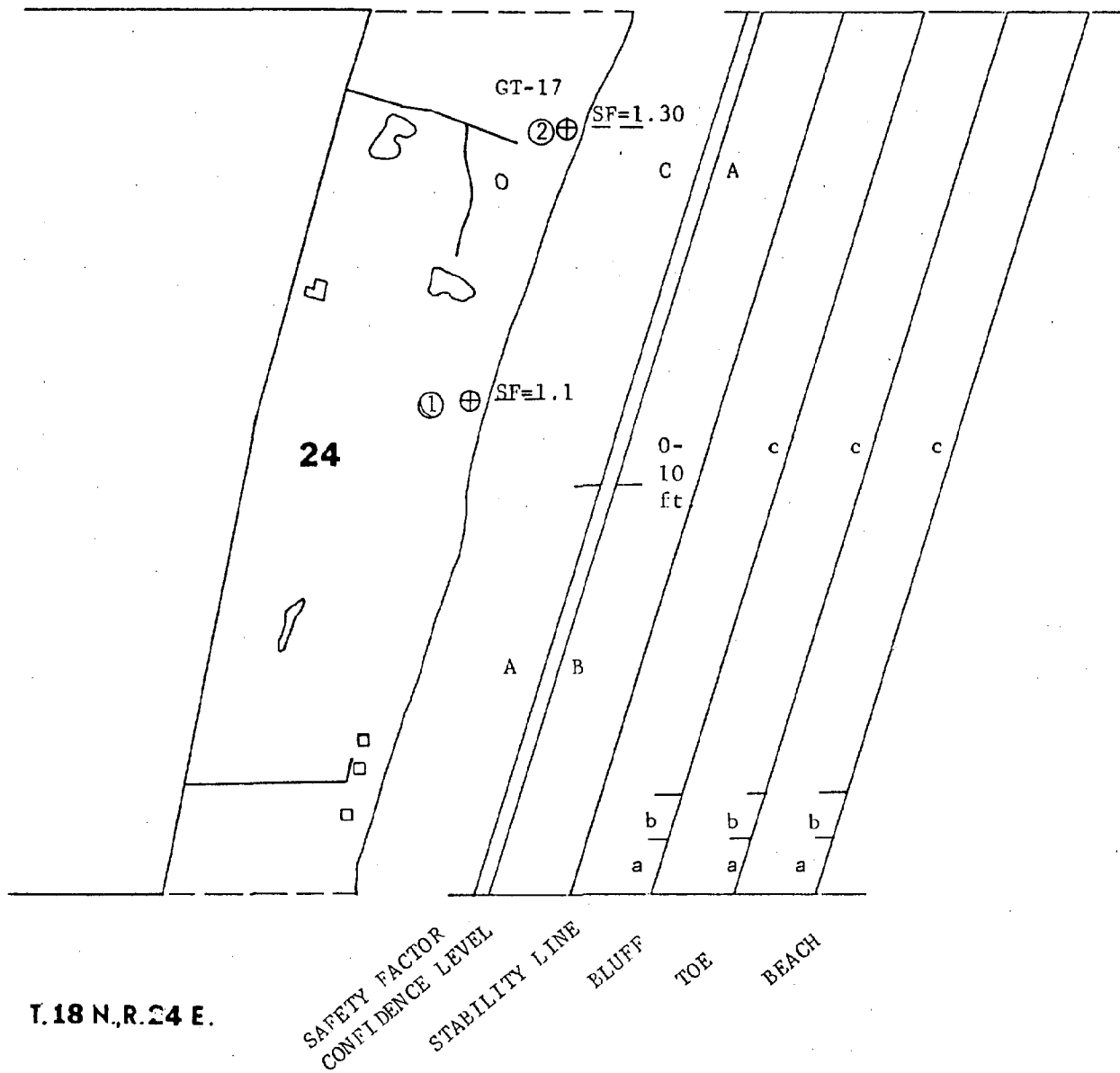
Profile 1- CF23

ft. to 5 ft. depth



T.18 N., R. 23 E., Sec. 25



SAFETY FACTOR

A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

CONFIDENCE LEVEL

A-boreholes

(high confidence)

B-near boreholes

stratigraphy visible

C-no stratigraphy

visible (low

confidence)

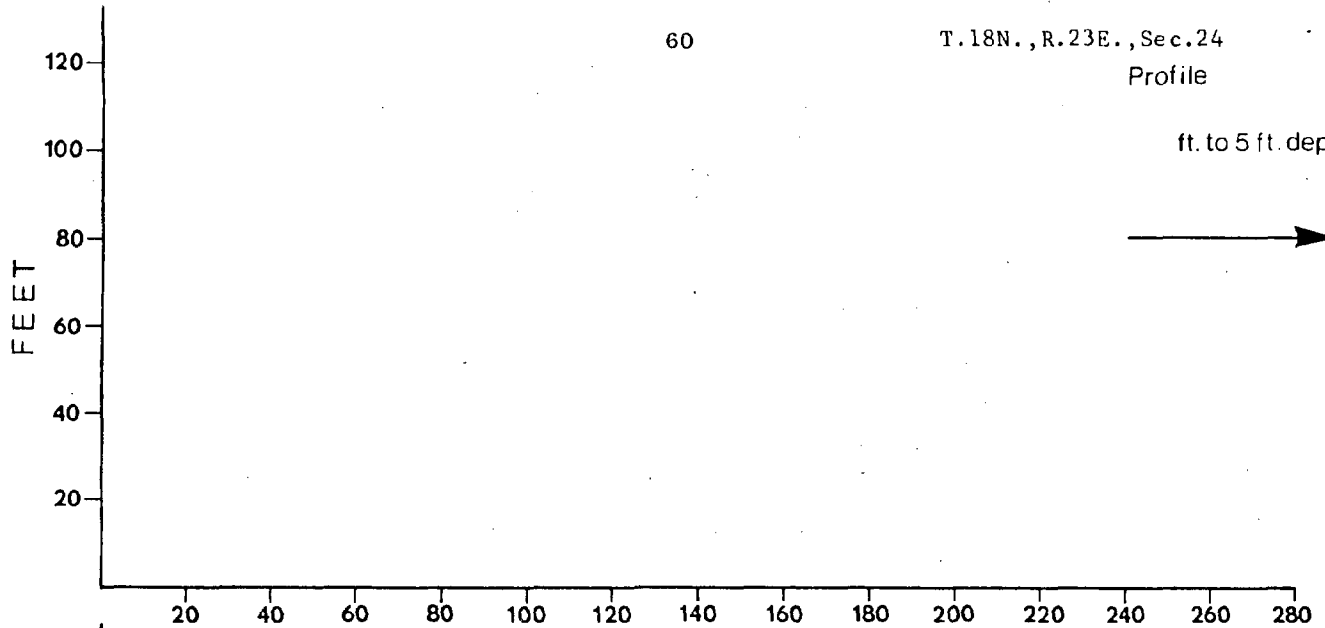
1. BLUFF	a-moderately steep bluffs with considerable slumping in the lower 1/3 of the slope; the upper 2/3 generally vegetated with grasses.	b-large slumps of the total face; vegetation still in place on the slump blocks	c-rapid erosion resulting in high angle slumping and soil falls; at some locations only the lower slopes are involved	
2. TOE	a-till '3A' together with slumped till and sand and gravel	b-slumped sand and gravel	c-till '3A' and slumped till and sand and gravel	
3. BEACH	a-20-30 ft. of cobbles	b-no beach	c-0-30 ft. of cobbles	

60

T.18N., R.23E., Sec.24

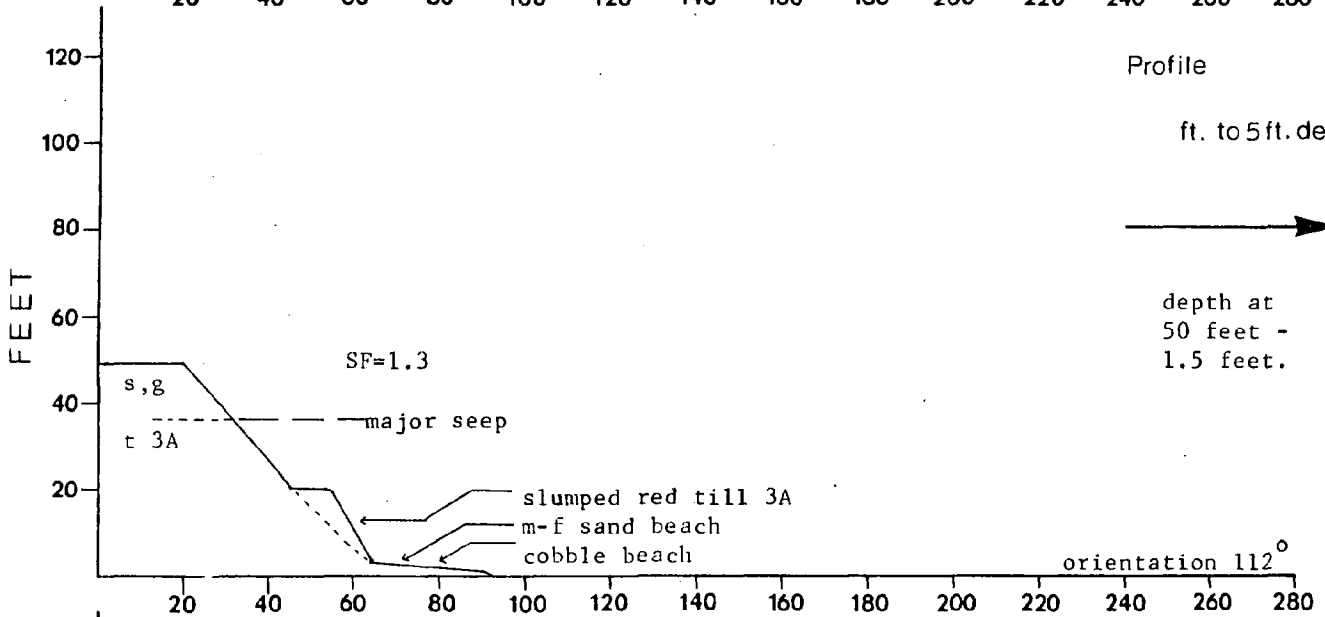
Profile

ft. to 5 ft. depth



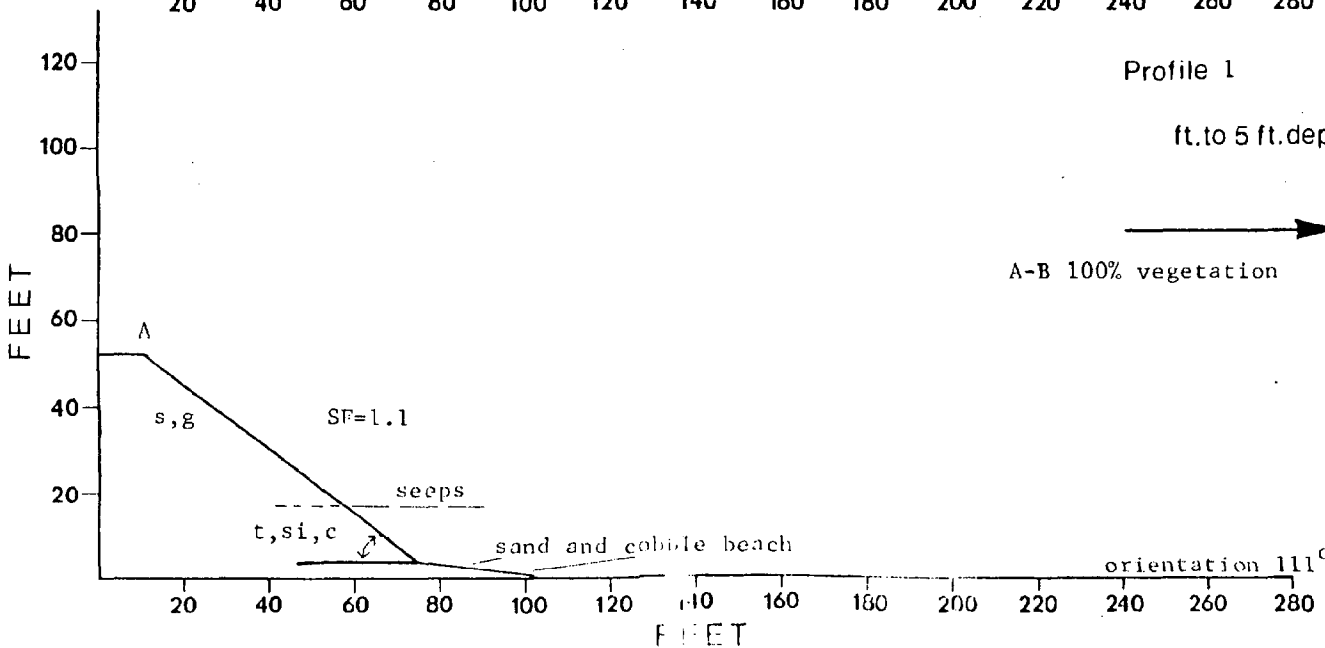
Profile

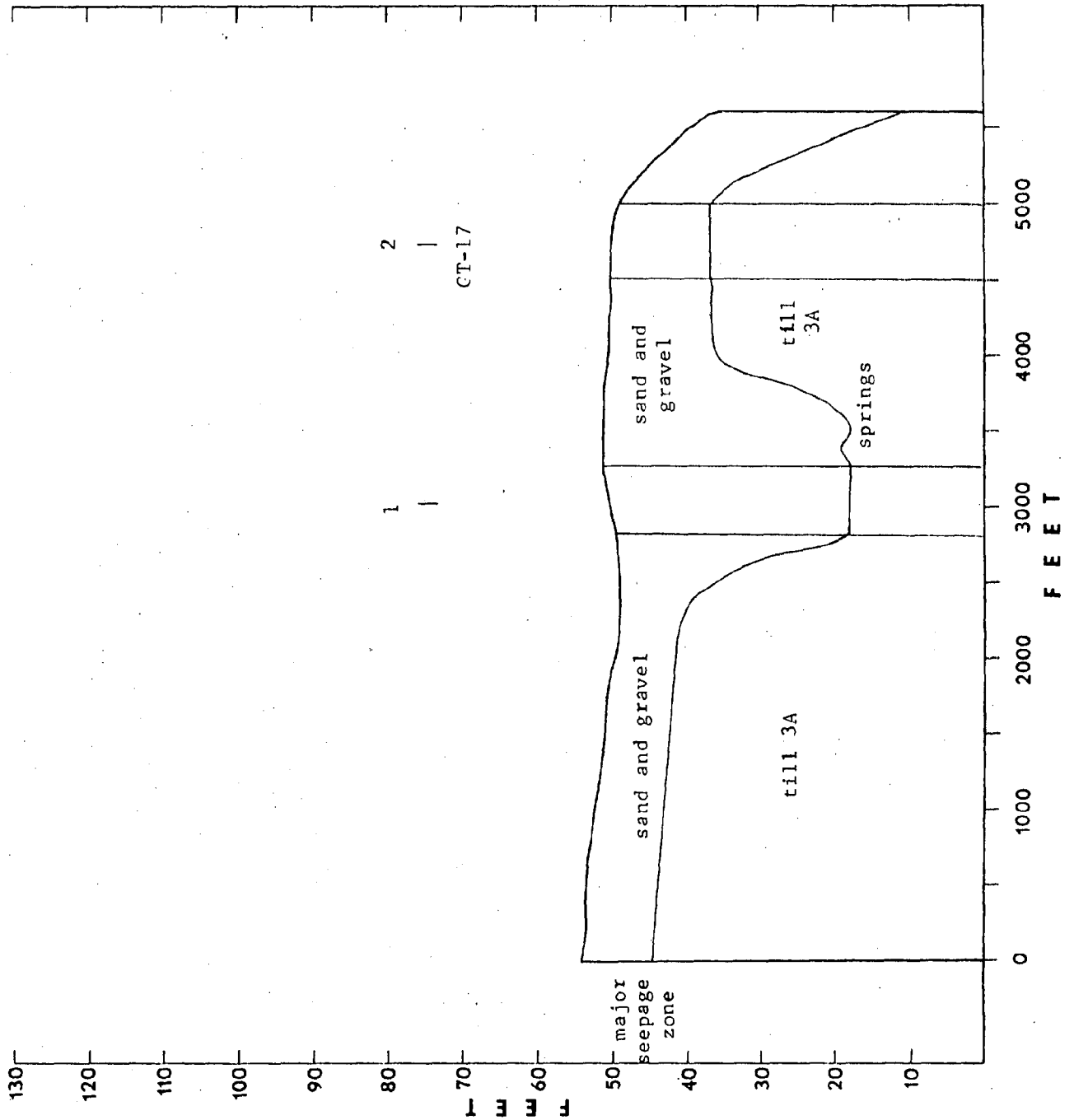
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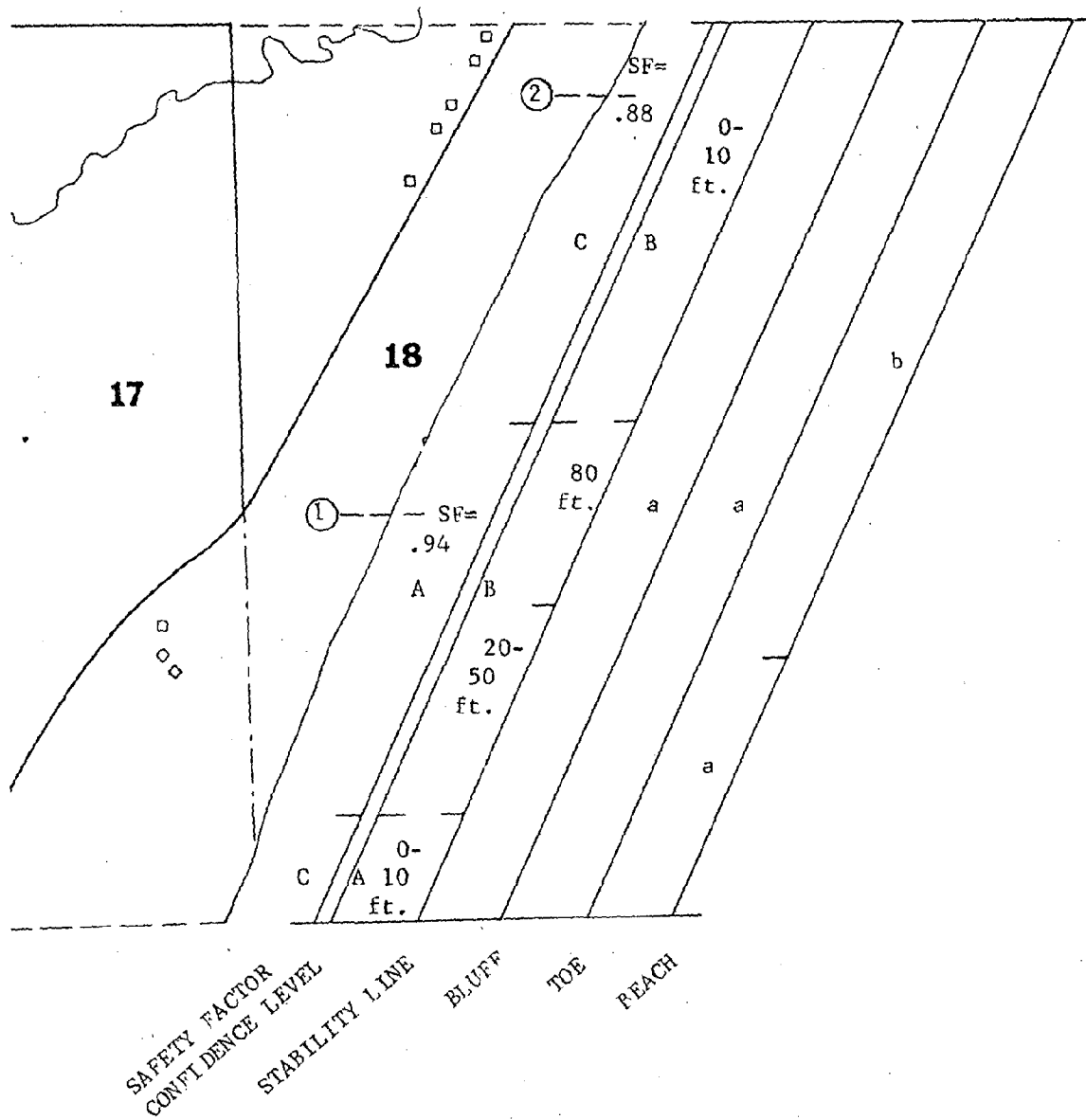
Profile 1

ft. to 5 ft. depth





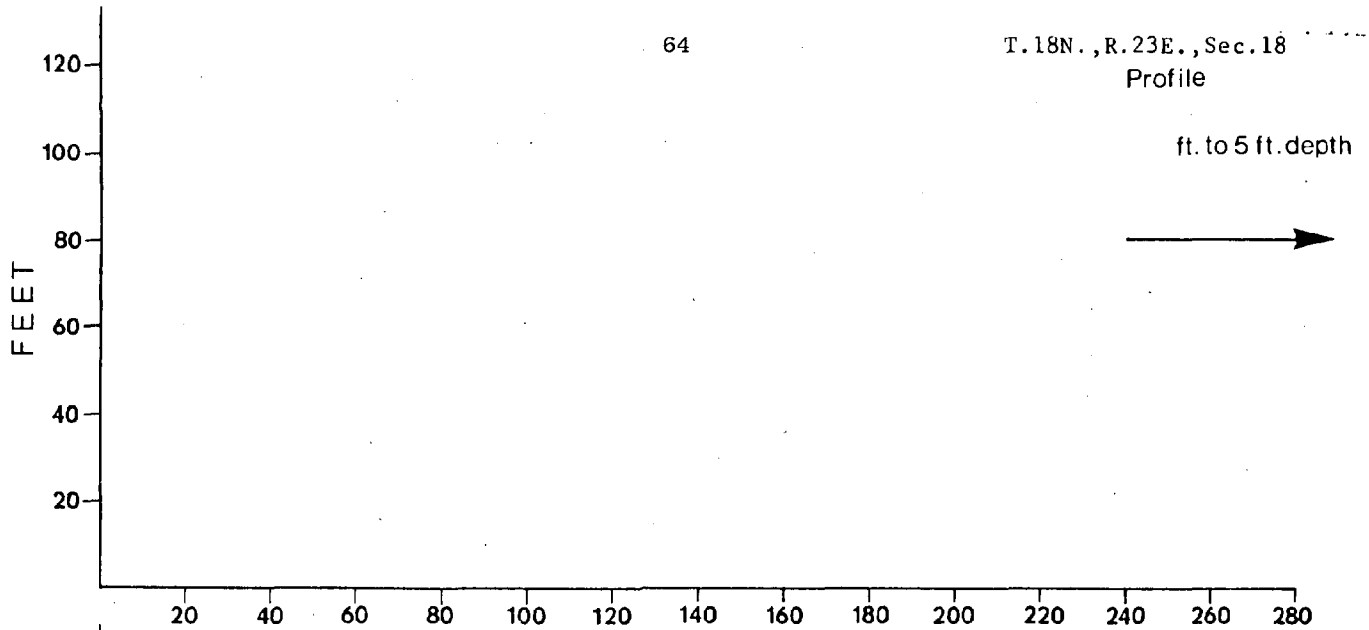




1. BLUFF	a-primarily soil falls, high angle slumping secondary		
2. TOE	a-slumped till '3A', some slumped sand		
3. BEACH	a-20-30 ft. gravel and cobbles	b-5-50 ft. gravel and cobbles	

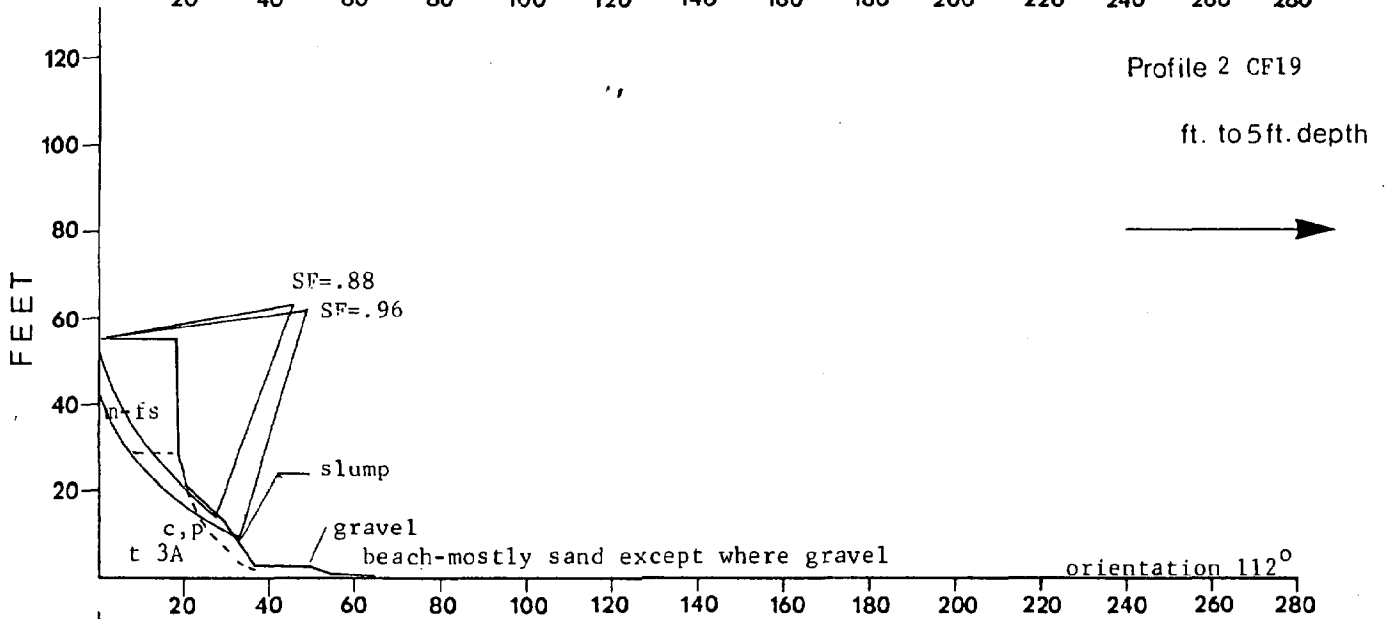
## Profile

ft. to 5 ft. depth



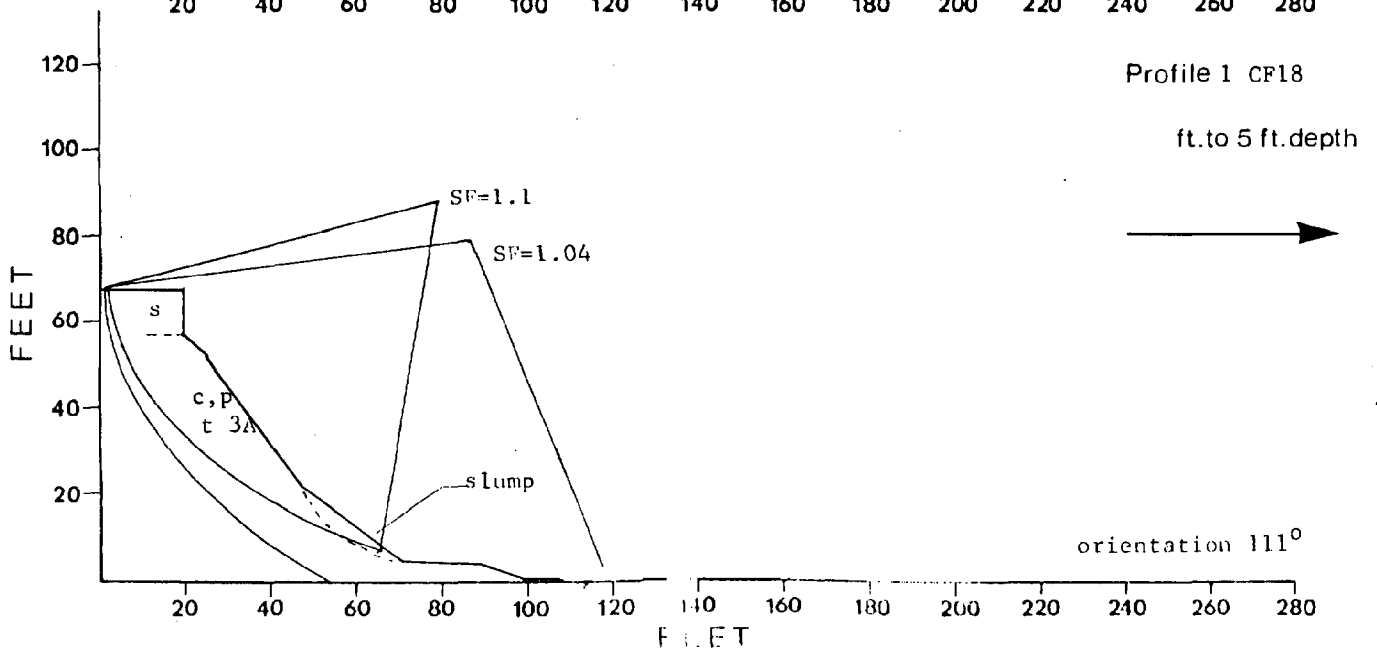
## Profile 2 CF19

ft. to 5 ft. depth

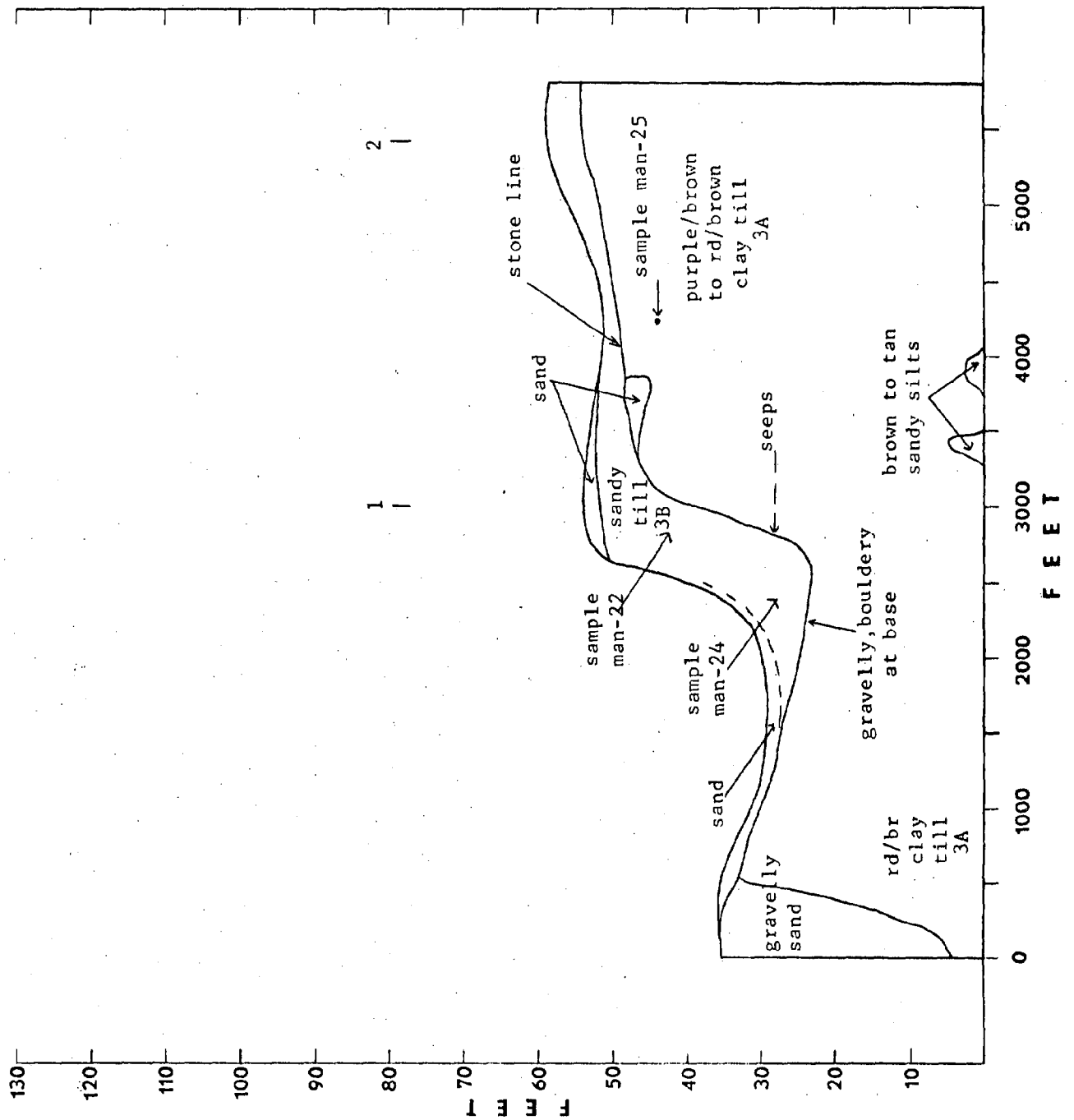


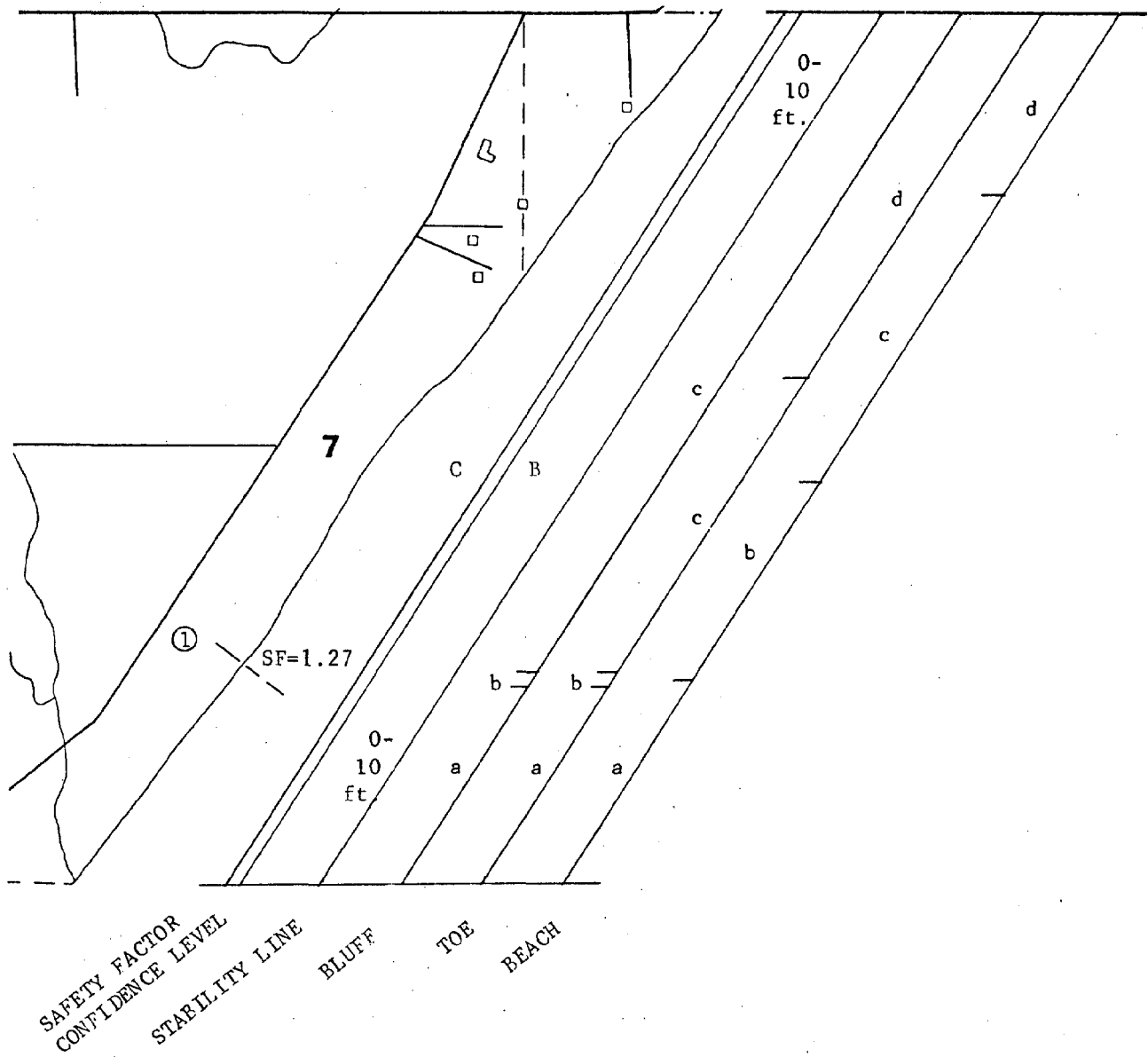
## Profile 1 CF18

ft. to 5 ft. depth



T. 18 N., R. 23 E., Sec. 18



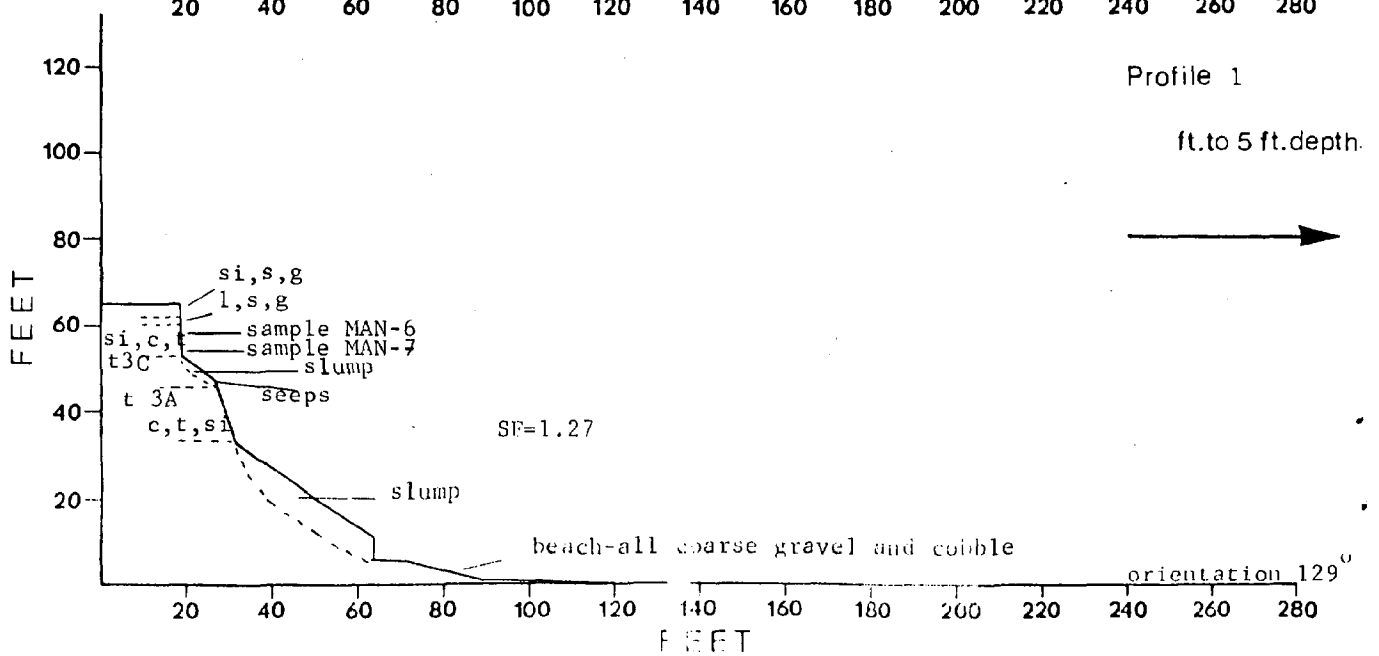
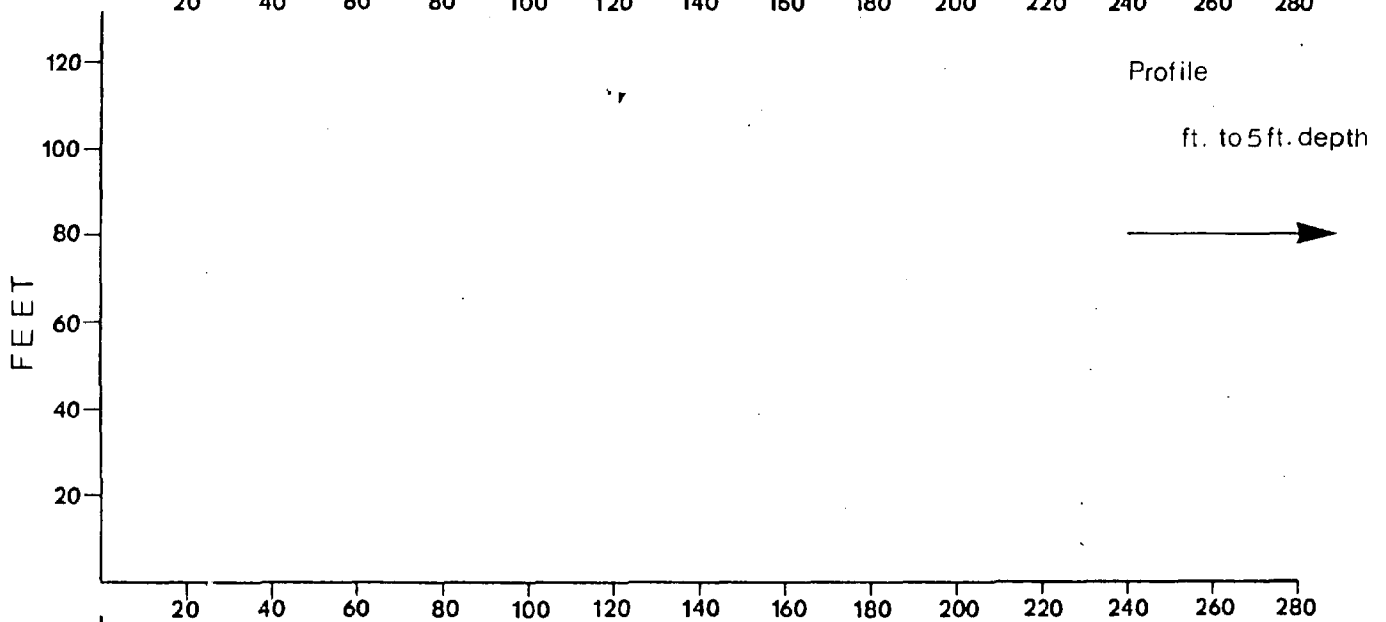
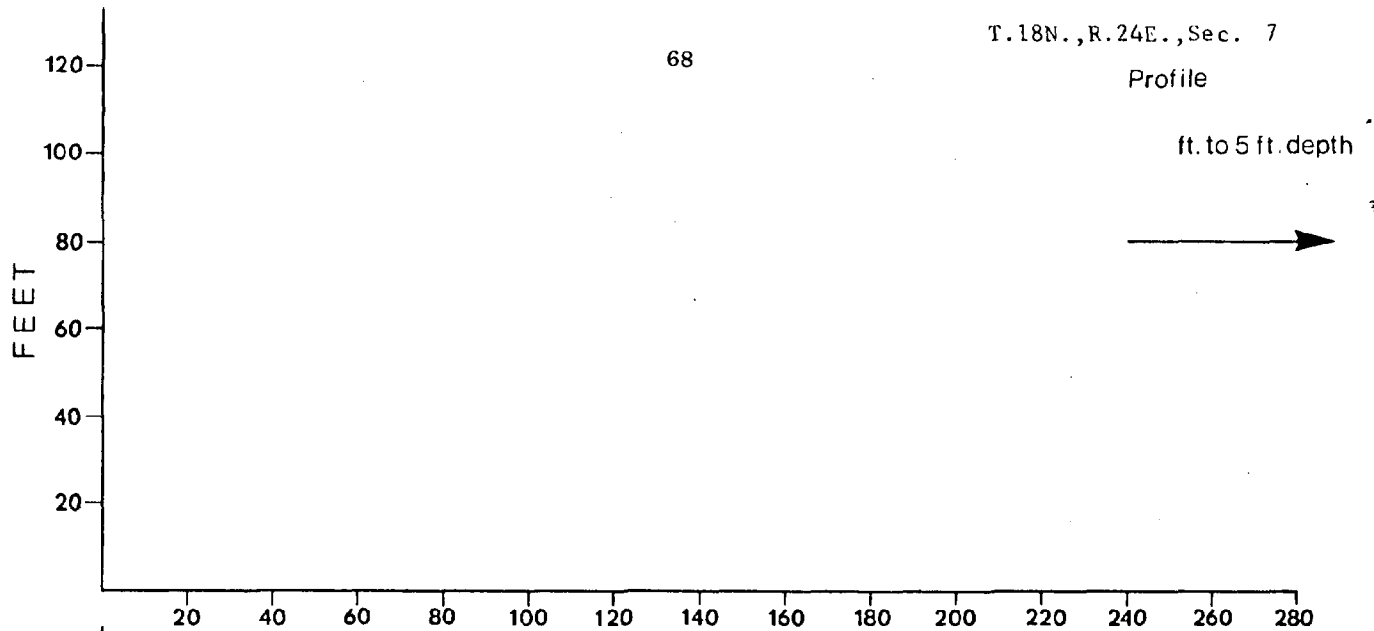
SAFETY FACTOR

- A-less than 1.00
- B-1.00 to 1.25
- C-greater than 1.25

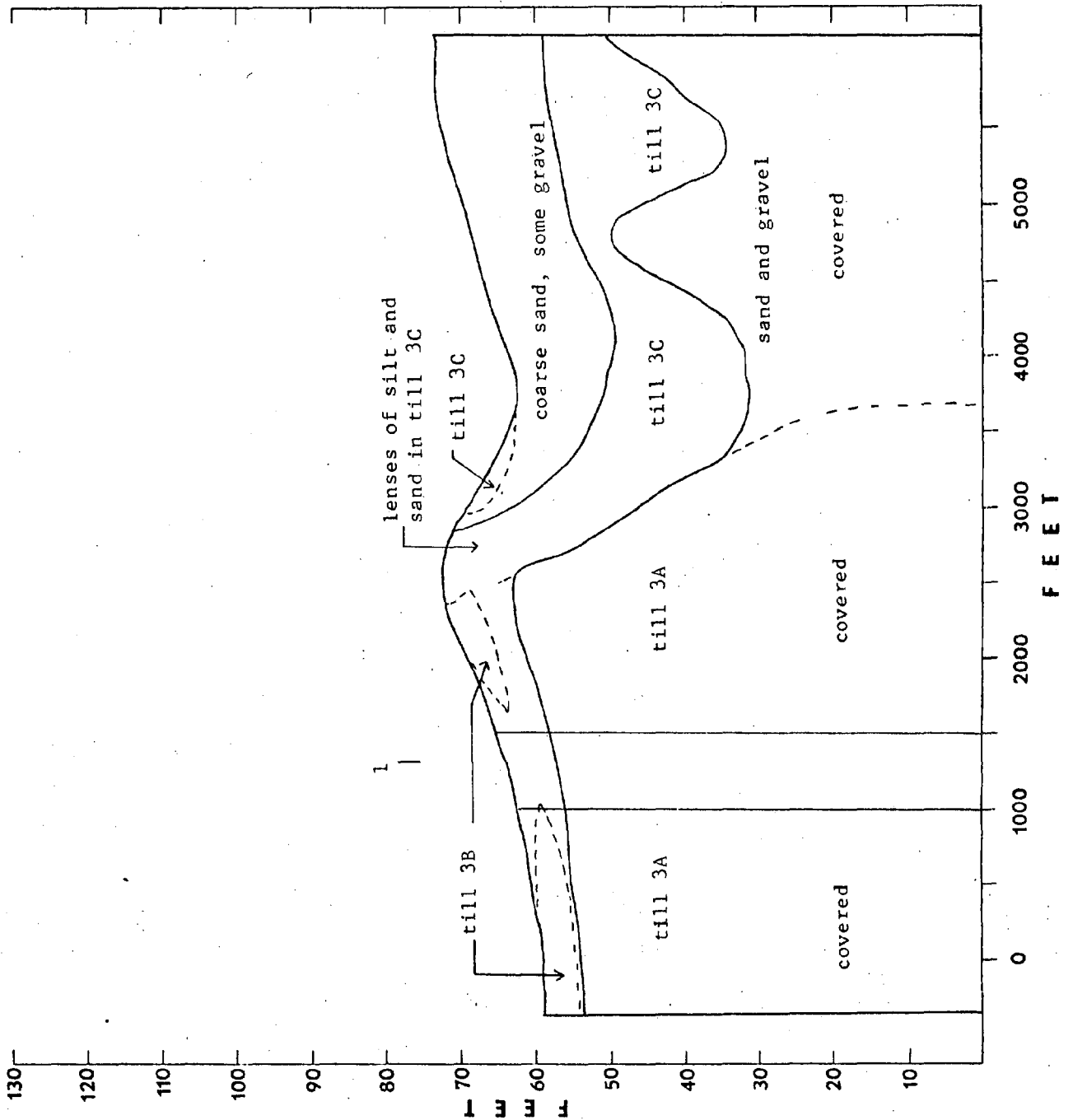
CONFIDENCE LEVEL

- A-boreholes  
(high confidence)
- B-near boreholes  
stratigraphy visible
- C-no stratigraphy  
visible (low  
confidence)

1. BLUFF	a-steep rapidly eroding bluffs; high angle slumps and soil falls; lower slopes covered by slumped material.	b-full face slumping; slump block heavily vegetated.	c-same as segment 'a'	
2. TOE	a-primarily slumped till '3A'	b-slumped till '3A' and overlying lacustrine sediments	c-mainly slumped till '3A'	d-slumped till '3C' and sand and gravel
3. BEACH	a-20-30 ft. cobbles	b-20-30 ft. cobbles and boulders	c-20-50 ft. sand and cobbles	d-20-30 ft. cobbles



## T.18 N., R.24 E., Sec 7





## FIELD REPORT - REACH 26

Location and General Description

Reach 26 extends from about  $\frac{1}{2}$  mile south of the city limits of Manitowoc at Silver Creek Park to the northern jetty at the Manitowoc Harbor. It includes Section 5 of T.18N., R.24E. and Sections 32 and 29 of T.19N., R.24E. This is a north-south distance of 3 miles. The reach has a priority ranking of 26 and is therefore the eleventh most highly ranked reach north of Ozaukee County.

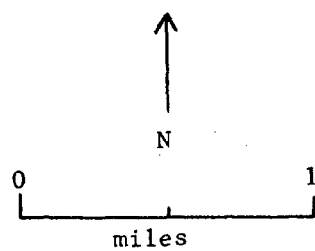
At the southern boundary of the reach land use is primarily agricultural with a scattering of private residences along the shoreline. Within  $\frac{1}{2}$  mile the shoreline is in parkland and at the northern two-tenths of a mile the shoreline is occupied by the campus of the UW-Manitowoc Center. Moving northward the reach passes through residential areas until reaching about the center of Section 32 at which point it enters Red Arrow Park. From the north end of the park to the end of the section land usage is primarily industrial.

Long term erosion rates have been measured at two points in Reach 26 and both gave values of 1 foot/year.

Section 5

At the southern end of Section 5 the bluffs are 70 feet high and are made up of 14 feet of coarse sand overlying 10 feet of till 3C which in turn overlies almost 50 feet of sand and gravel. Moving northward from this point both the upland surface and the contact between the stratigraphic units drop rapidly. At the south valley wall of Silver Creek the contact between the lower sand and gravel unit and till 3C is 40 feet lower than at the south sectionline, 0.6 miles to the south.

From the south section line to about 0.15 erosion is very rapid and slumping and sliding of the lower sand and gravel in this high bluff area appears to cause quite rapid retreat of the bluffs. From 0.15 to about 0.7 at the mouth of Silver Creek slope failures occur mainly as slumps which often involve most, if not all,



PUBLIC PERCEPTION: EROSION HAZARDS { 3 Public safety  
2 Property  
1 Environment

1952 SHORE DAMAGE SURVEY - 1-310,000 (1952)

RECESSION RATES { 8 Long-term - approx. 100 yrs.  
Short-term - approx. 10 yrs. } (in feet/yr.)

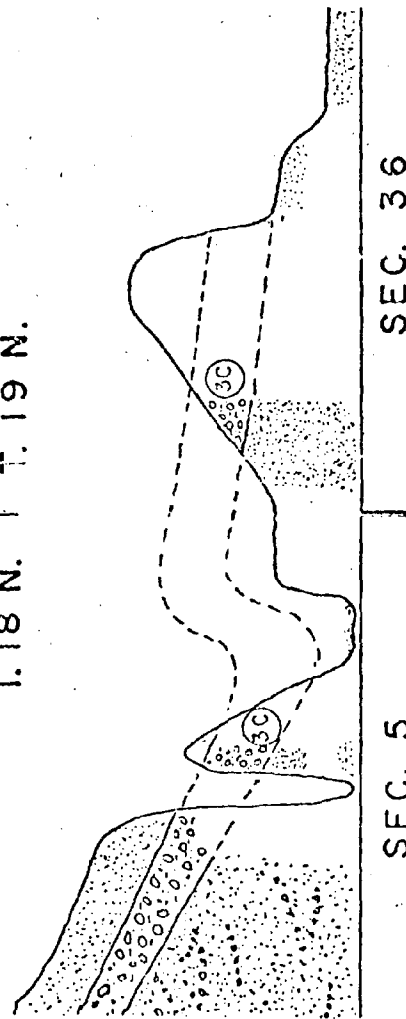
SHORE HEIGHT (in tens of feet)

SHORE PROTECTION STRUCTURES

(2) - HOUSES/MILE - Non-urban

• - BOAT RAMPS

T. 18 N. | T. 19 N.



REACH 26

1000 ft.

Vertical Exaggeration = 50 X

## LEGEND

	SAND		SILT		COVERED OR INACCESSIBLE
	GRAVEL		CLAY		TILL
	SAND AND GRAVEL		CLAYEY SILT, SILTY CLAY		MIXED SEDIMENTS

of the face of the bluff. From Silver Creek north to the end of Silver Creek Park at about 0.9 there are no bluffs and shoreline erosion occurs through the action of waves against the low lying shoreline. From this point north to the section line slopes are gentle and completely vegetated with grasses.

In the south half of the section sand and cobble beaches are present, ranging from between 20 and 40 feet in width. From about 0.5 to the mouth of Silver Creek at 0.7 sand beaches predominate and range in width from 0 to 20 feet. From Silver Creek north to the northern section line the beaches are once again made predominantly of sand and are for the most part wider than 50 feet.

Two structures were described in this section. The first of these was a bulkhead constructed with sheet piling which was located at about 0.5. The second was a revetment that was located at 0.66.

There was one long term erosion rate measurement made near the northern border of the section and showed a rate of 1 foot/year. Housing density was given as 4 houses per mile. Finally, a water depth measurement taken in the vicinity of Profile #1 showed the water 50 feet from shore to be 2.5 feet deep.

#### Section 32

At the south section line the bluffs of this section are 18 feet high and are composed entirely of sand. The bluffs rise steeply to the north and at the site of Profile #1 (also the location of boring GT-19) the bluffs have risen to a height of almost 30 feet and till 3C is now exposed overlying the sand. The Profile site, which is about 0.15 mile north of the south section line, marks the northernmost area in which good exposures of the bluff can be found. North of this point the bluffs are heavily vegetated and where exposures are present it is often found that the surface of the bluff is veneered with fill material that has been pushed over the edge of the bluff.

The surface continues to rise to the north until about 0.4 at which point the bluffs are about 50 feet high. Northward from this point the bluffs lose height rapidly and by about 0.8 have completely given way to a low sand plain along the shoreline.

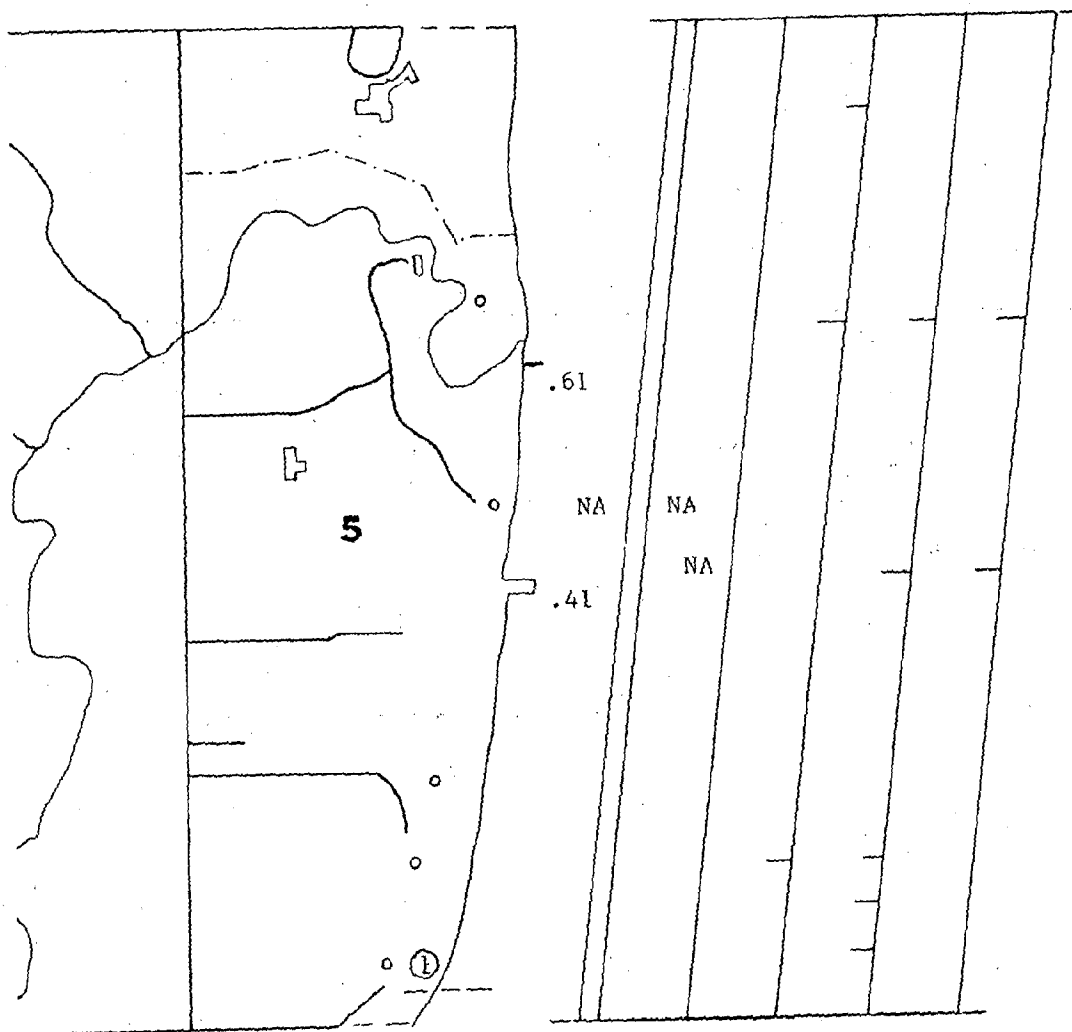
The beaches along Section 32 are excellent sand beaches, ranging in width from 30 to 50 feet from the south and extending from the south section line up to about 0.7 at the north end of Red Arrow Park. North of this point the beaches are either absent or obtain a maximum of about 20 feet.

Two protective structures were described in this section. One of them was a sheet piling bulkhead and the other was a low revetment.

One long term recession measurement was available near the south section line and showed an average recession rate of 1 foot/year. Water depths were checked at the vicinity of Profile #1 where it was found that the water was less than 2 feet deep at a distance of 50 feet from the shoreline.

#### Section 29

As part of a separate investigation the author inspected the south half of Section 29 (the remainder is Manitowoc Harbor) and photographed the structures lying along the shoreline in this area. It was found that the entire shoreline is armored by heavy revetments or bulkheads and that the bulkheads were backed by sand, some of which is undoubtedly fill. Since this is a fully armored section, Section 29 has been deleted from this investigation.



SAFETY FACTOR  
CONFIDENCE LEVEL  
STABILITY

FOR  
CE LEVEL  
STABILITY LINE

PLUFFE

TOE

BEACH

SAFETY FACTOR

A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

CONFIDENCE LEVEL

### A-boreholes

(high confidence)

B-near boreholes  
stratigraphy visible

C-no stratigraphy  
visible (low  
confidence)

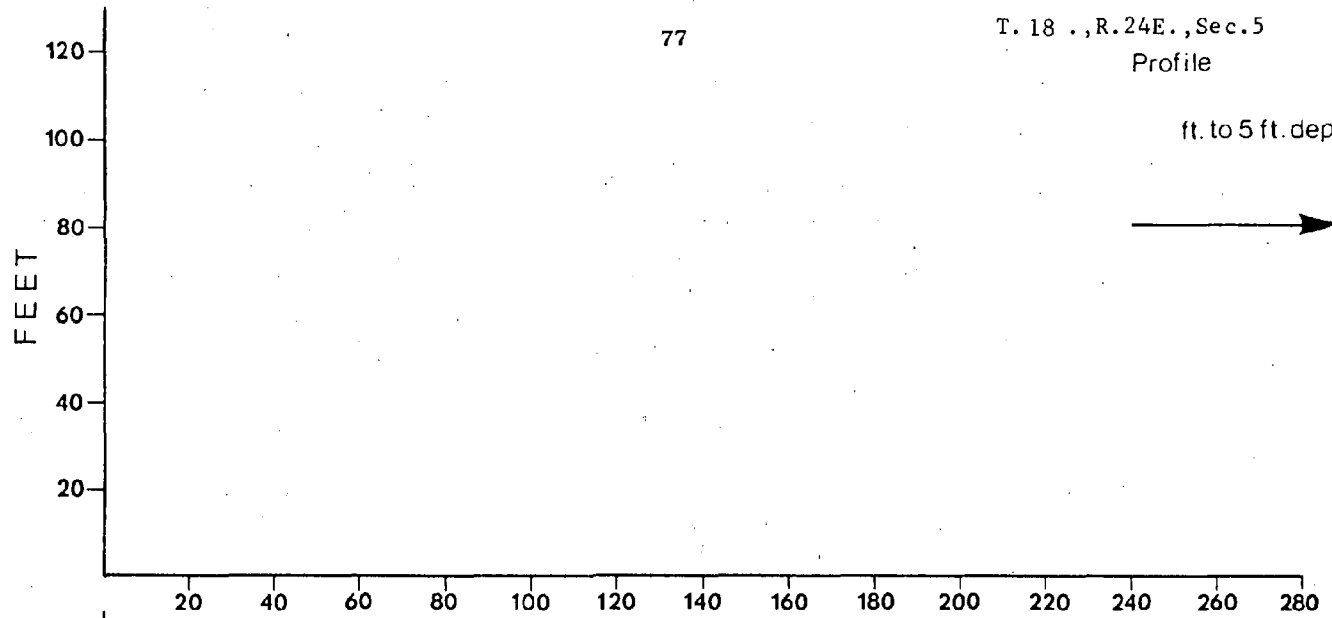
1. BLUFF	a-rapidly eroding high bluff; slumping and sliding, largely based in sand and gravel in lower half of the slope	b-large scale slumping; slump blocks vegetated	c-no bluff	d-grass covered stable slopes
2. TOE	a-slumped sand and gravel	b-slumped till '3C'	c-slumped till '3C' and sand	d-slumped till '3C'
	e-slumped till '3C' and sand	f-sand		
3. BEACH	a-20-40 ft. sand and cobbles	b-0-20 ft. sand	c-greater than 50 ft. of sand	

77

T. 18 ., R. 24 E., Sec. 5

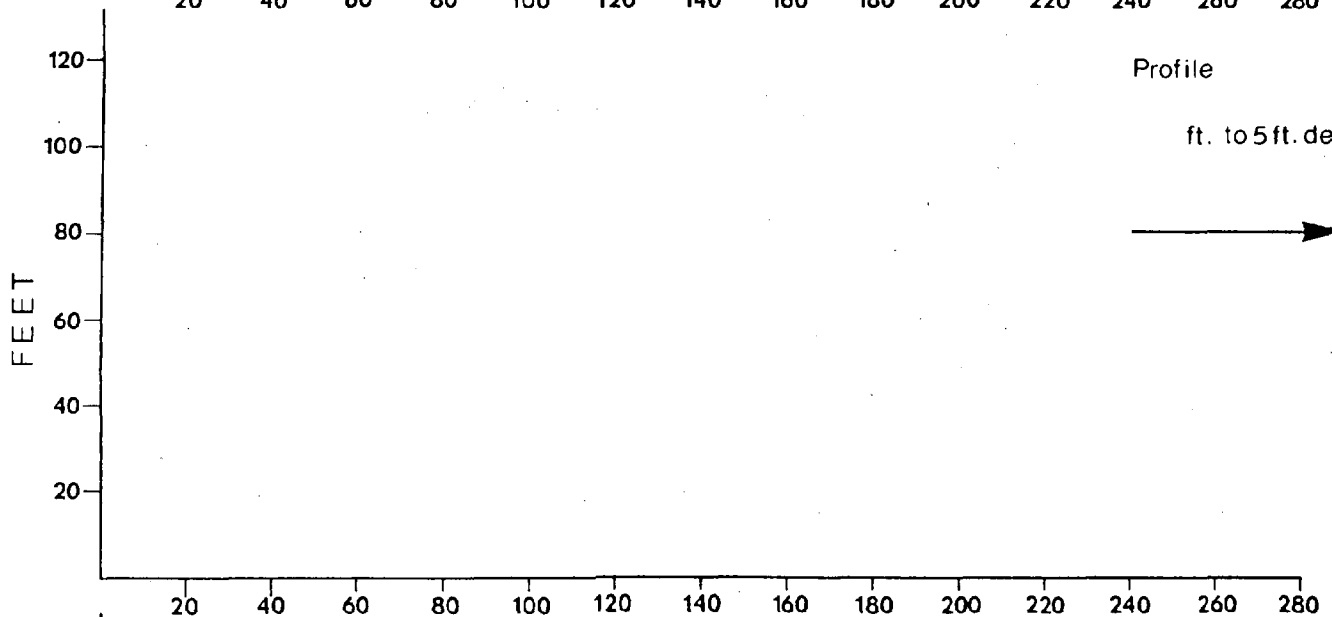
Profile

ft. to 5 ft. depth



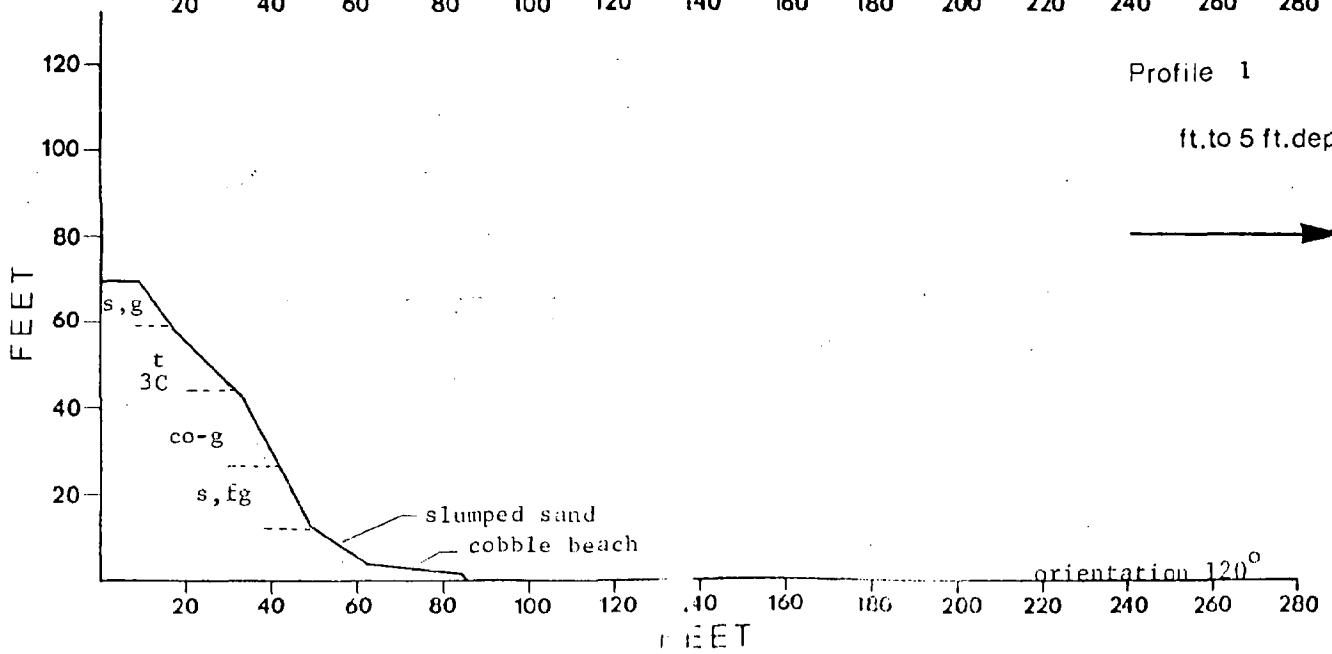
Profile

ft. to 5 ft. depth

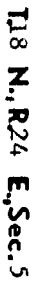


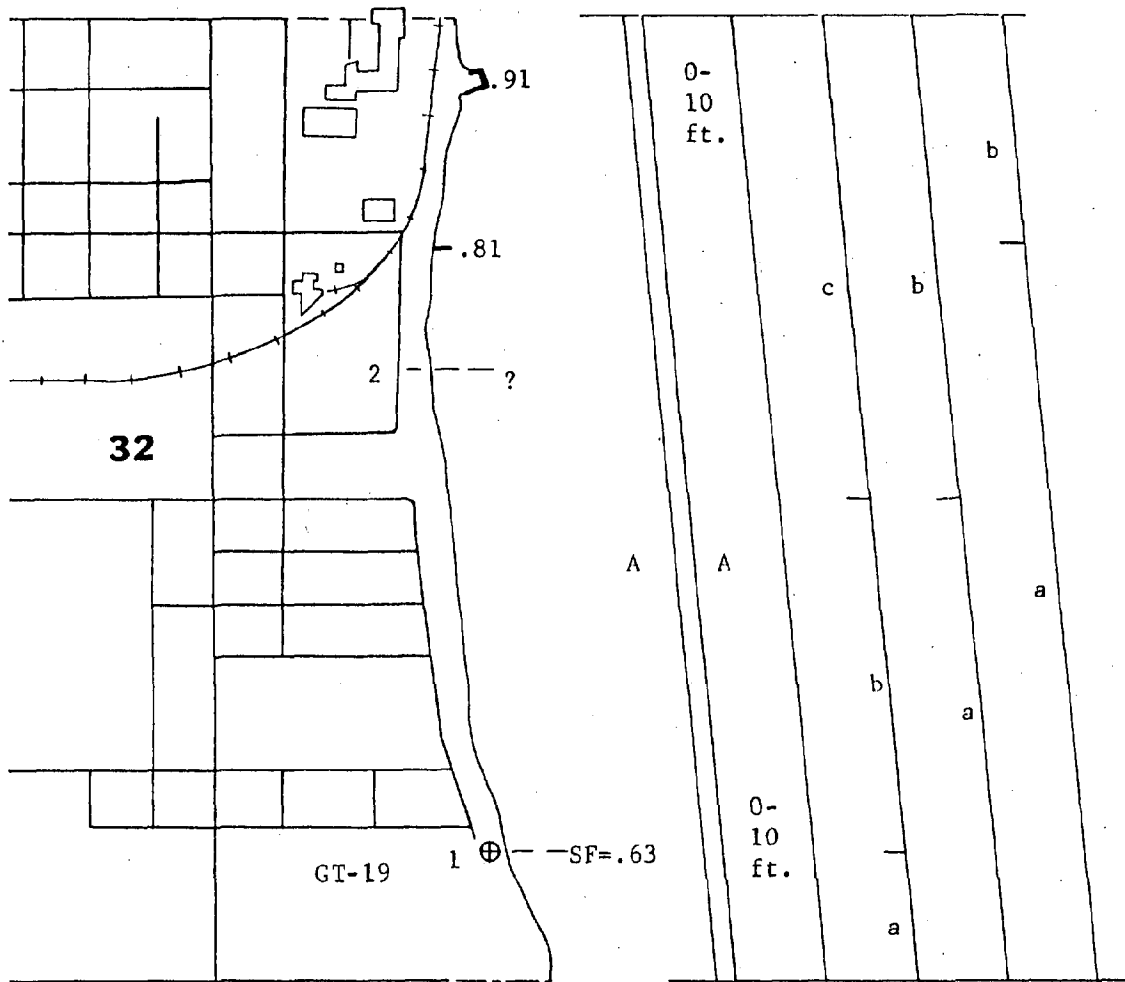
Profile 1

ft. to 5 ft. depth









SAFETY FACTOR  
CONFIDENCE LEVEL  
STABILITY LINE  
BLUFF  
TOE  
BEACH

SAFETY FACTOR

A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

CONFIDENCE LEVEL

A-boreholes

(high confidence)

B-near boreholes

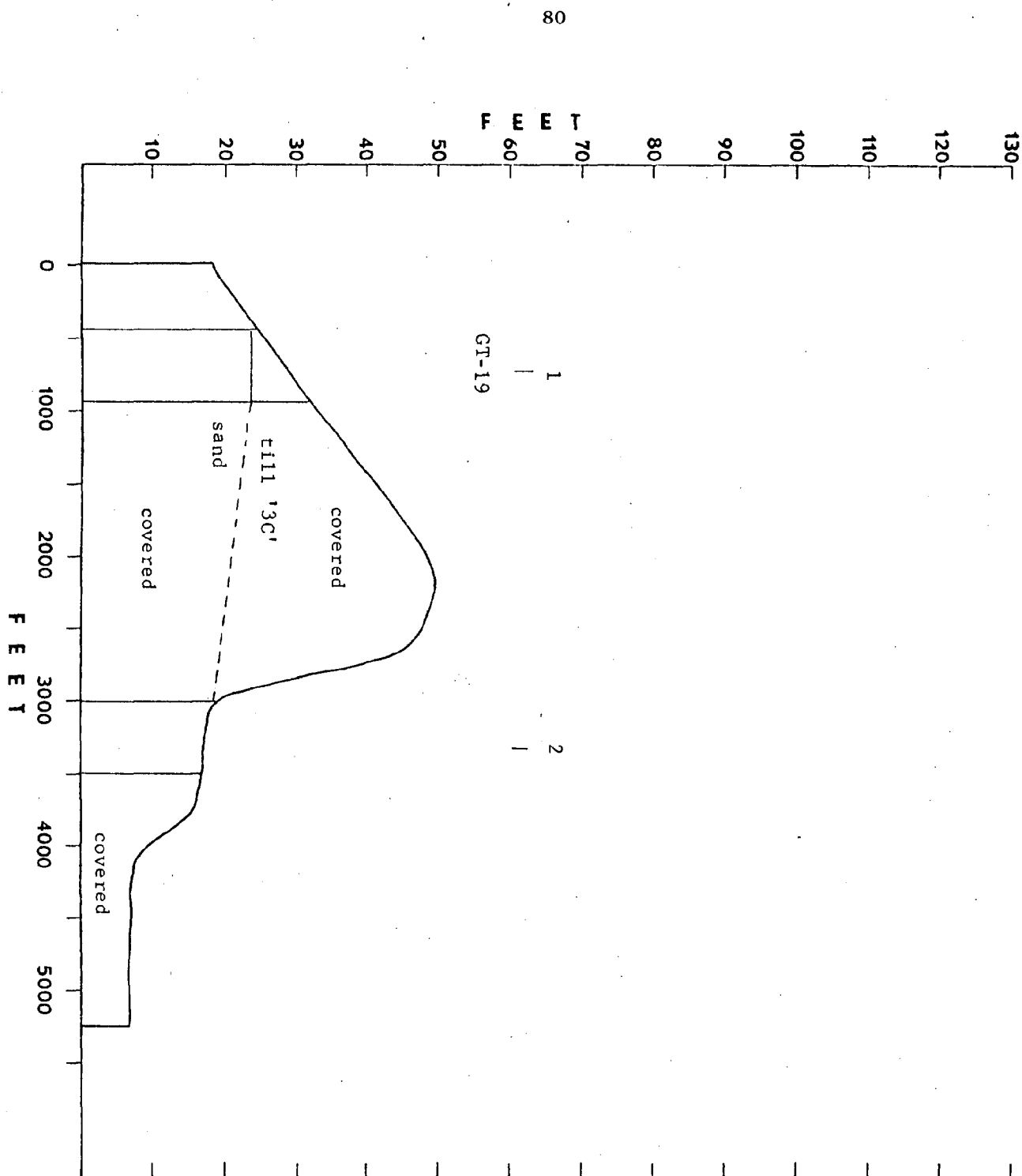
stratigraphy visible

C-no stratigraphy

visible (low

confidence)

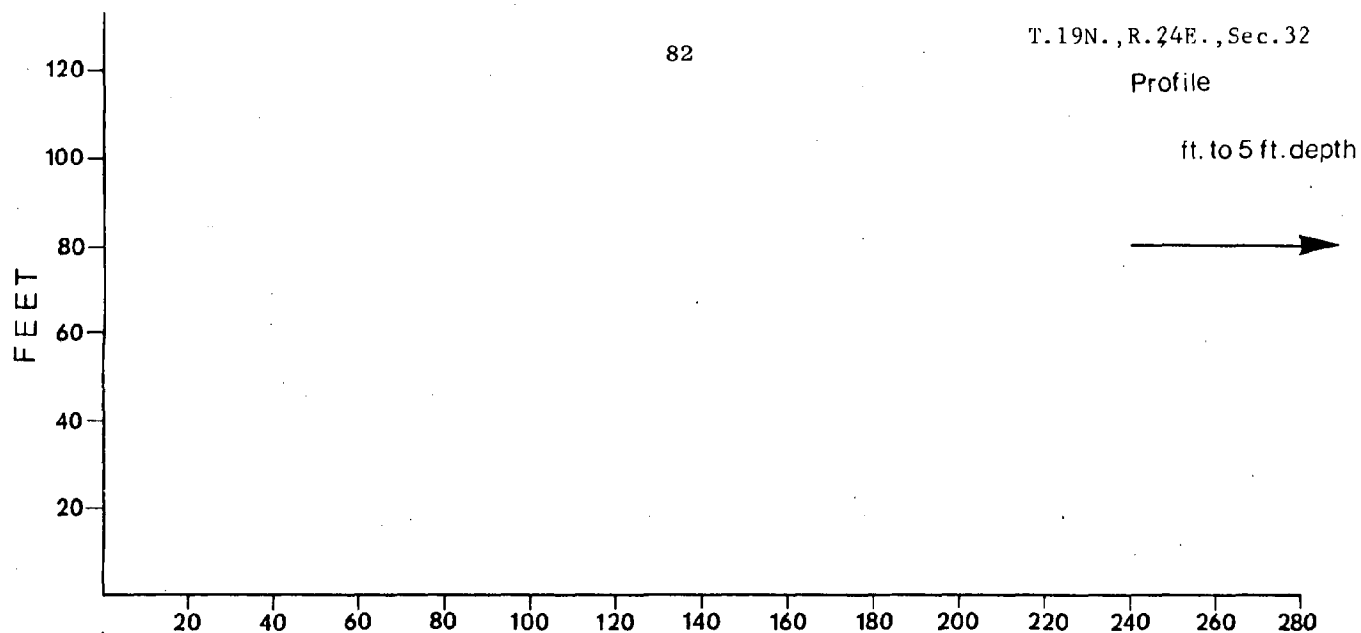
I. 19N., R. 24 E., Sec. 32



1. BLUFF	a-low bluff, mostly slumped till and sand	b-high bluff, fully vegetated and much of the slope has a veneer of fill	c-no bluffs; sand
2. TOE	a-slumped sand and till '3C'	b-sand	
3. BEACH	a-30-50 ft. sand	b-0-20 ft. sand	

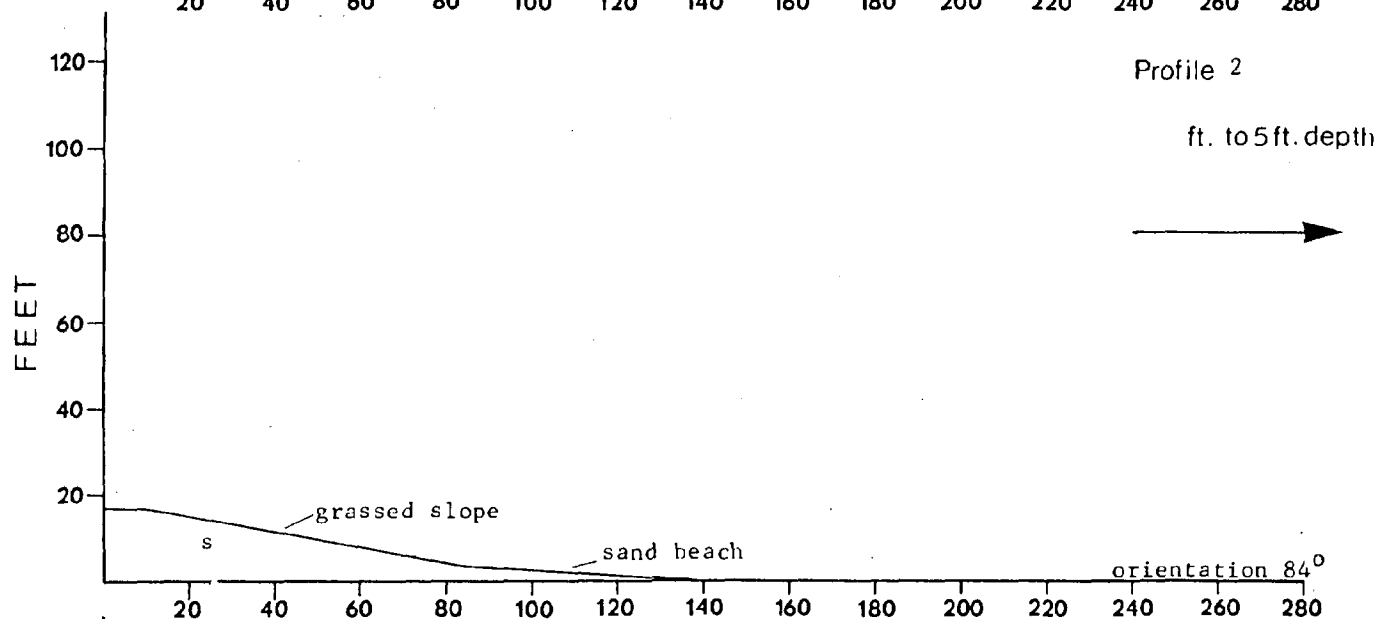
Profile

ft. to 5 ft. depth



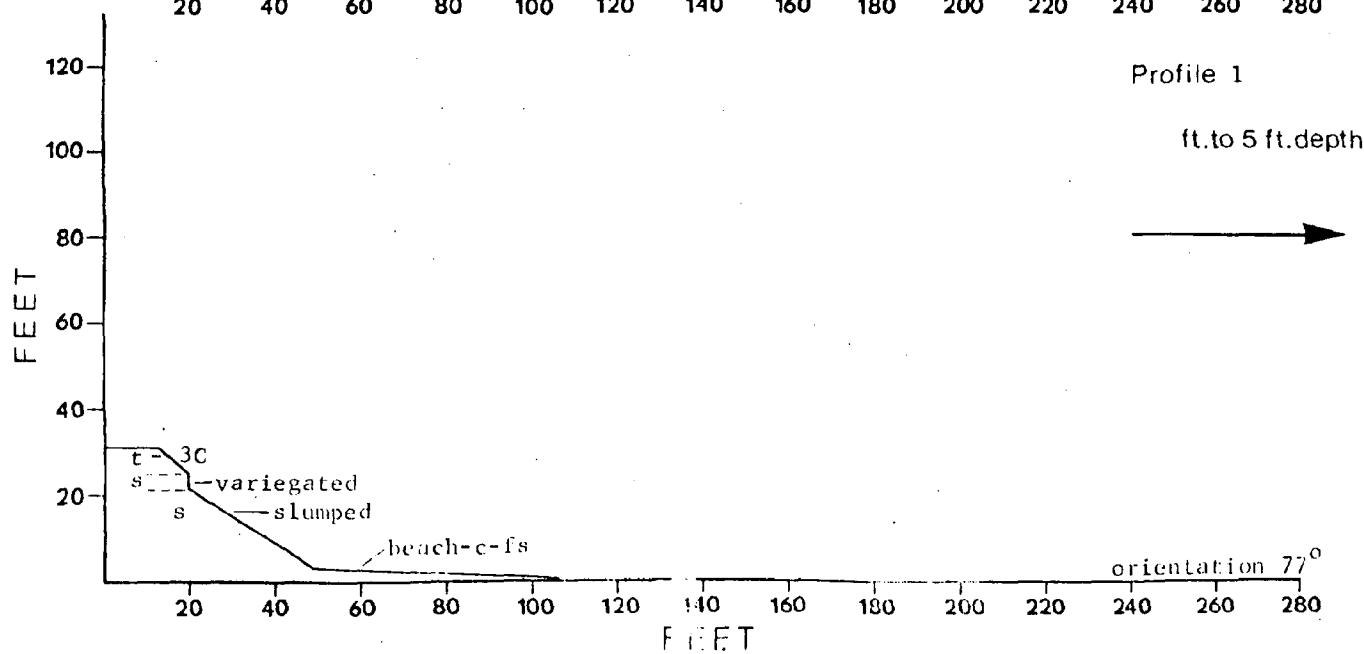
Profile 2

ft. to 5 ft. depth



Profile 1

ft. to 5 ft. depth



## FIELD REPORT - REACH 27

Location and General Description

Reach 27 consists of the area between the northern jetty of the harbor at Manitowoc and the town of Two Rivers. The reach includes the shoreline in portions of Sections 20, 17, 16, 10, 11, and 1 of T.19N., R.24E. The reach has a priority rating of 16, and is the most highly ranked reach in the Sheboygan-Manitowoc study area.

Over most of this reach, the shoreline consists of a well constructed revetment with either sand, fill, or both behind. The immediate shore zone is separated from residential, commercial, or park lands by a four lane highway in most of the reach.

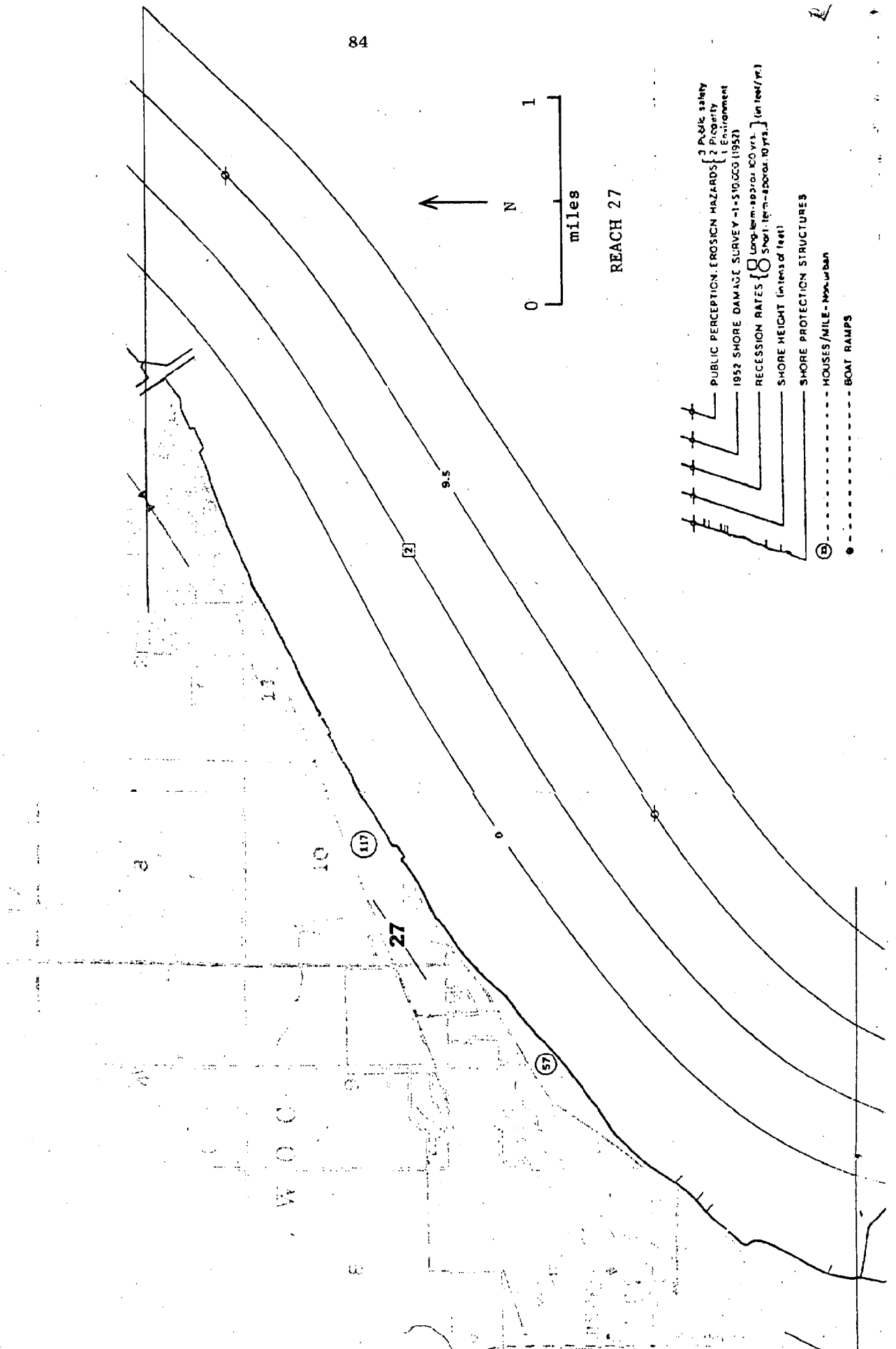
A few small, scattered beaches are found in this reach, but many appear to be ephemeral. Some of the beaches present when the reach was inspected were not found to be visible on the air photographs taken earlier in the year, and some beaches shown on the photos were no longer present.

Because this reach is, with the exception of a single section to be discussed later, protected by heavy structures, which over large areas are backed by fill, no profiles or longitudinal profiles were prepared for most sections in the reach.

Significant exposures of stratigraphy and unprotected shoreline segments are, however, present in Section 16. The remainder of this discussion will, therefore, be confined to this section.

Section 16

The bluffs in Section 16 rise to a maximum height of about 30 feet above the beaches. In the southwestern portion of the shoreline in that section, very little stratigraphy is exposed due to heavy vegetative cover and the large amount of slumped silt that covers the greater part of even actively eroding areas. About 3 feet of buff silt over 2 feet of silty clay was the

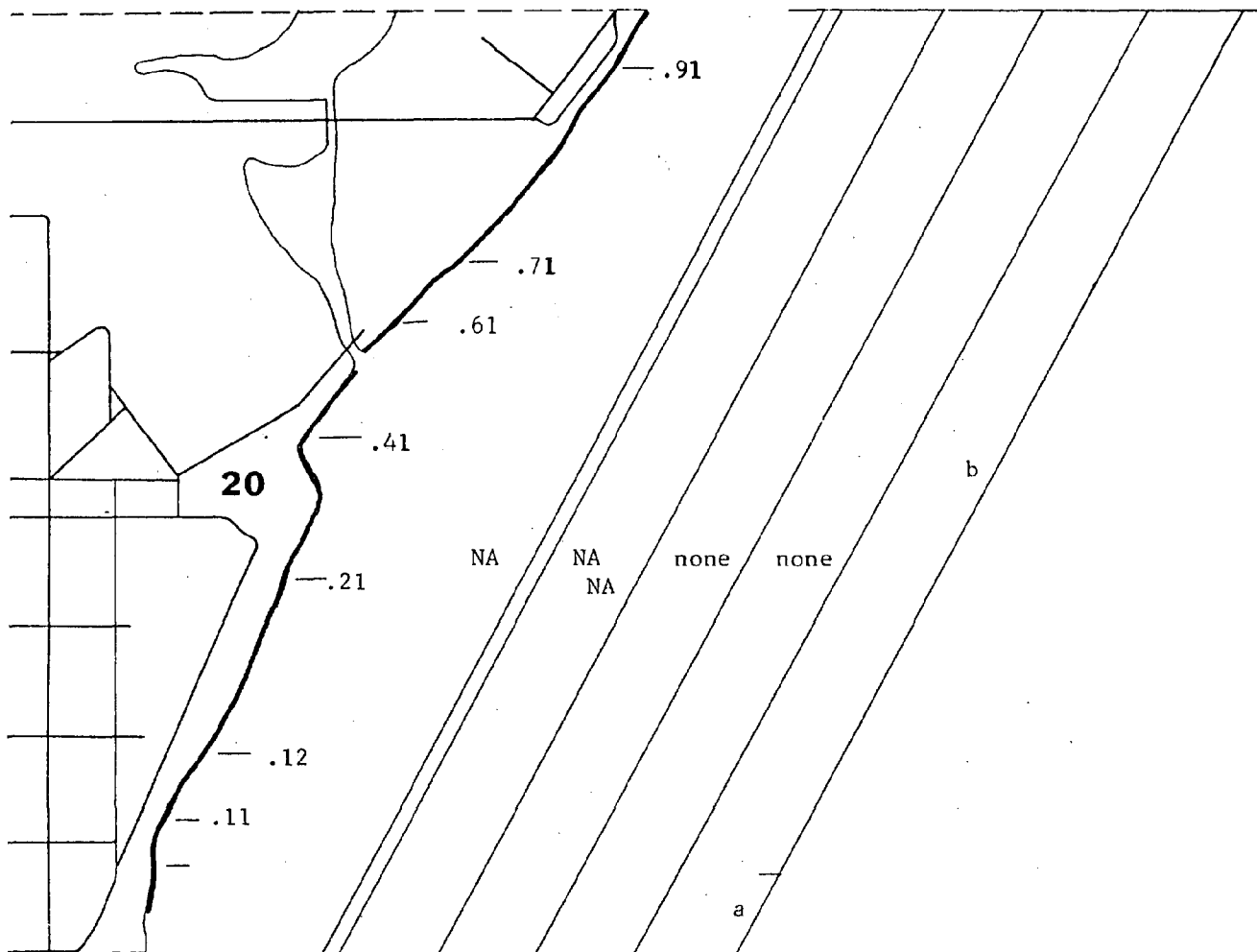


maximum section observed in the southwestern portion of Section 16.

In the northeastern portion of the section, several excellent exposures were located from which it was possible to determine the stratigraphy from the top of the bluff to beach level. The section was found to consist of basal lacustrine sands, which were overlain by a one to three foot thick bed of till 3B, which was in turn overlain by roughly 10 feet of the same red silty clay observed to the southwest. The silty clay was in turn overlain by the bluff silt found in the equivalent stratigraphic position in the southwestern exposure. The silt was overlain by a highly oxidized till identified as till 3C, and the section was capped with about a foot of sand. A thin greenish-gray sand layer in this unit was found to make an excellent marker bed.

Although essentially flat lying where first observed, all of the units described were found to plunge to the northeast at the wayside on top of the hill in Section 16. The beds were then overlapped by a horizontally bedded sand. The top of the bed of till 3C dipped into the subsurface at the north section line.





SAFETY FACTOR  
CONFIDENCE LEVEL  
STABILITY LINE  
BLUFF  
TOE  
BEACH

SAFETY FACTOR

A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

CONFIDENCE LEVEL

A-boreholes

(high confidence)

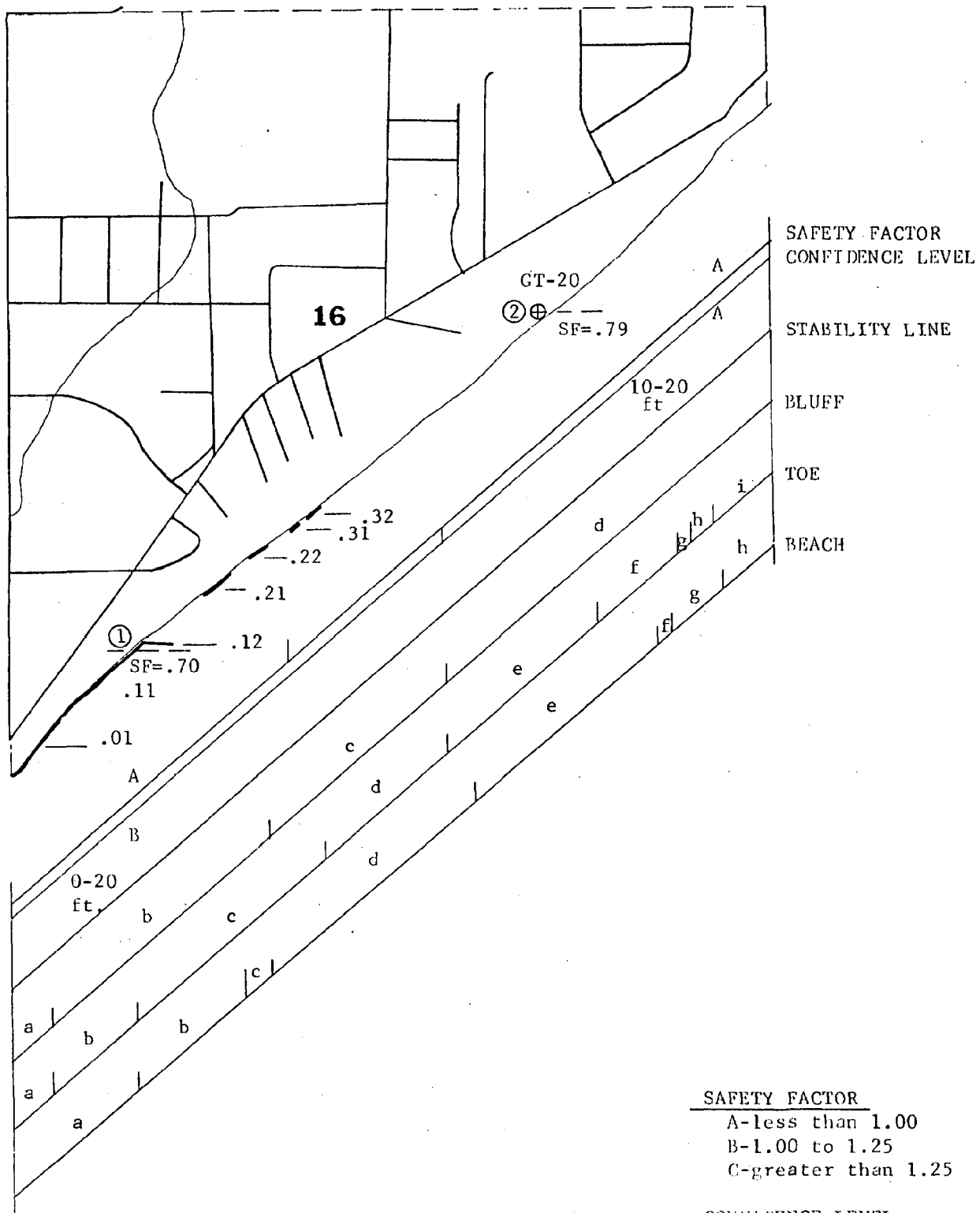
B-near boreholes

stratigraphy visible

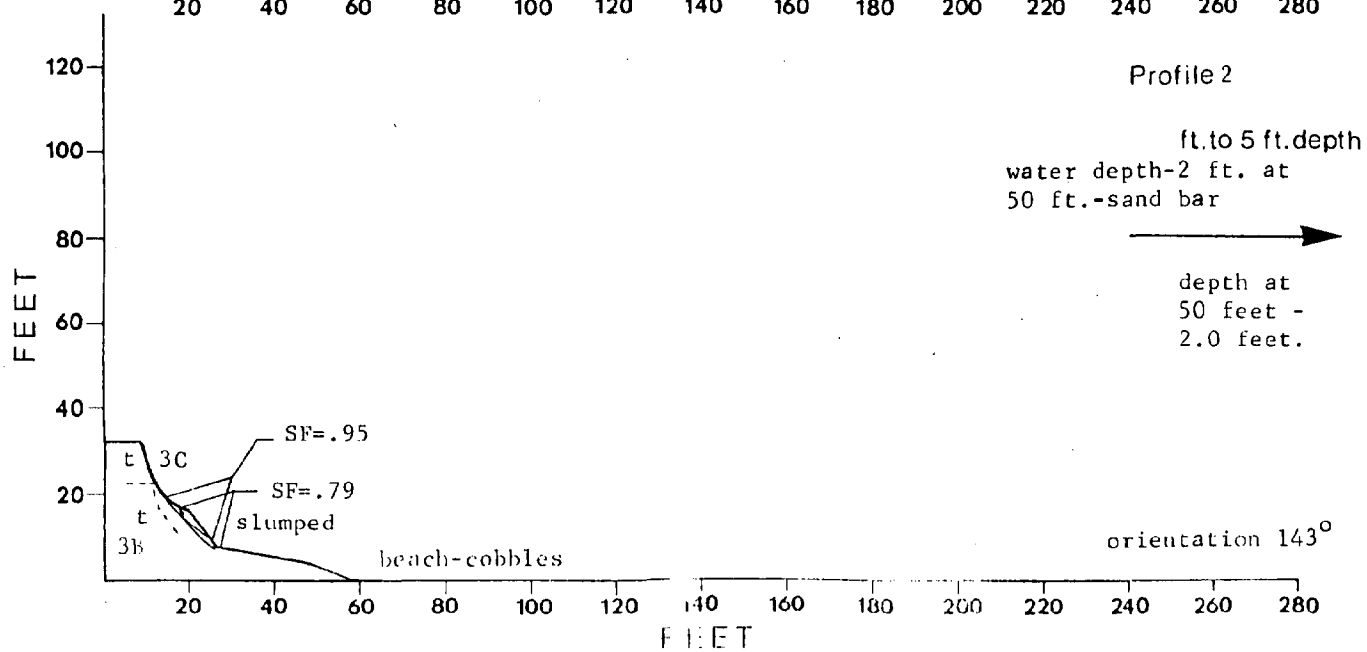
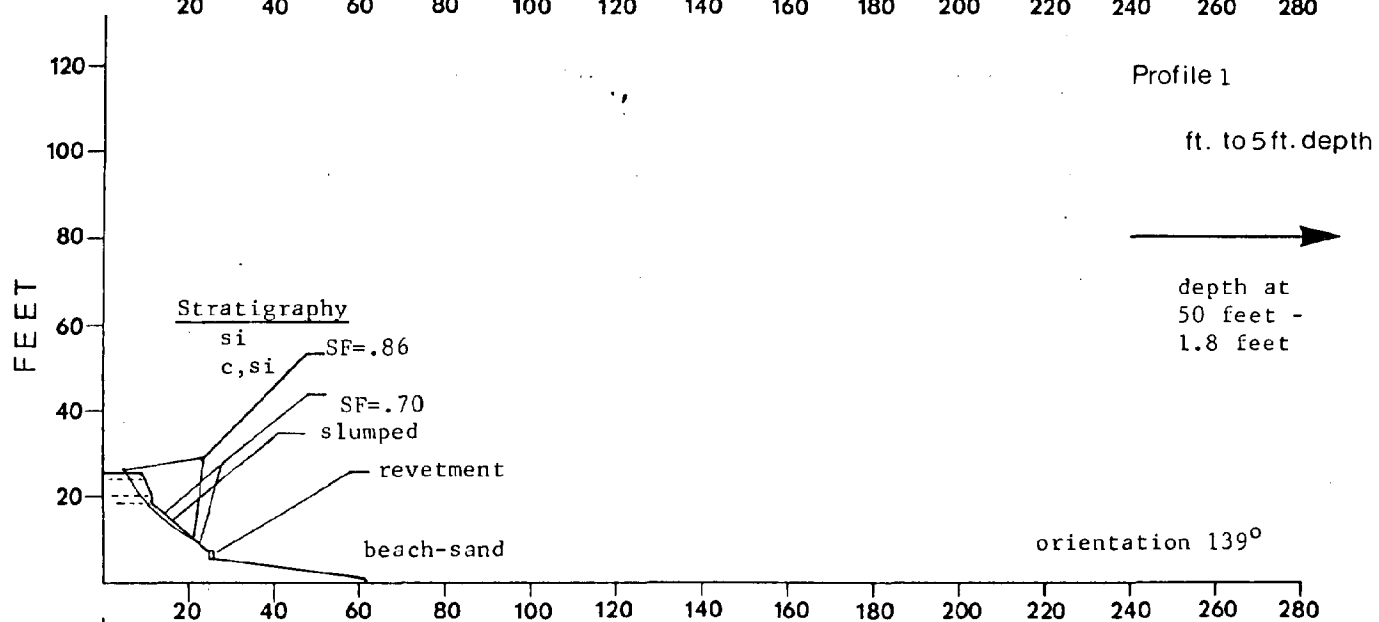
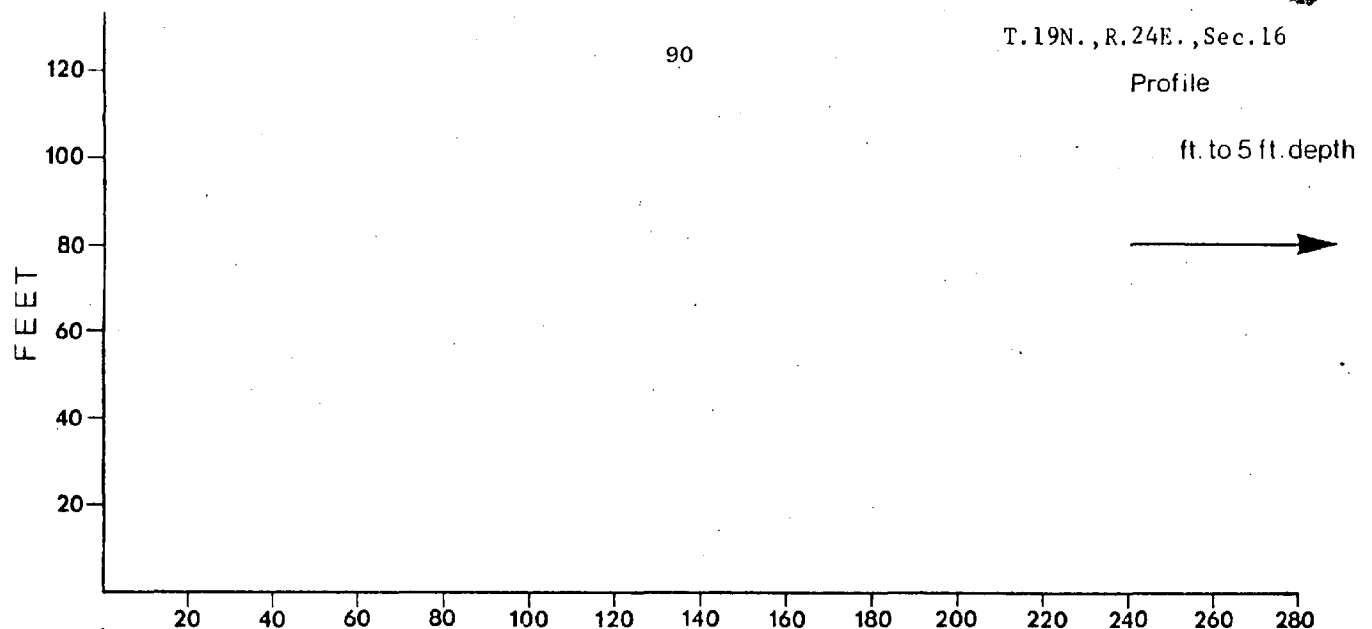
C-no stratigraphy

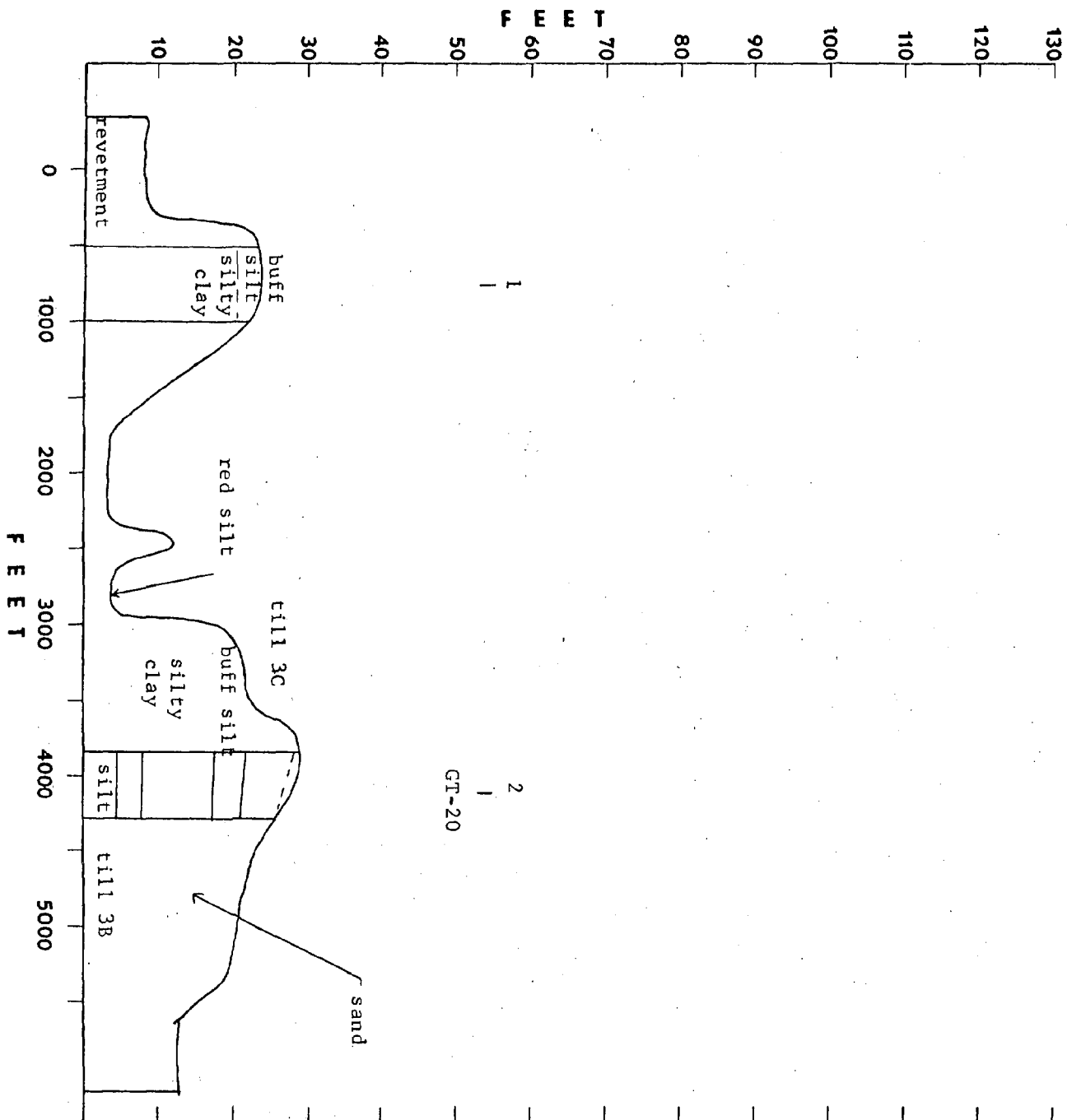
visible (low  
confidence)

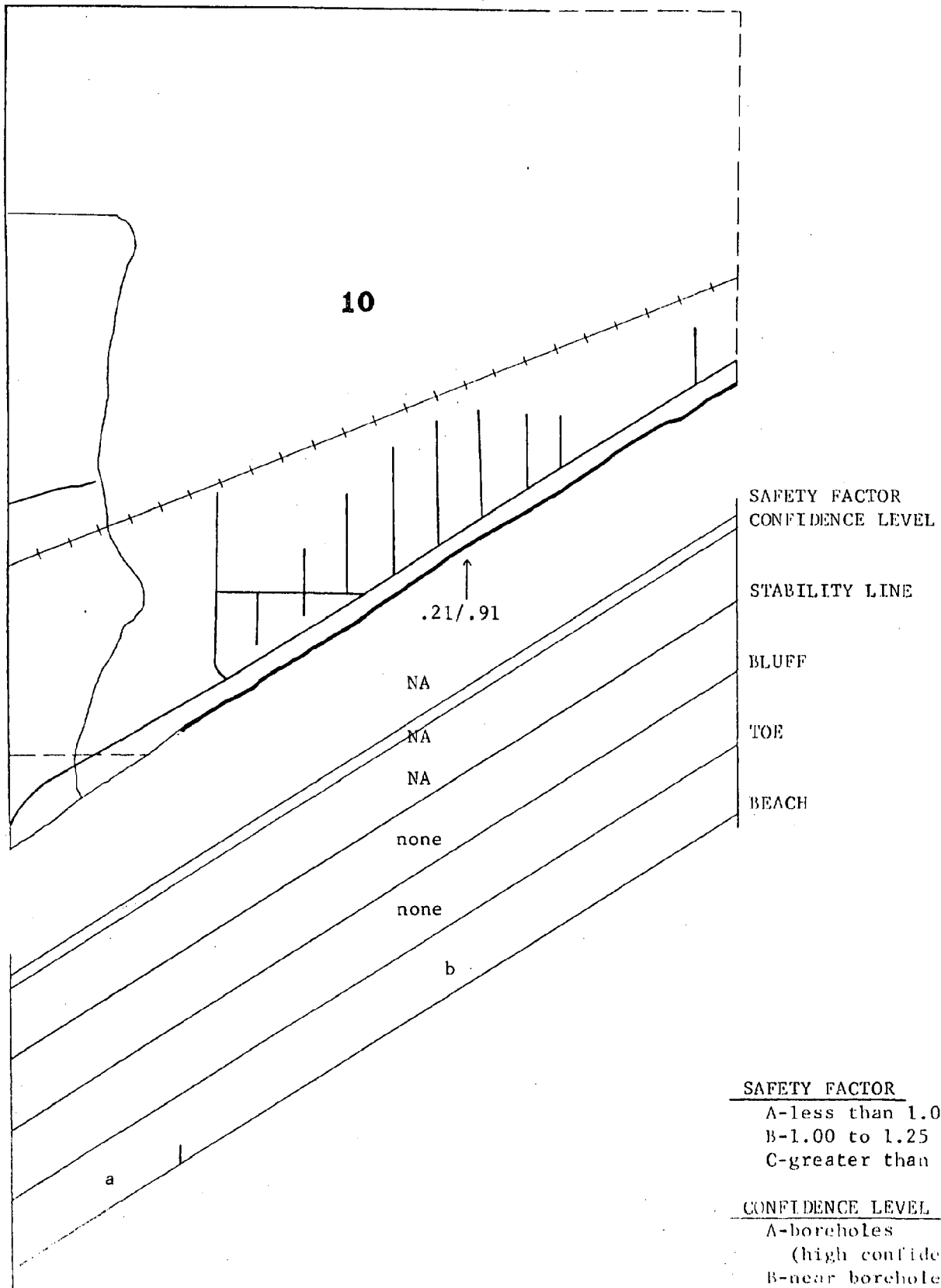
1. BLUFF	none		
2. TOE	none		
3. BEACH	a-0-30 ft. sand	b-no beach	



1. BLUFF	a-no bluff	b-low bluff; slumps and flows	c-no bluff	d-steep medium to low bluff, sapping and soil fall
2. TOE	a-revetment	b-slumped silt and clay behind revetment	c-cobbles and fill	d-silt
	e-slumped silt and clay	f-sand and silt	g-till '3B'	h-silt
	i-till '3C'			
3. BEACH	a-0-20 ft. sand	b-30-50 ft. sand	c-no beach	d-30-50 ft. sand
	e-0-20 ft. cobbles	f-no beach	g-200 ft. cobbles	h-30 ft. sand and cobbles







SAFETY FACTOR  
 A-less than 1.00  
 B-1.00 to 1.25  
 C-greater than 1.25

CONFIDENCE LEVEL  
 A-boreholes  
 (high confidence)  
 B-near boreholes  
 stratigraphy visible  
 C-no stratigraphy  
 visible (low  
 confidence)

1. BLUFF	none		
2. TOE	none		
3. BEACH	a-20-30 ft. sand	b-no beach	



94

11

[.01/.91

NA

NA

NA

none

none

a

b

c

SAFETY FACTOR  
CONFIDENCE LEVEL

STABILITY LINE

BLUFF

TOE

BEACH

SAFETY FACTOR

A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

CONFIDENCE LEVEL

A-boreholes

(high confidence)

B-near boreholes

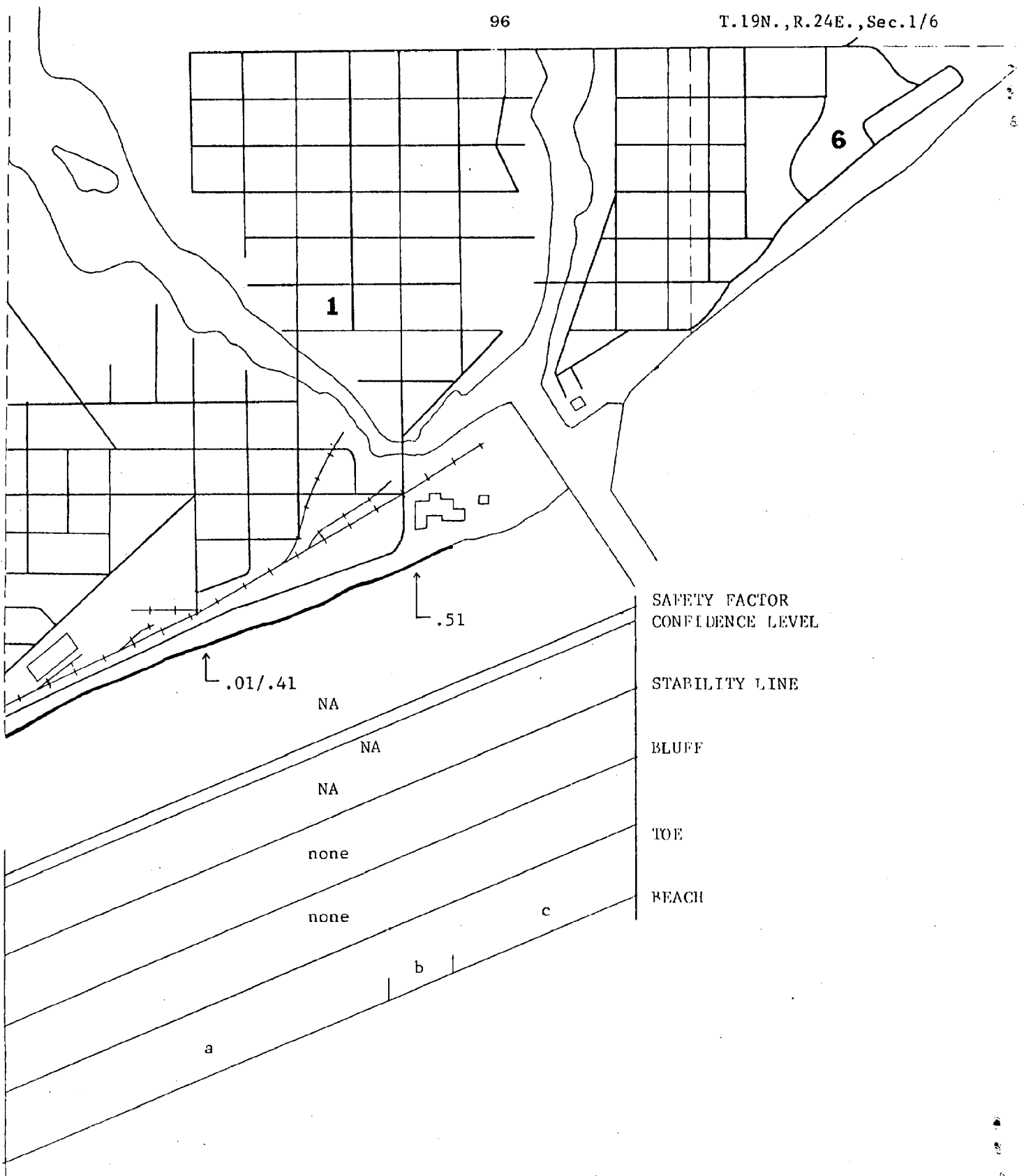
stratigraphy visible

C-no stratigraphy

visible (low

confidence)

1. BLUFF	none			
2. TOE	none			
3. BEACH	a-no beach	b-20-30 ft. sand	c-no beach	



1. BLUFF	none		
2. TOE	none		
3. BEACH	a-no beach	b-50 ft. + sand	c-no beach

**COASTAL ZONE  
INFORMATION CENTER**

