

W.P.

10672

Coastal Zone  
Information  
Center

COASTAL ZONE  
INFORMATION CENTER

JUN 14 1977

# **SHORE EROSION STUDY**

## **TECHNICAL REPORT**

### **APPENDIX 2**

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

### **RACINE COUNTY**

A.F. Schneider

T. Edil

B. Haas

**FEBRUARY 1977**

GB  
459.5  
.M5  
S5  
appendix 2

**WISCONSIN**

**COASTAL MANAGEMENT**

Wisconsin Coastal Zone Management Program

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-Ayers 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.

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INTRODUCTION

## COASTAL ZONE INFORMATION CENTER

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-

GB459.5:MS 55 Appendix 2

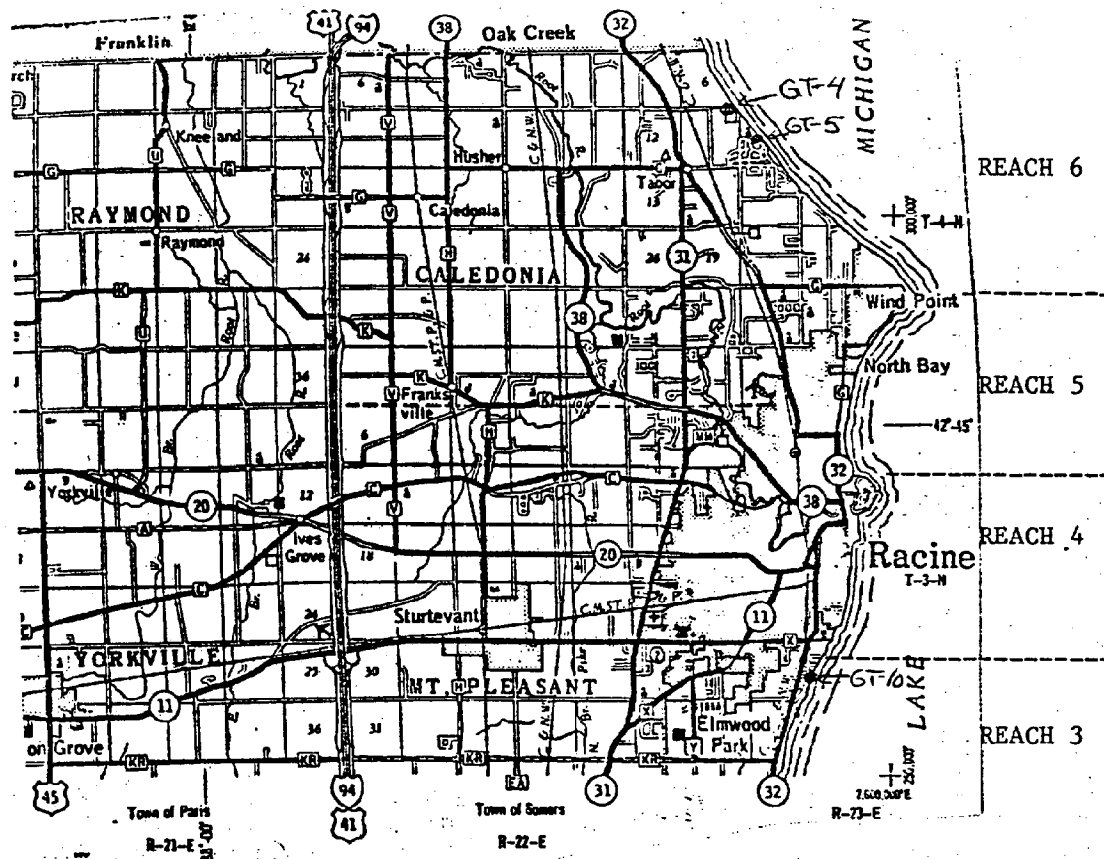
tance to a 5 foot depth of water is also given. The date when the profile was measured is also given. Remember that the bluff profile could have changed since the profiles were measured.

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.



# RACINE CO.

DEPARTMENT OF TRANSPORTATION

DIVISION OF HIGHWAYS

STATE OFFICE BUILDING

Madison, Wisconsin

SCALE 0 1 2 MILES

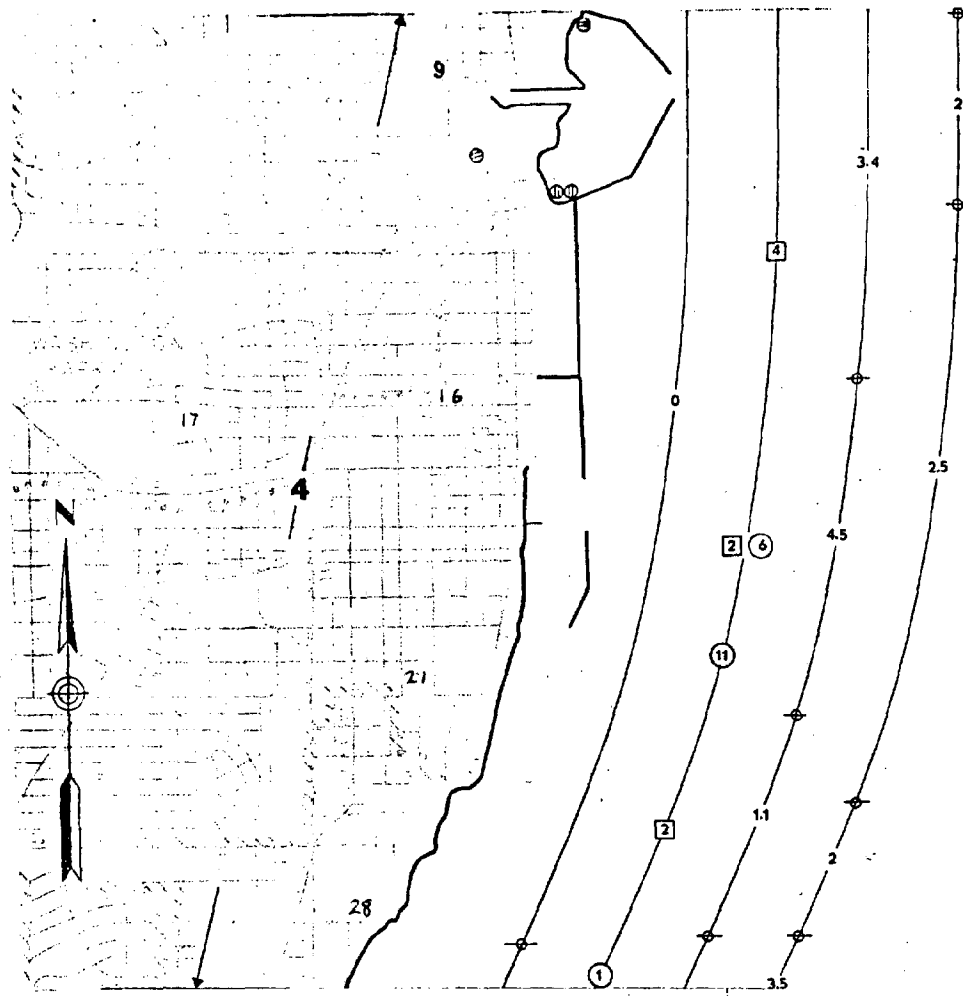
Reach 4

Erosion reach 4 extends through the southern and central parts of the City of Racine in Township 3 North, Range 23 East, Racine County. It is approximately  $3\frac{1}{4}$  grid miles and  $3\text{--}3\frac{3}{4}$  shoreline miles in length. The northern two-thirds of the reach is marked by continuous shore protection structures, principally in the form of offshore breakwaters and shoreline revetments. These structures provide protection for the Racine harbor facilities and industrial sites on the north, Pershing Park and the downtown business district in the central part, and residential properties farther south. As a direct and indirect consequence of these structures, Reach 4 received a relatively low priority for the purpose of this study, ranking twenty-ninth on the priority list with a low value per mile figure of three. Accordingly, only the southern half of the reach was examined in our investigation and the following summary of conditions is restricted to this portion. The northern and southern parts of this segment are residential in character, with the longer intervening strip being occupied mostly by the City of Racine sewage treatment plant and the J. I. Case Co. tractor plant.

Most of the shoreline has no beach, mainly because of man's past and current activities. For the most part, the shore is armored with extensive stone (dolomite) revetments constructed at the base of the bluff and steel (sheet piling) bulkheads built some distance offshore and completely backfilled to form made land. In some places, however, notably south of the Case tractor plant in section 28, a narrow and discontinuous beach does exist. Nowhere was it found to be more than 10 feet wide and generally it is between 0 and 5 feet in width. Beach materials consist of gravel, broken concrete, stone, broken asphalt, dead trees, old lumber, cinders, iron, and slag from the old Case foundry.

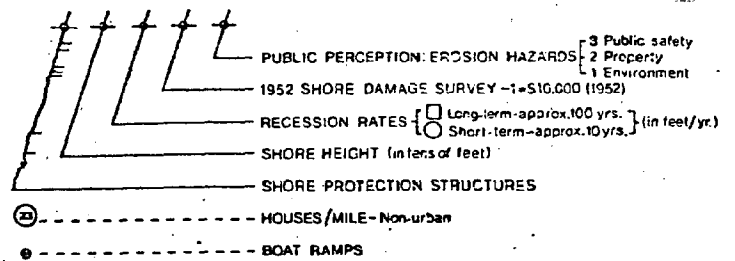
The height of the bluff in the southern part of Reach 4 nearly everywhere is about 40 feet. Bluff materials and toe materials in all but the southernmost 1,500 feet of the reach appear to consist mostly of artificial fill composed of stone, brick, glass, concrete, iron, slag, and garbage (see profile 2, section 21). In places where natural deposits can be seen, chiefly at the south end of the reach, the bluff is made of interbedded clays, silts, and sands of lacustrine origin overlying calcareous silty clay till (see profile 1, section 21 and profiles 1, 2, and 3, section 28). The contact between the till and the overlying lake sediments occurs about a third to half-way down from the top of the bluff.

Although much of the bluff has been graded and grassed and appears to be fairly stable, slope failure is evident in several places. It is most severe in section 28 along the virtually unprotected shoreline south of the Case factory at the southern end of the reach. Much of the failure is directly related to the presence of multiple seep zones within the more permeable beds, especially the sand layers, in the lacustrine sequence, particularly where the more permeable layers rest on the clay till and on a massive pink clay layer in the lower part of the lacustrine unit (see profile 1, section 21 and profiles 1, 2, and 3, section 28). Failure occurs mainly in the form of flows and small slump blocks. Toe erosion is also an important erosional process.



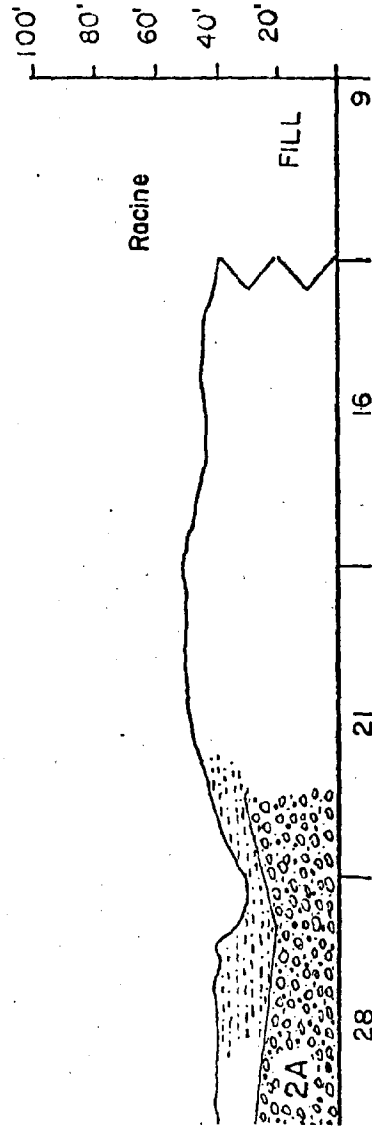
Reach 4

1 mile





T. 3 N.



# LEGEND



SAND



GRAVEL



SAND AND GRAVEL



SILT



CLAY



CLAYEY SILT, SILTY CLAY



COVERED OR INACCESSIBLE

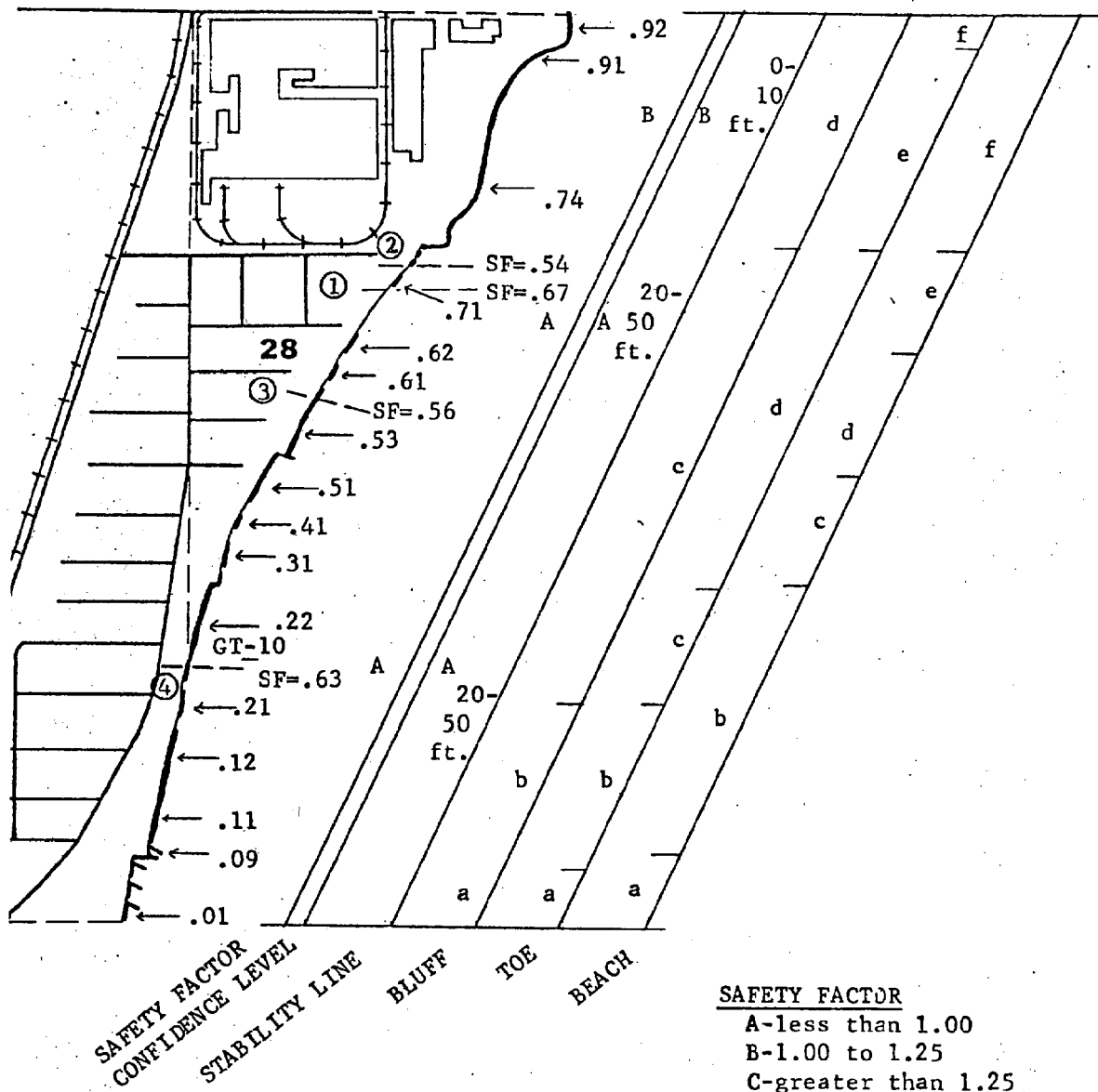


TILL



MIXED SEDIMENTS

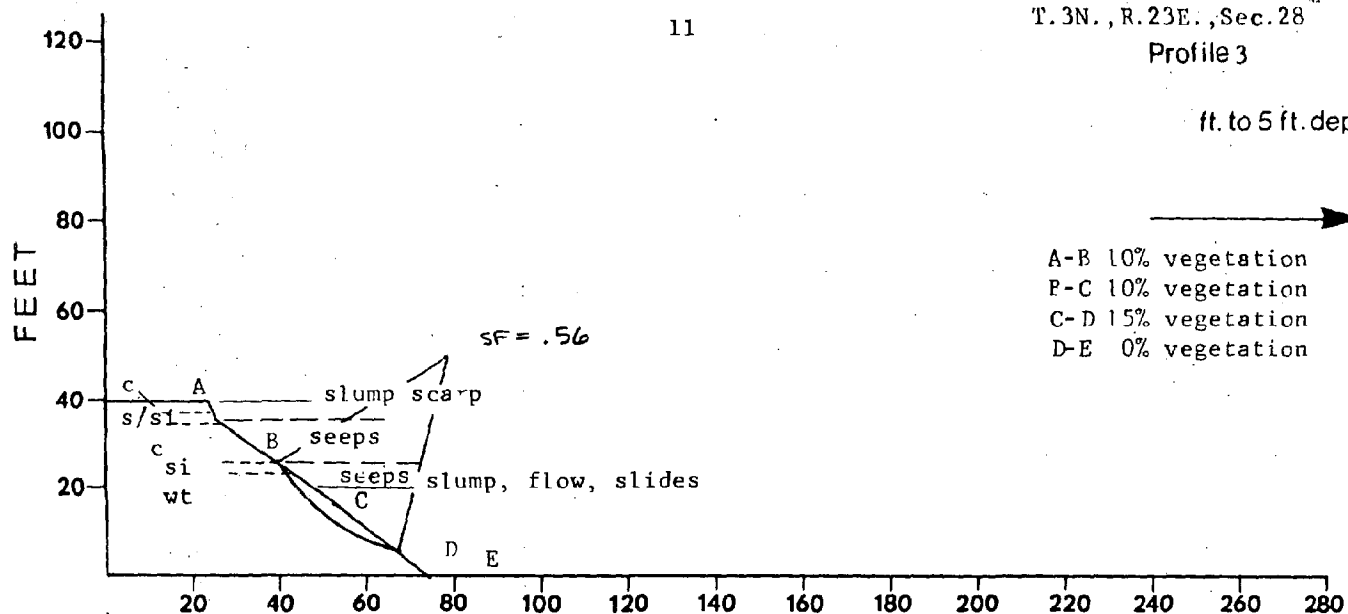
Generalized longitudinal section showing bluff stratigraphy in Reach 4. Numbers along base of diagram are geographic (1 mile) sections.



1. BLUFF	a-failure by slump	b-bluff consists of recent artificial fill	c-serious slope failure caused by slump, debris flow; also by the erosion, surface water coming over top of bluff, water issuing from seep zones in silt and sands above till. Foundations undercut and exposed. Scalloped bluff margin, slump scarps at top of bluff.	d-artificial fill; slope in back of revetment is vegetated and appears stabilized.
2. TOE	a-natural toe material is till, covered in most places by slump or artificial fill debris.	b-toe material consists mostly of artificial fill and debris dumped over top of bluff (broken concrete, slag, iron, bicycles, kitchen sinks)	c-dolomite blocks (revetment), with till behind	d-natural toe material is clayey till, till covered in many places by slag (at northern end), broken concrete, dolomite blocks and various types of debris
	e-dolomite blocks (revetment)	f-sheet-steel piling (bulkhead)		
3. BEACH	a-0 to 5 ft., cobbles and pebbles	b-5 to 10 ft., pebbles and cobbles	c-no beach	d-0 to 8 ft., gravel, broken concrete, stone, wood, junk
	e-5 to 10 ft., beach is gravel, slag, bricks, junk and iron	f-no beach less than 5 ft., slag, pebbles, junk		

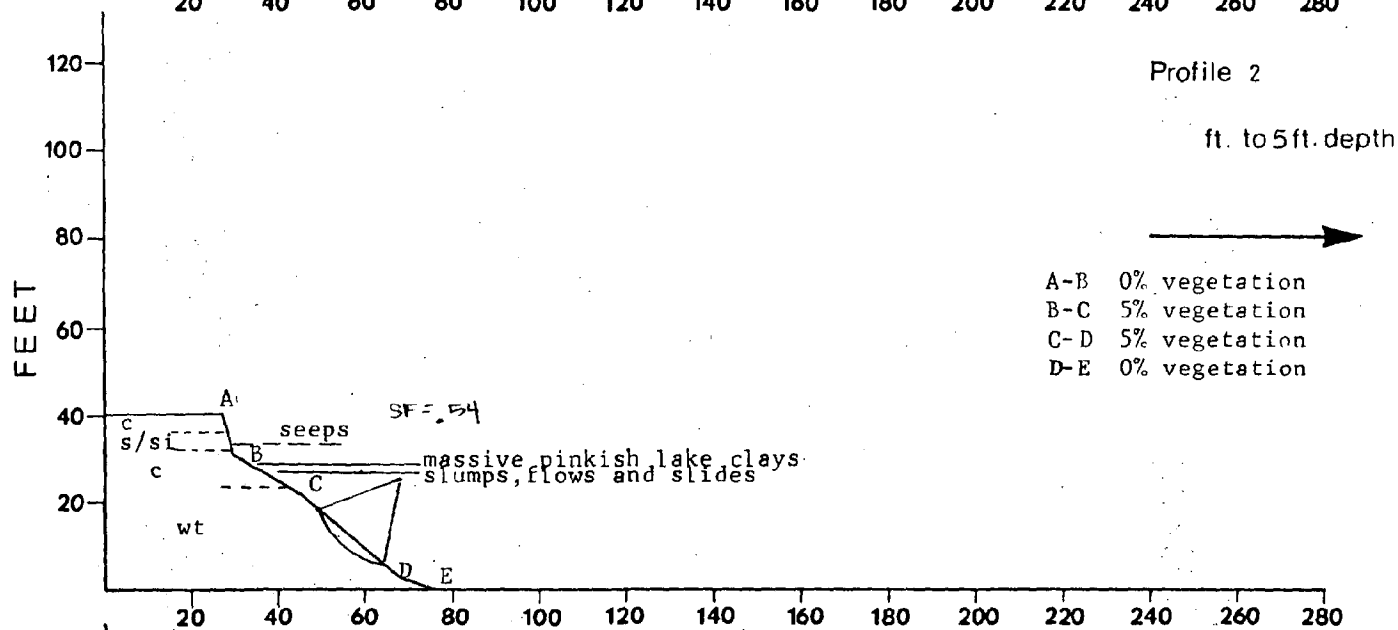
## Profile 3

ft. to 5 ft. depth



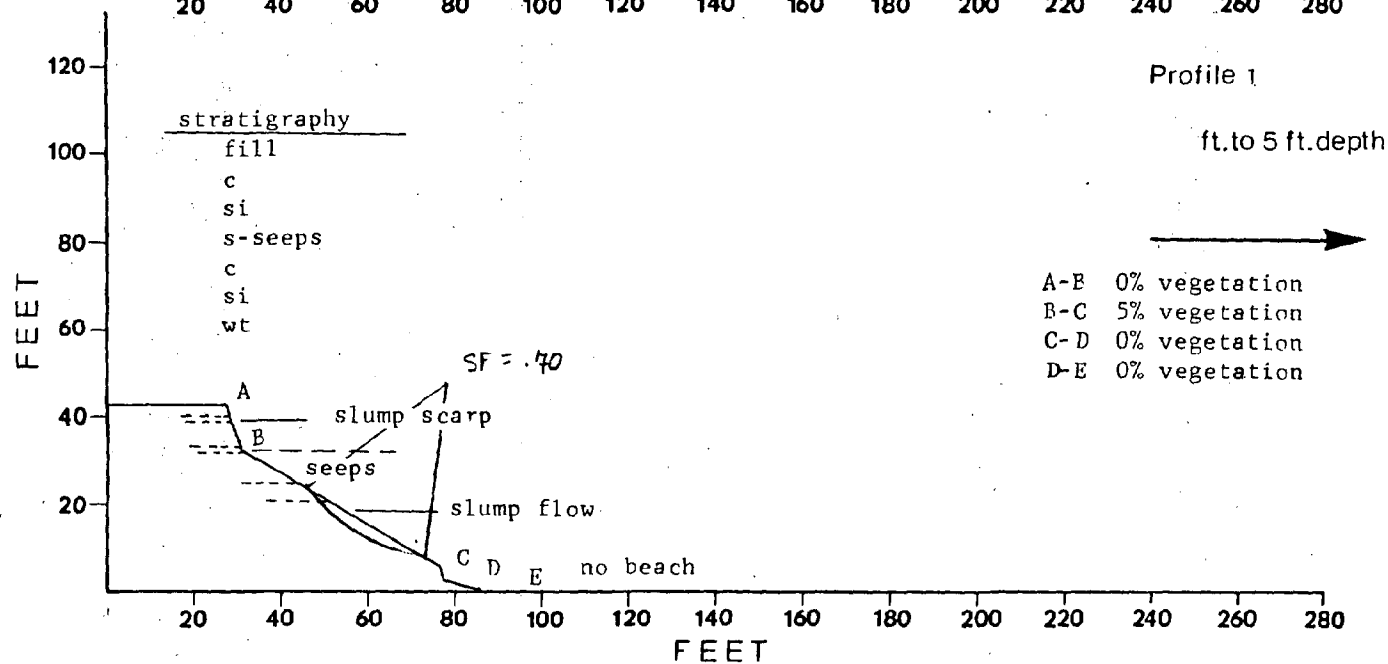
## Profile 2

ft. to 5 ft. depth



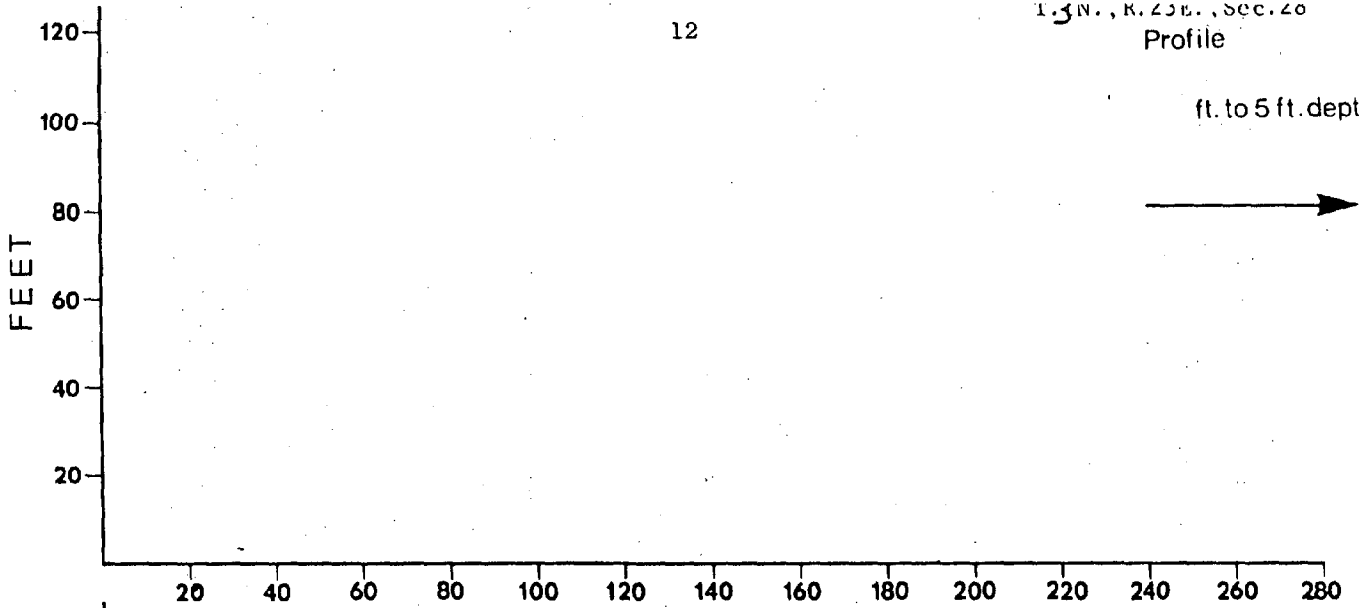
## Profile 1

ft. to 5 ft. depth



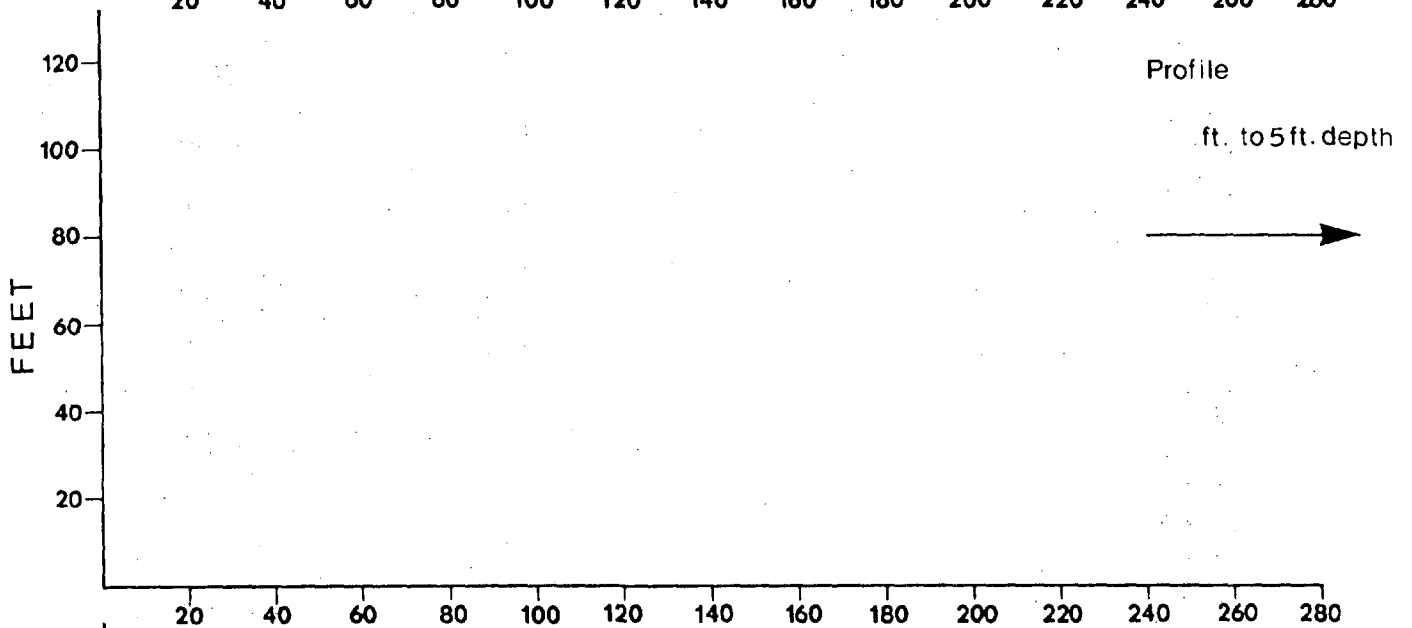
## Profile

ft. to 5 ft. depth



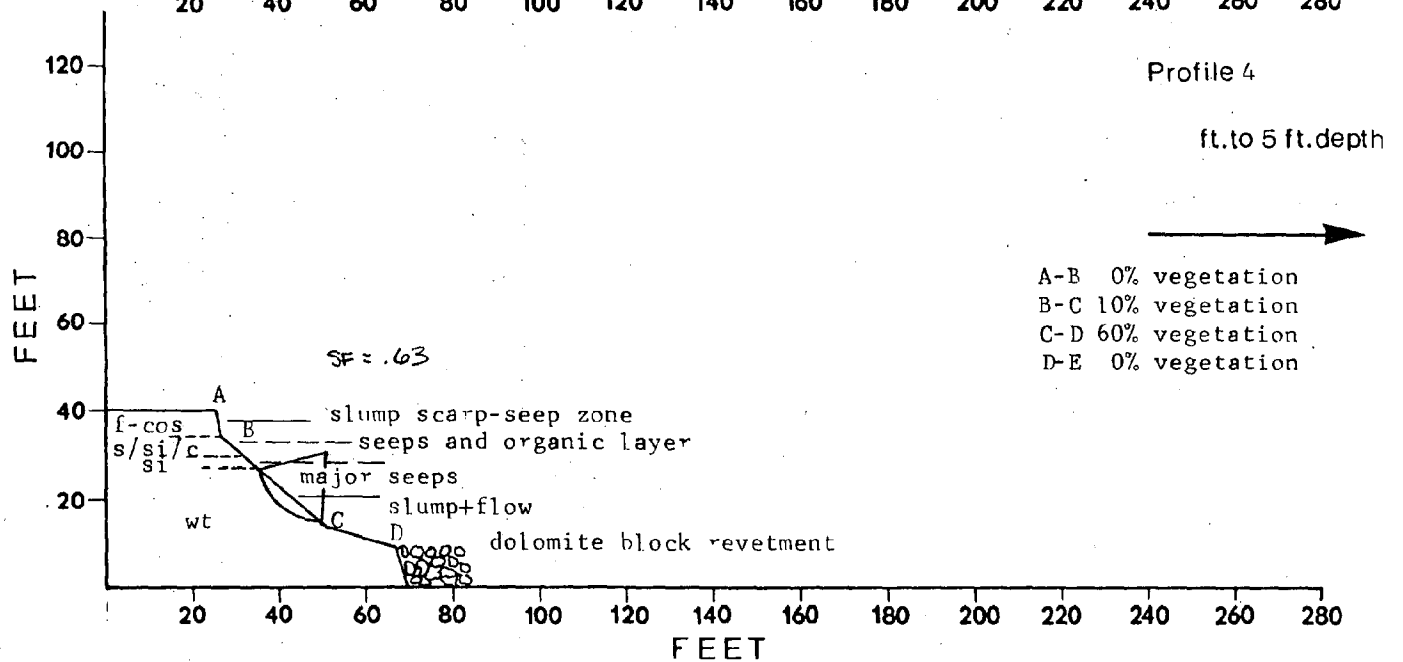
## Profile

ft. to 5 ft. depth

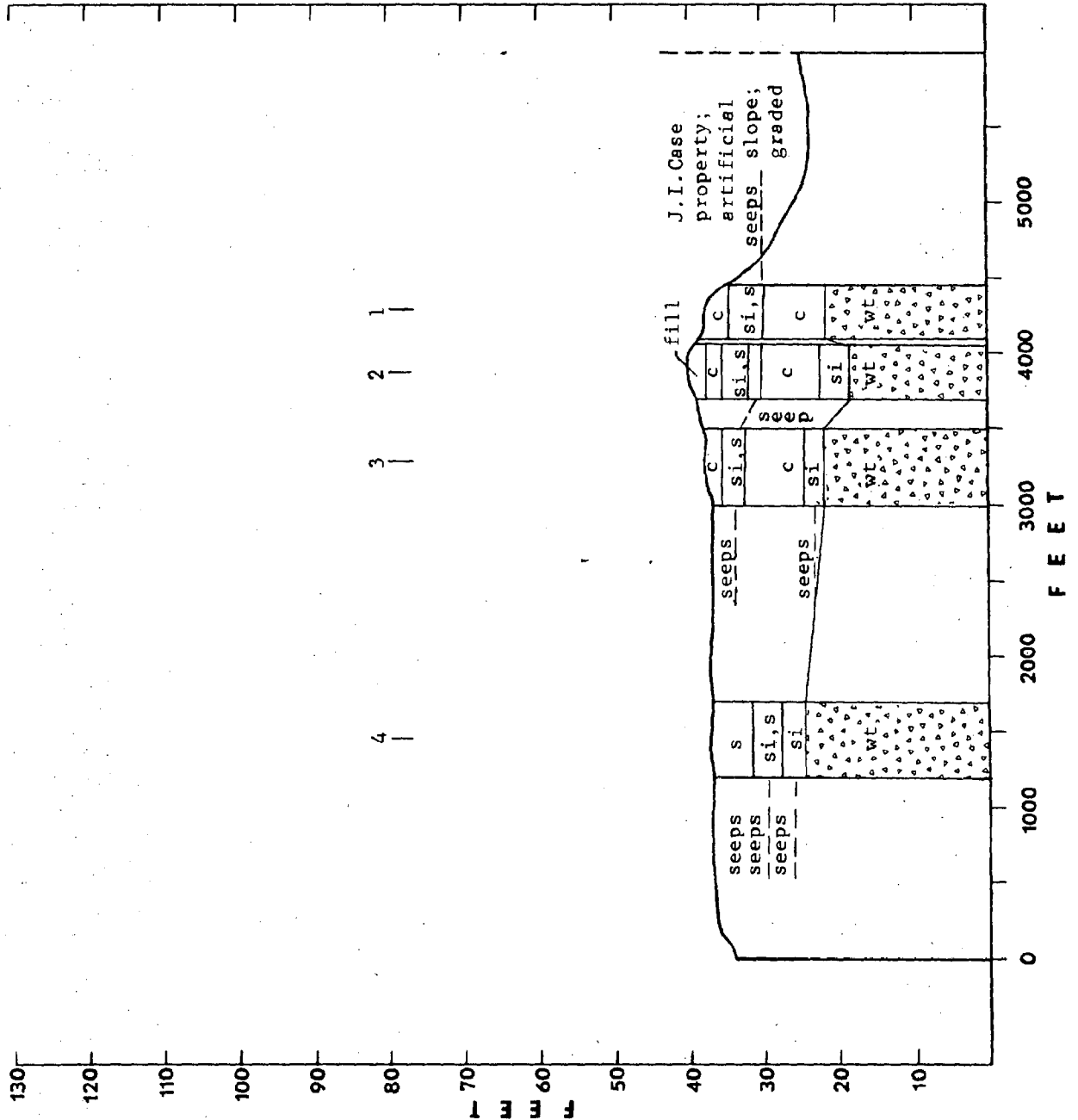


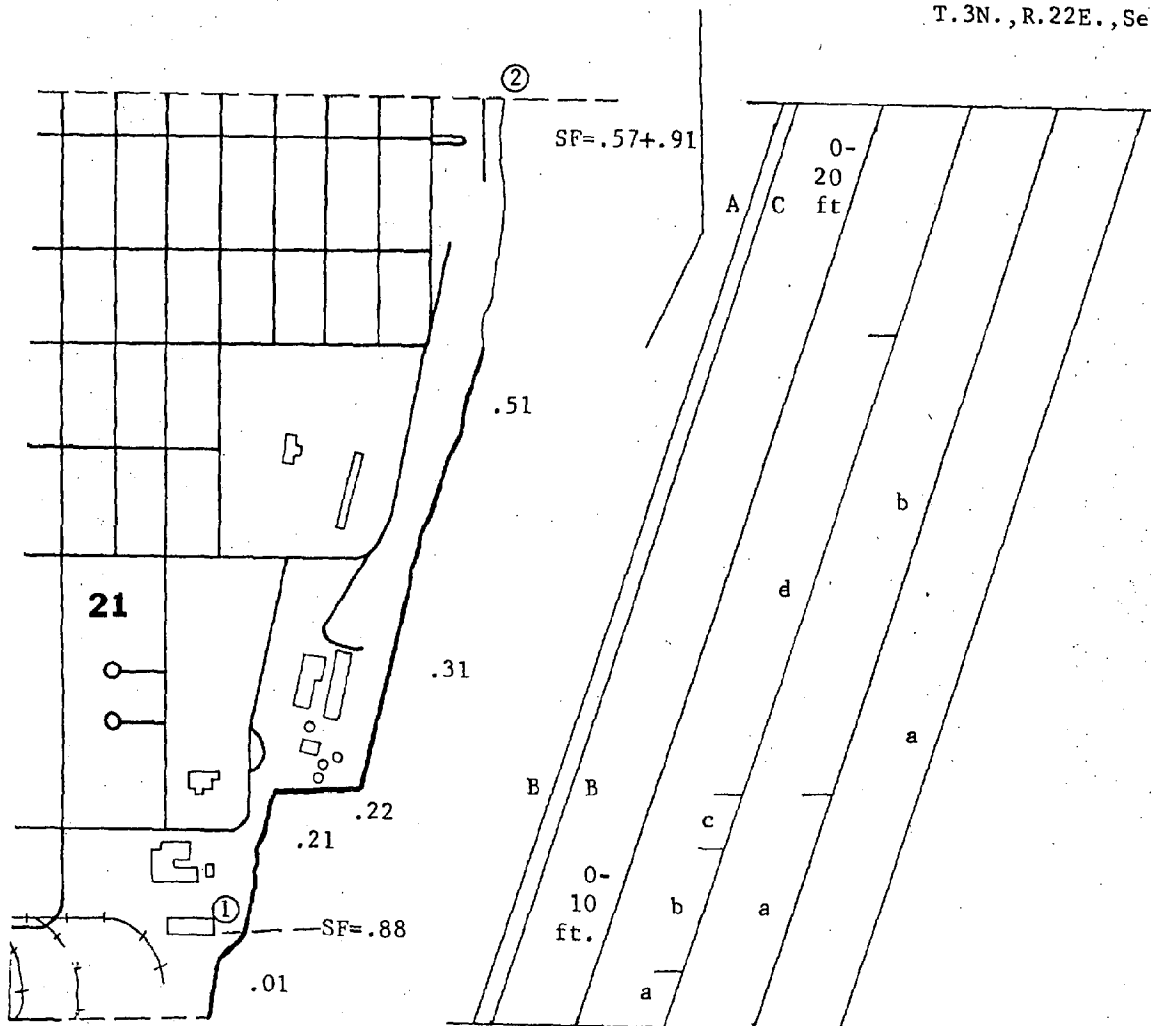
## Profile 4

ft. to 5 ft. depth



**T. 3 N., R.23 E., Sec. 28**





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

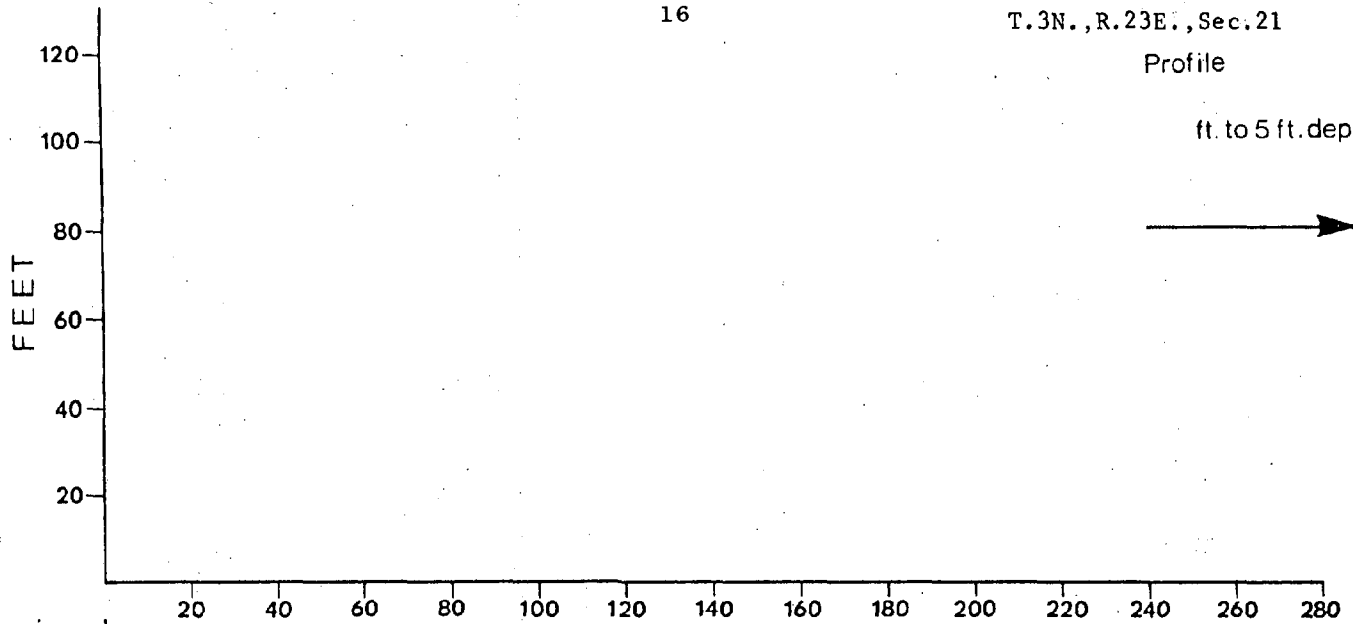
C-no stratigraphy visible (low confidence)

1. BLUFF	a-fairly stable	b-failing by slump and some flow with seep zones near top of bluff; artificially graded and planted	c-fairly stable seep in sand near upper part of bluff	d-artificial fill; bluff has been graded and retains its former height only at considerable distance from lakeshore; fill consists of stone, brick, glass, concrete, and refuse.
2. TOE	a-till, gray clayey, Wadsworth	b-fill, iron, glass, brick, stone and refuse		
3. BEACH	a-no beach			

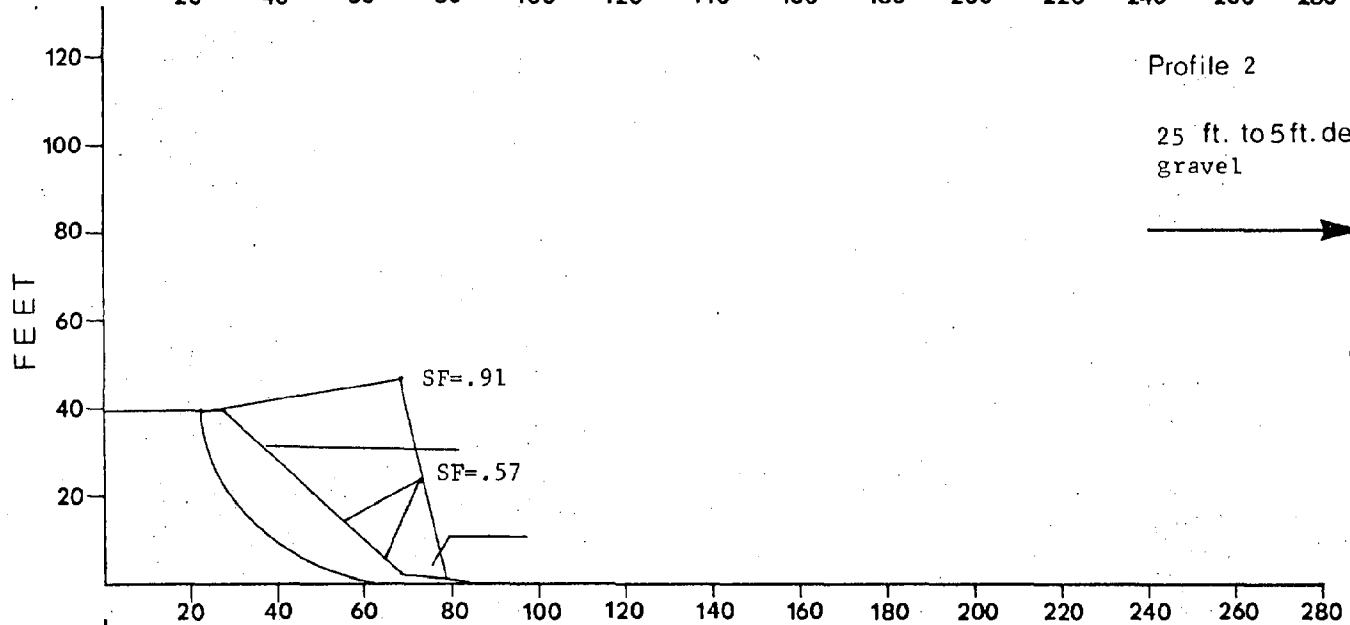


## Profile

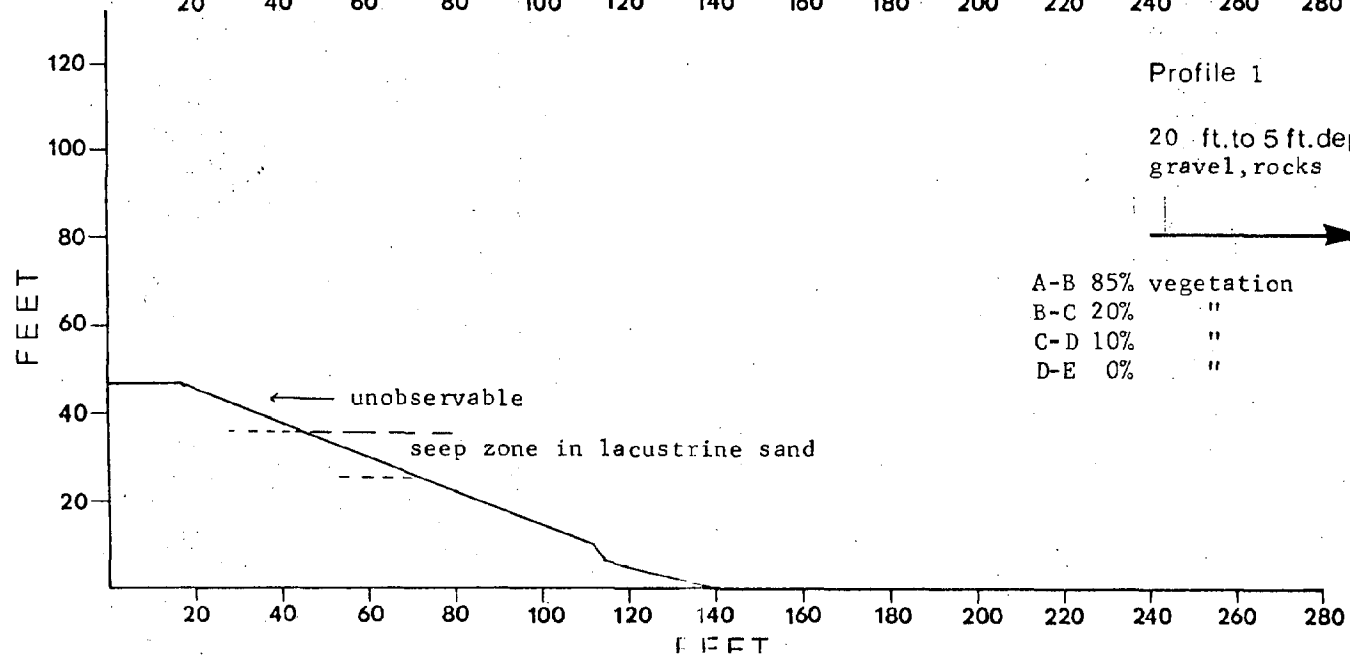
ft. to 5 ft. depth



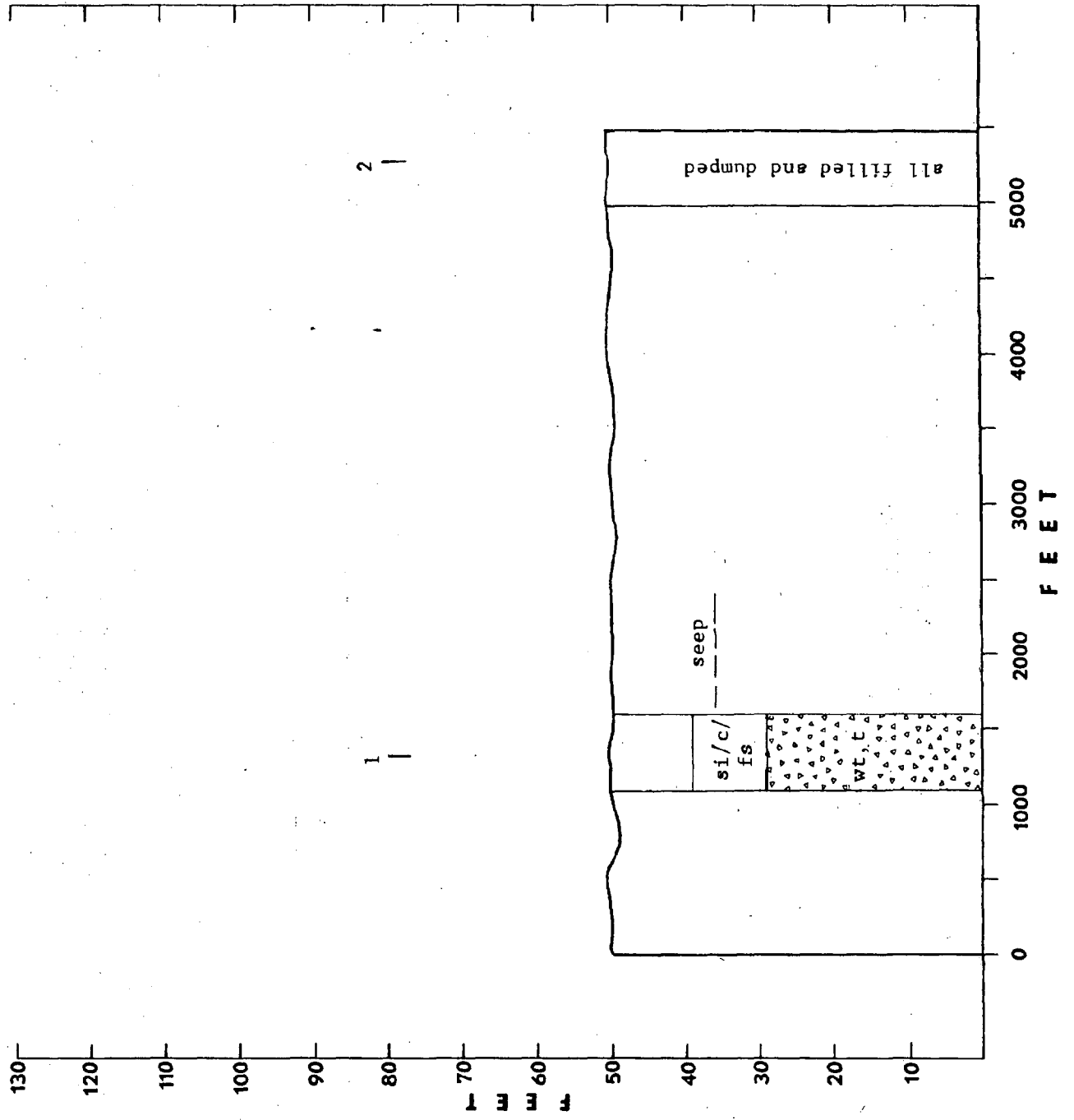
## Profile 2

25 ft. to 5 ft. depth  
gravel

## Profile 1

20 ft. to 5 ft. depth  
gravel, rocks

I. 3 N., R. 23 E., Sec. 21



Reach 5

Reach 5 runs through the northern part of the City of Racine, through the village of North Bay, and about half-way through the village of Wind Point, in Townships 3 and 4 North, Range 23 East, extending from the north end of the Racine harbor structure in section 9 to the mid-line of the Wind Point headland in section 27. The grid length of the reach is 3 miles; the shoreline distance is  $3\frac{1}{2}$  miles.

About 55% of the reach is public land. The southern mile is occupied by the Racine public beach, Lake View Park, and the Racine Zoological Park. Shoop Park is at the north end of the reach. The remaining 45% of the shoreline is residential in character, with most of the properties in northern Racine and North Bay being in the \$100,000-plus category. Reach 5 was rated tenth in the ranking of critical erosion areas, with a per-mile value of 13, the same as Reach 3.

The beach in Reach 5 ranges in width from 0 to almost 300 feet. It is widest at the south end, where the north-south longshore current is obstructed and the sand supply is effectively trapped by the harbor breakwater. Low dune ridges (see profile 2, section 4) indicate that some of the sand has been reworked by the wind. Northward the beach gradually narrows to zero within a mile. Elsewhere in the reach, however, abrupt and very substantial changes in beach width are common.

Much of the shoreline is heavily armored with various types of shore-parallel and shore-normal protective structures, especially in the residential segment. Approximately 85 such structures were identified and described in slightly less than 2 miles between the Racine Zoo and Shoop Park. The effectiveness of these structures, especially the more recently built groins, is readily apparent from the abrupt changes in beach width and the locations of eroding and non-eroding shoreline segments. Virtually all of the well

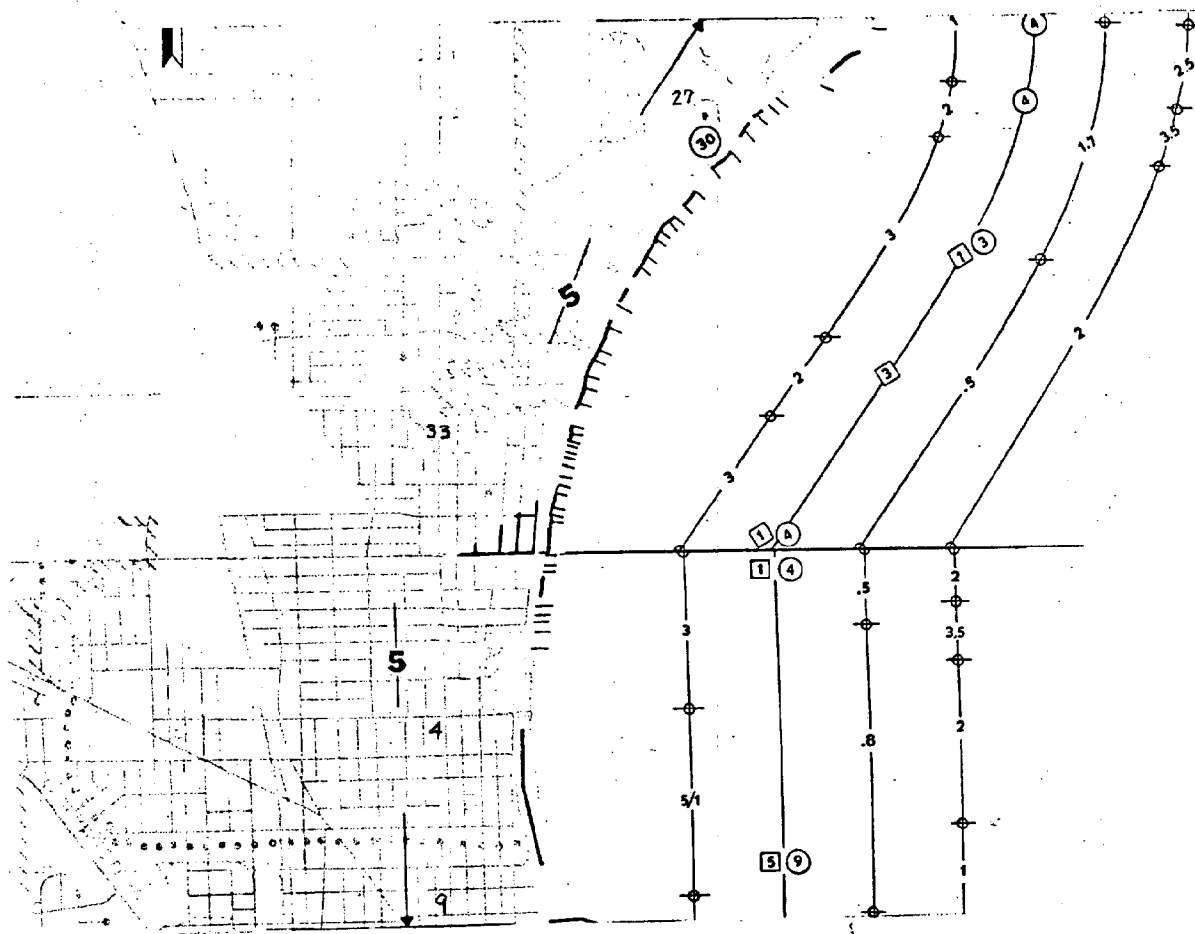
constructed groins are trapping sand on their updrift (north) sides, and it is this process that accounts for the common and abrupt changes in beach conditions. Poorly protected and unprotected segments of the shore are subject to severe wave erosion at the toe of the bluff, debris fall and flowage higher on the slope, and slump at the top of the bluff; scalloped bluff edges are not uncommon in this reach, even though much of the bluff has been graded and grassed.

Bluff height ranges from slightly under 20 feet to just over 30 feet. Exceptions occur at stream mouths, in places where the bluff has been terraced or otherwise modified by Man, and at the northern end of the reach in Shoop Park. Here the bluff splits, and a low natural terrace separates the shoreline from the main upland surface. At the northern end the terrace is about 750 feet wide. The shore bluff along the terrace is generally between 5 and 10 feet high, but it is virtually absent at the northern boundary of the reach.

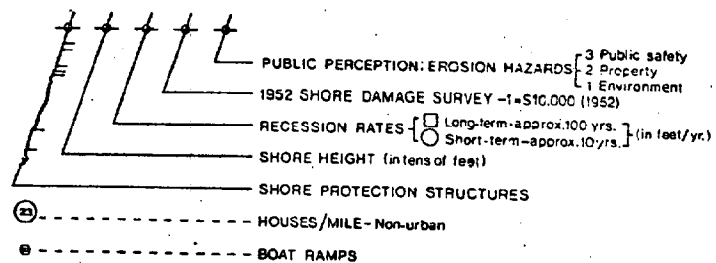
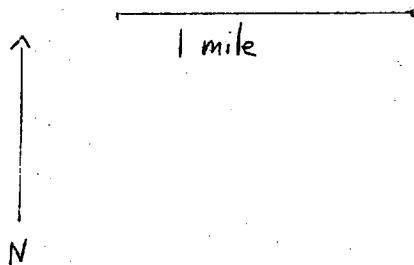
Much of the bluff is covered by vegetation, and in many places it is composed of artificial fill (see profiles 1 and 2, section 4). Where they are exposed, the natural sediments consist of calcareous gray (where unoxidized) or tan (where oxidized) silty clay till overlain by lacustrine deposits (see profiles 1, 2, and 3, section 27 and profile 1, section 33). At several places a thin layer of water-bearing sand or sand and fine gravel occurs slightly above mid-bluff height, between the till and pinkish-brown lake clay (see profiles 1, 2, and 3, section 27). Water seeping from this horizon, and also from other zones within the lacustrine beds, are undoubtedly a major cause of slope failure involving slump.

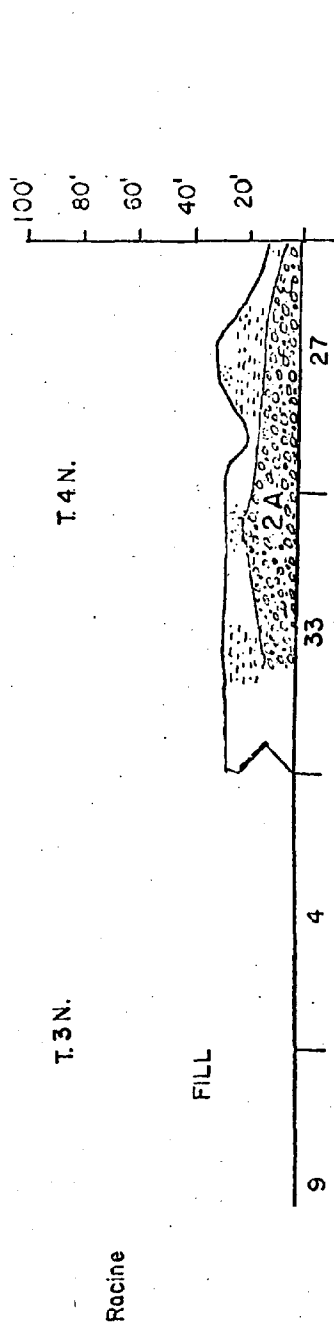
The overall conditions and general shoreline characteristics of Reach 5 are strikingly similar to those of Reach 3. In both reaches, bluff and beach conditions cover a moderate to wide range and also show considerable variability

within short distances. The bluff in the northern part of both reaches is subject to toe erosion and slope failure, particularly by slump. Property owners in both reaches have taken a variety of measures to minimize the damage and to protect their homes and property, but where the bluff and toe are not adequately protected scalloped bluff edges and other indicators of degradation are apparent. In both reaches, sizable segments of the coastline are marked by beach accretion deposits, as evidenced by beautiful sandy beaches whose widths approach the length of a football field. Both in Reach 3 and in Reach 5 these beaches occur in the southern part of the reach, and their locations appear to be fundamentally uncontrolled by groins and revetments. Rather, they are the direct consequences of being located north of cities, whose harbor structures interrupt the natural longshore currents and induce deposition to the north.



Reach 5

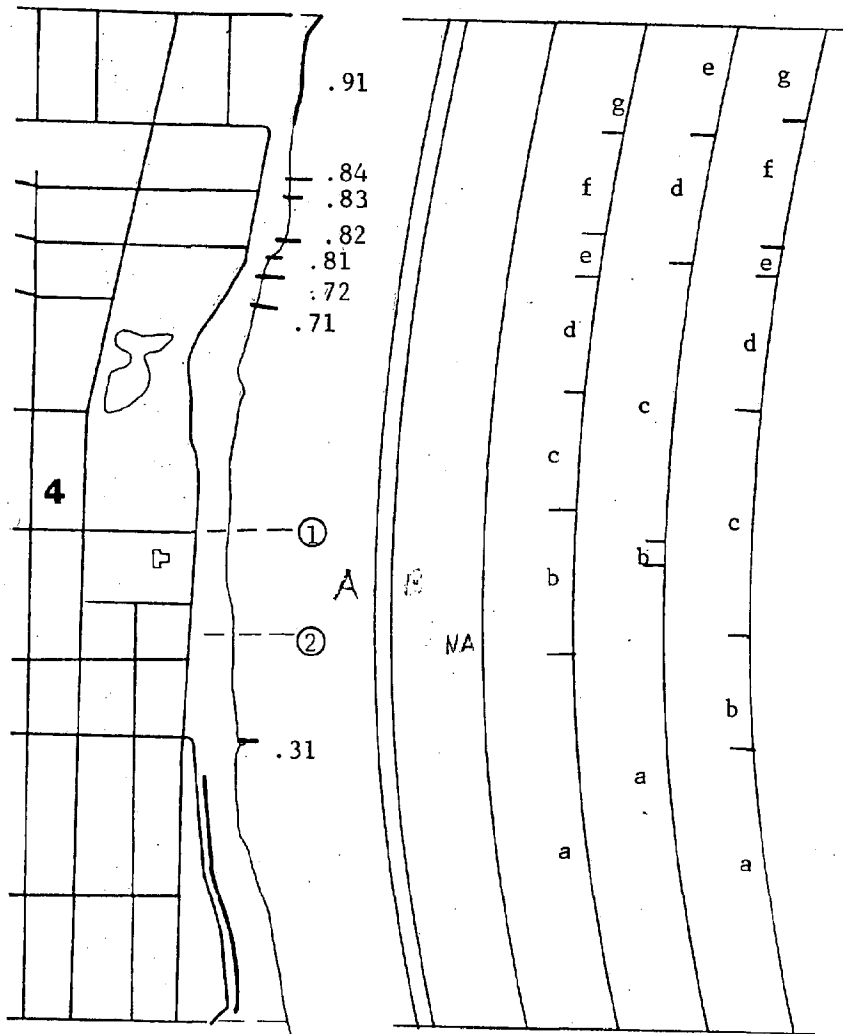




# LEGEND

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

Generalized longitudinal section showing bluff stratigraphy in Reach 5. Numbers along base of diagram are geographic (1 mile) sections.



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

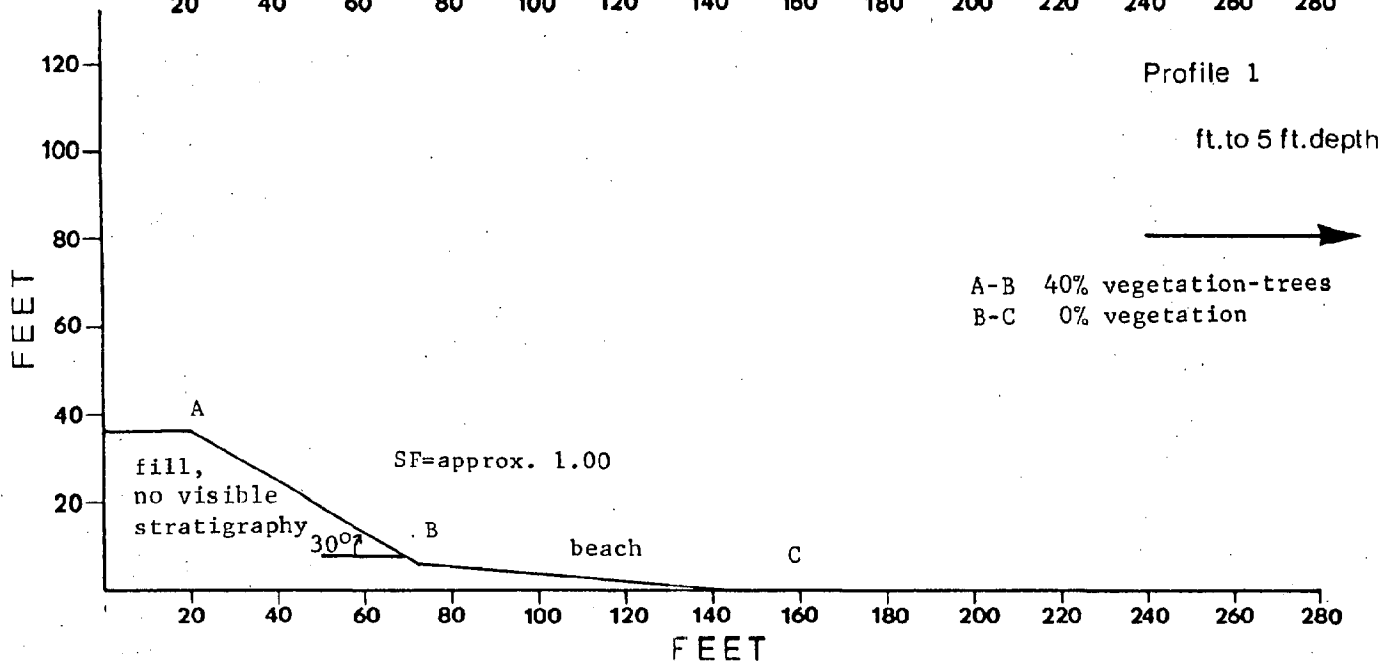
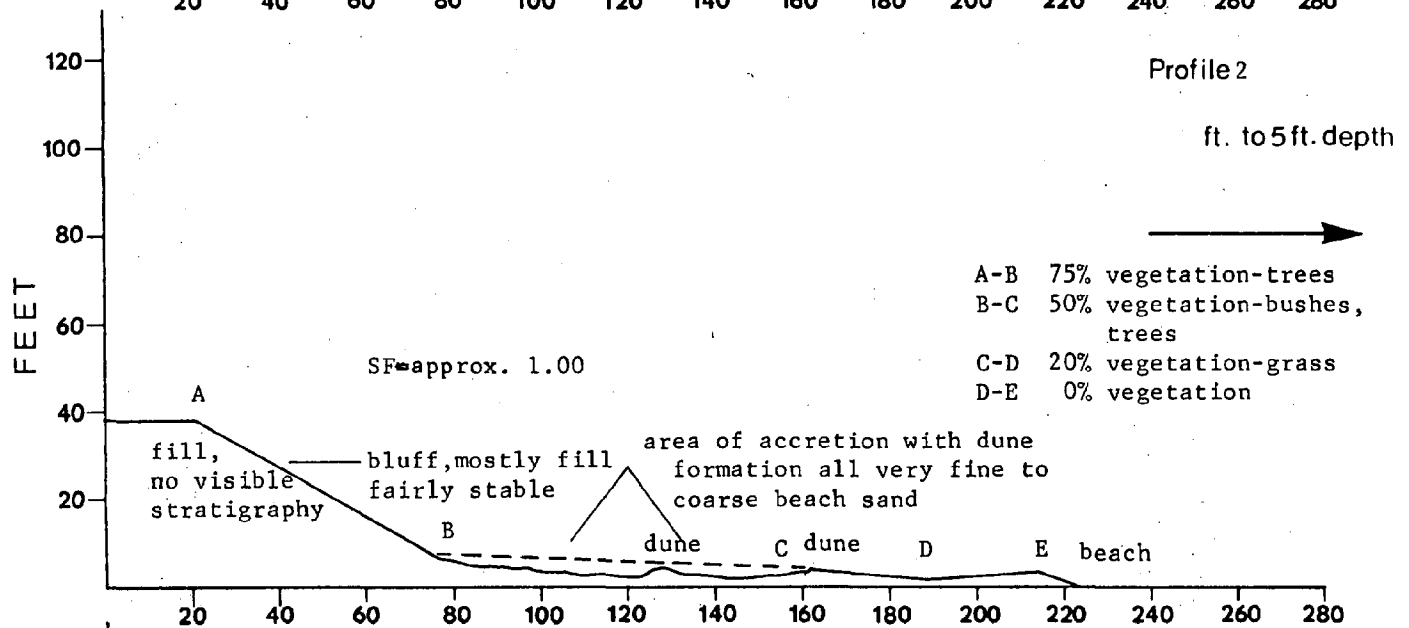
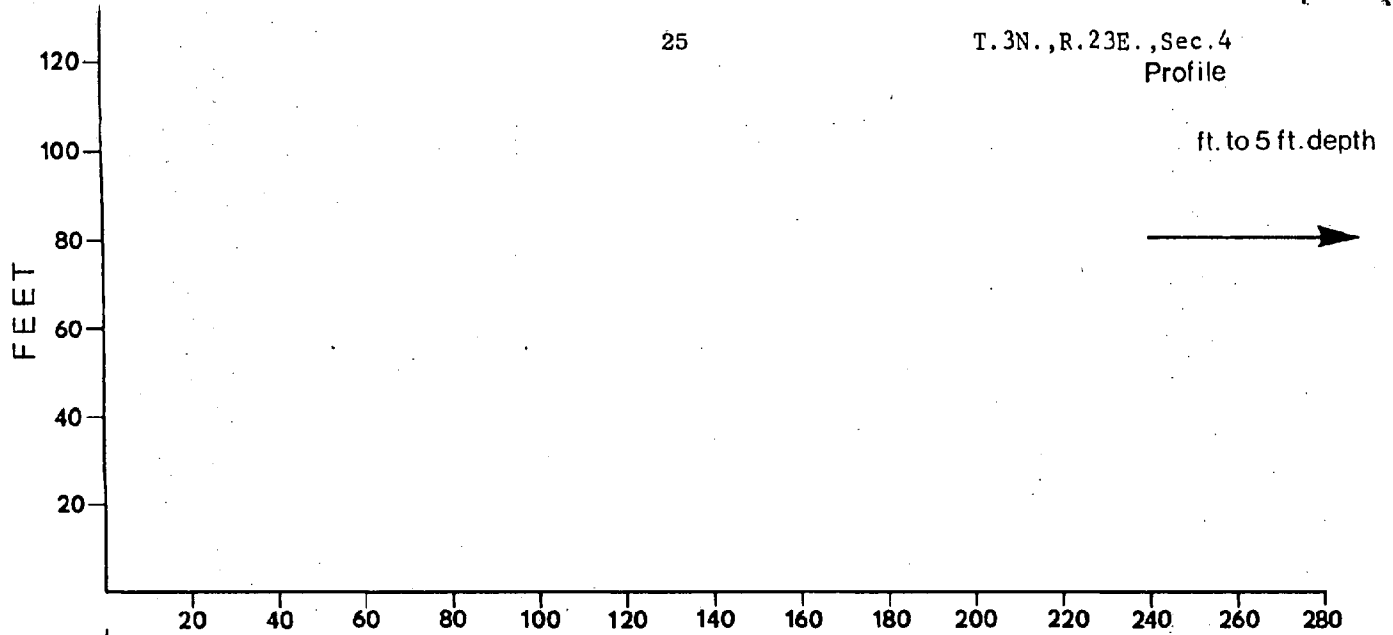
visible (low

confidence)

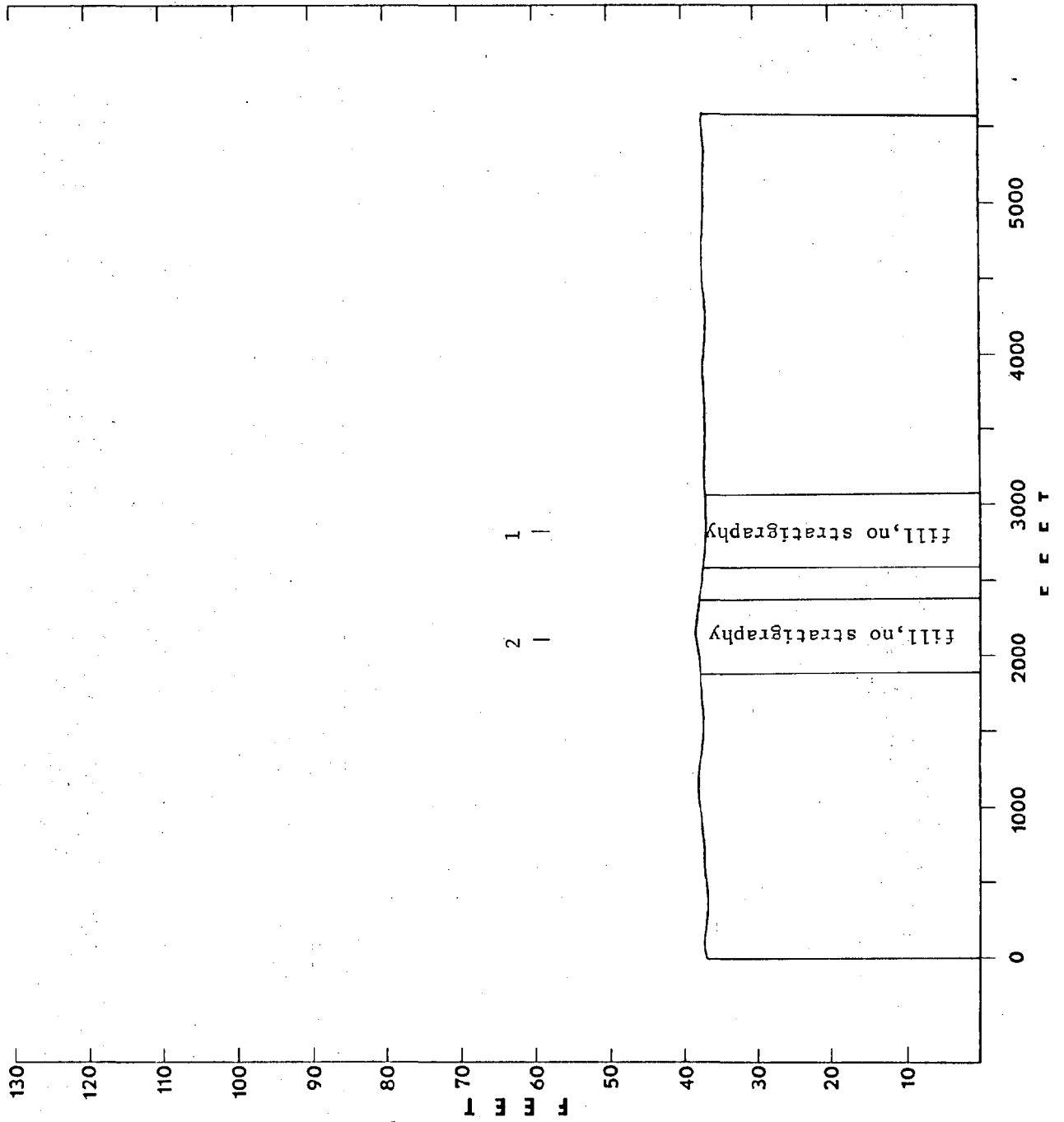


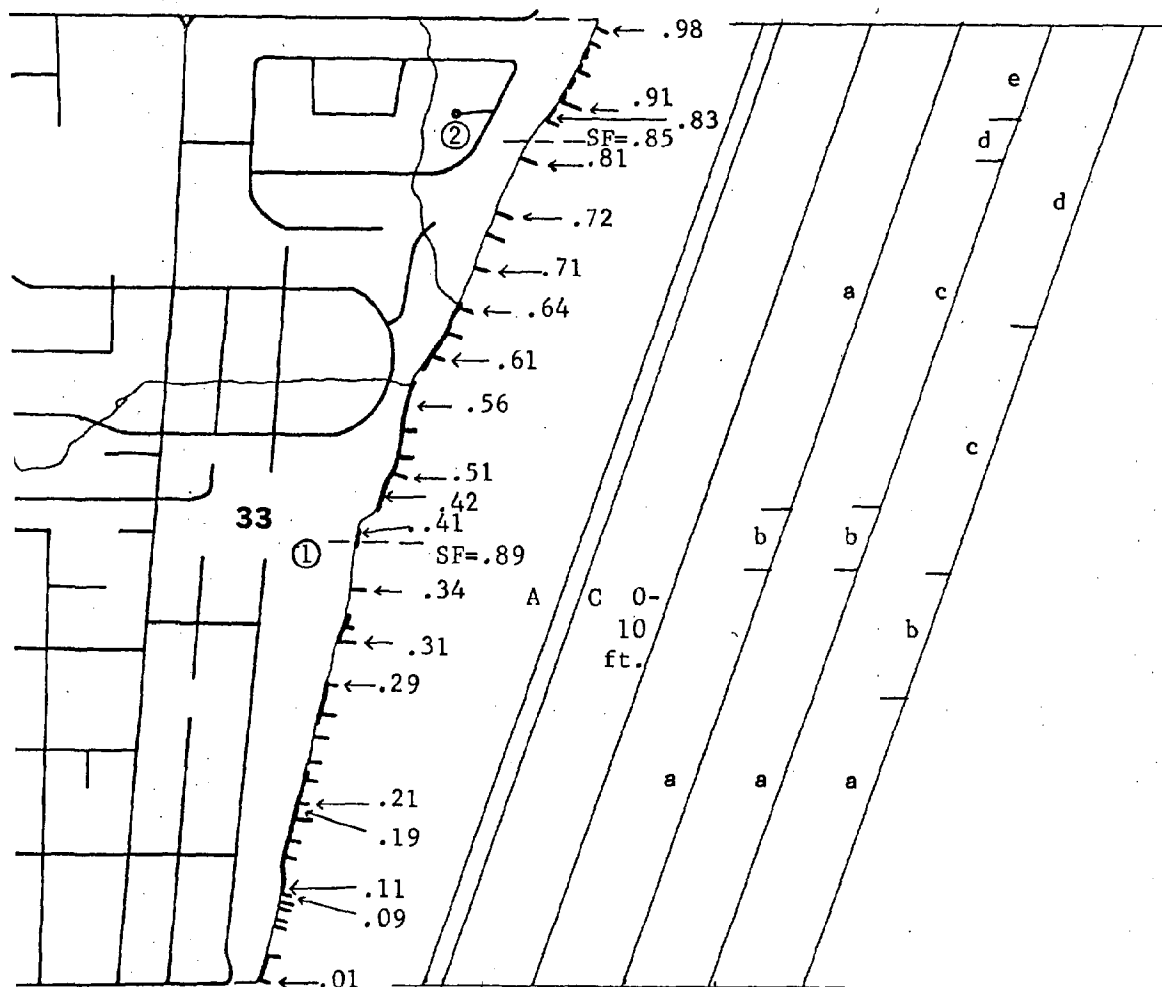
1. BLUFF	a-bluff is fairly stable and concealed with vegetation	b-some slumping but not significant	c-concealed	d-fairly stable, vegetated
	e-slump, wave erosion of toe	f-fairly stable and concealed by vegetation	g-primary fill slumping, wave erosion of bluff, 30 ft.	
2. TOE	a-mostly sand where observable, dune formation in this area	b-some fill visible	c-concealed	d-mostly concealed, some gravel, till, fill visible
	e-till, filled materials			
3. BEACH	a-much accretion, 150 to 250 ft. sand beach	b-dunes, 150 ft. of sand	c-beach increases 25 to 150 ft. southward from structure 519	d-15 to 25 ft. sand
	e-no beach	f-37 ft. sand and gravel at north; widens southward	g-beach less than 5 ft., gravel	

## Profile



T. 3 N., R. 23 E., Sec. 4





SAFETY FACTOR  
CONFIDENCE LEVEL

STABILITY LINE

BLUFF

TOE

BEACH

SAFETY FACTOR

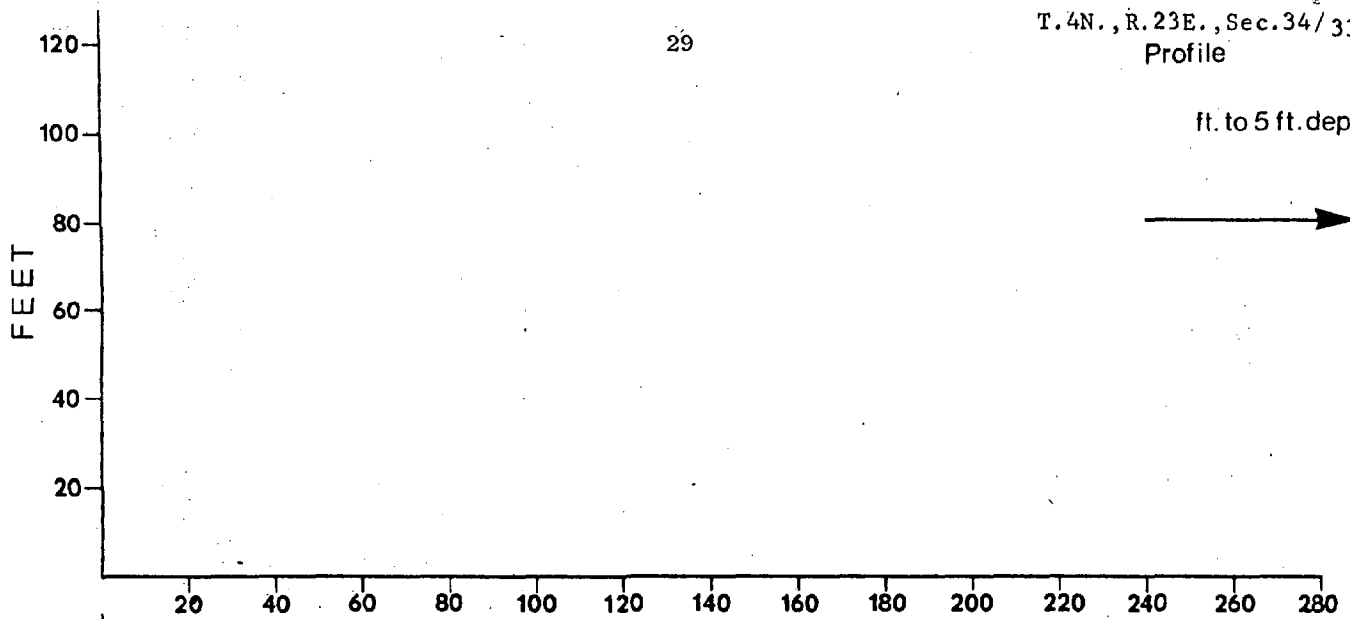
- A-less than 1.00
- B-1.00 to 1.25
- C-greater than 1.25

CONFIDENCE LEVEL

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

1. BLUFF	a-bluff in nearly entire section is fairly stable stabilized by terraced lawns, vegetated bluff, etc. Minor slump scarps and scalloped bluff edge visible in several places however, partially at north and south ends of section.	b-slump blocks		
2. TOE	a-dolomite blocks, concrete and artificial fill	b-till, slump units	c-dolomite blocks, artificial fill, concrete	d-till slump
	e-dolomite blocks, concrete and artificial fill			
3. BEACH	a-0 to 20 ft., typically 5 to 10 ft., but absent in many places. Sand and gravel	b-generally 20 to 40 ft., sand accretion	c-0 to 20 ft., sand and some pebbles, nearly all sand in some places	d-beach width highly variable; ranges from 10 to 65 ft., depending on protective structures, Sand and pebbles; in some places pebbles constitute nearly 50% of beach material.

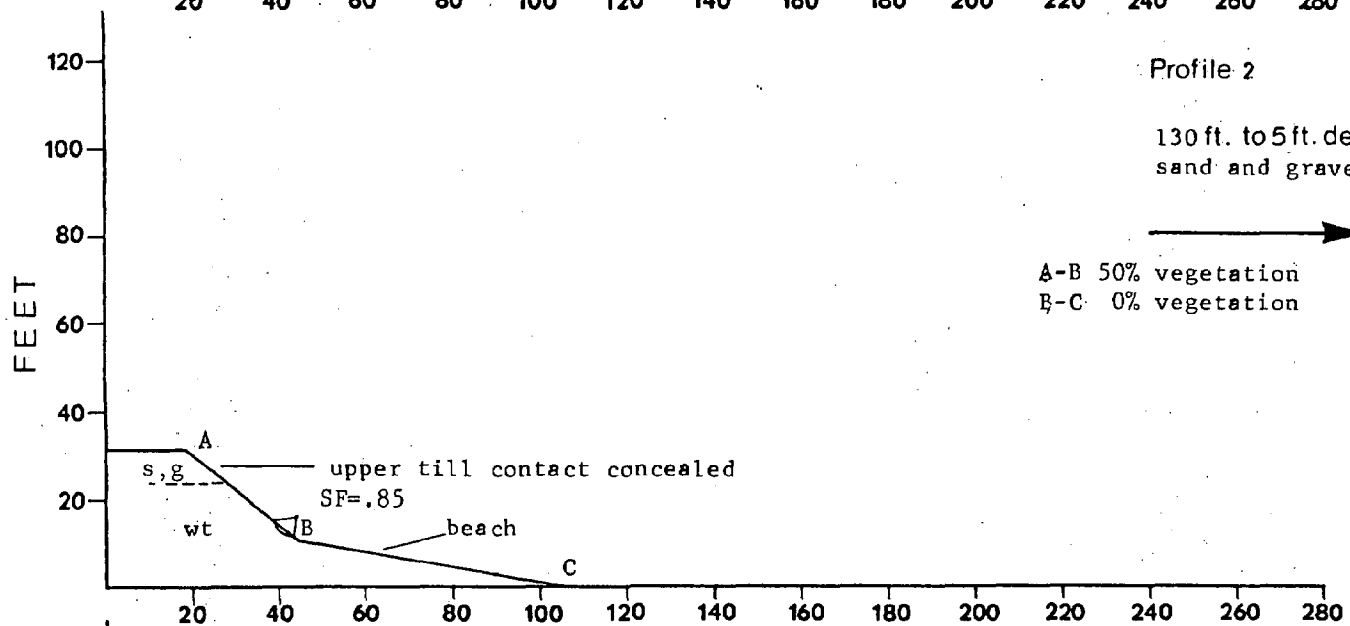
ft. to 5 ft. depth



Profile 2

130 ft. to 5 ft. depth  
sand and gravel

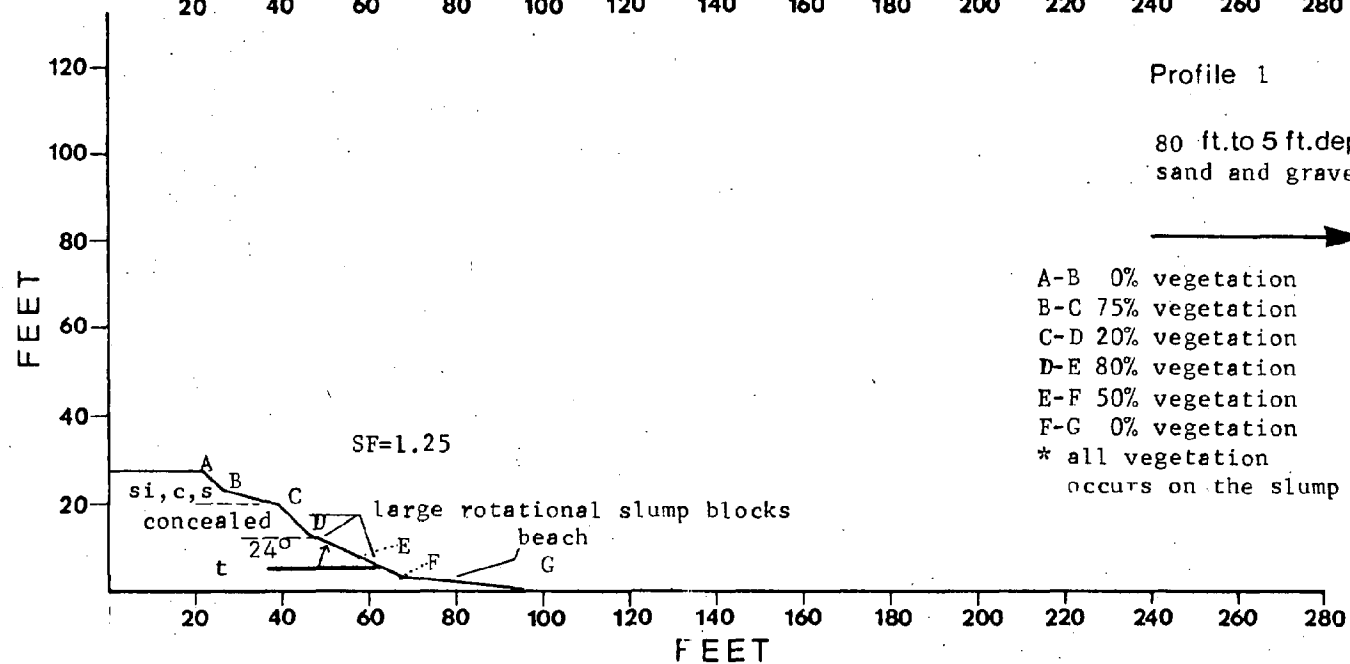
A-B 50% vegetation  
B-C 0% vegetation



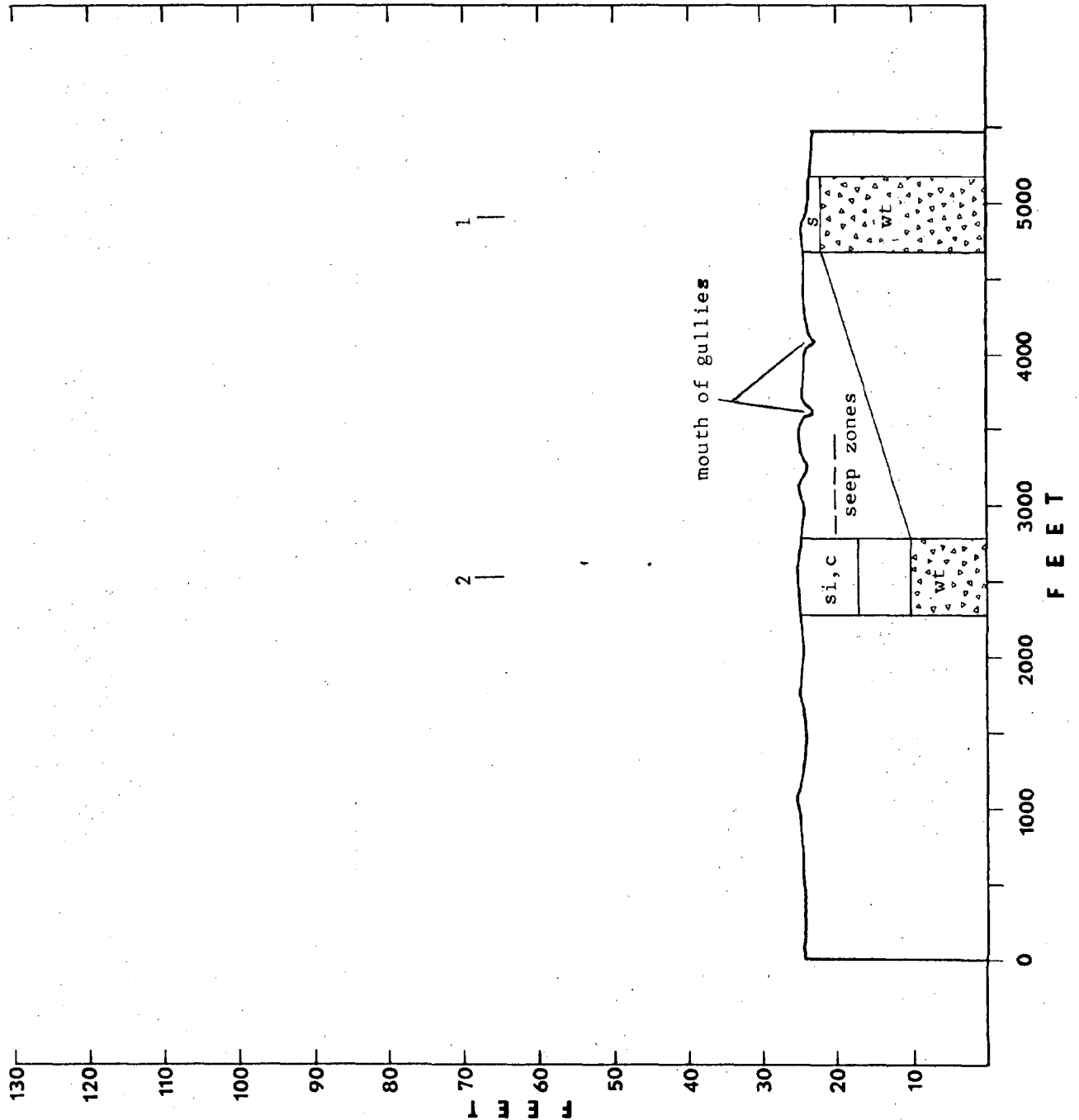
Profile 1

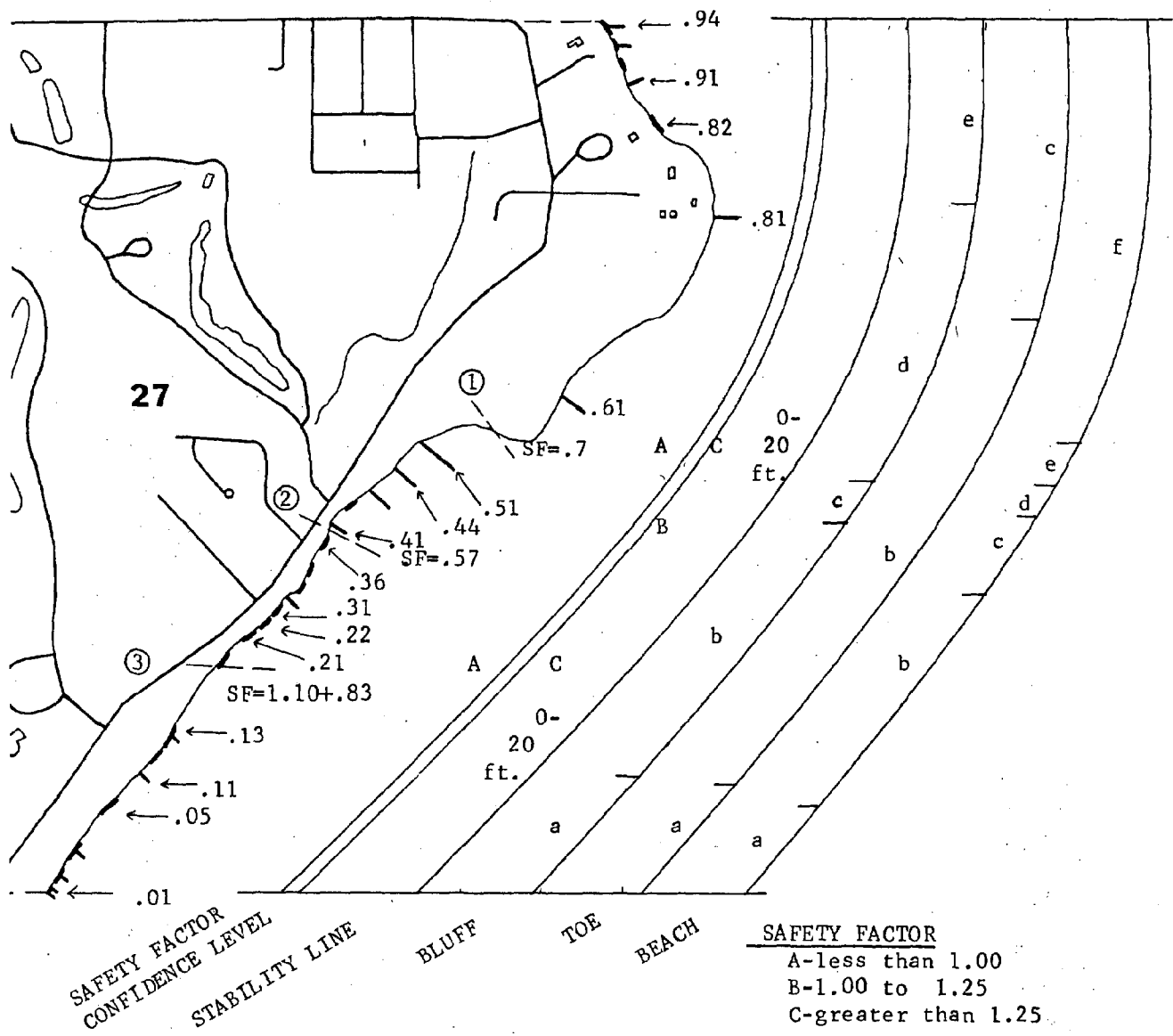
80 ft. to 5 ft. depth  
sand and gravel

A-B 0% vegetation  
B-C 75% vegetation  
C-D 20% vegetation  
D-E 80% vegetation  
E-F 50% vegetation  
F-G 0% vegetation  
\* all vegetation  
occurs on the slump



T. 4 N., R. 23 E., Sec. 33/34





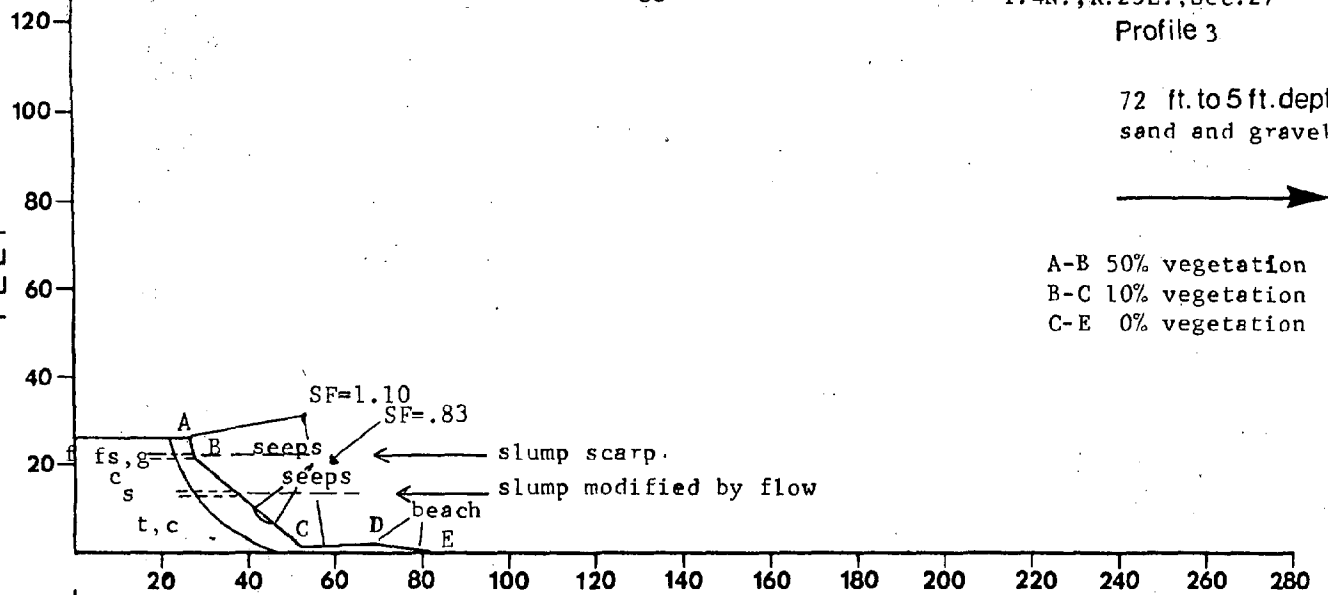


1. BLUFF	a-mostly man-made material forms bluff face, small slump blocks in places.	b-stabilized by vegetation in some places, marked by small slump blocks and scalloped bluff edge in other places, seep zones present at and above mid-bluff	c-bluff behind wide beach grassed and stable	d-low bluff, subject to slump and toe erosion
	e-virtually no bluff present, minor toe erosion at upper edge of beach			
2. TOE	a-concealed by artificial fill, debris dumped along shore and over bluff (broken concrete, asphalt, dolomite blocks, etc)	b-clayey till, concealed in most places by debris, revetments, and bulkheads.	c-appears mostly sand, largely concealed by vegetation	
3. BEACH	a-0 to 5 ft. generally absent, covered by dumped debris	b-beach width variable, 5 to 65 ft. dependent on structures, sand, pebbles, cobbles	c-no beach, protective structures to water's edge	d-10 to 100 ft., sand accretion due to groins, some gravel
	e-5 to 10 ft., mostly gravel	f-10 to 30 ft., mostly pebbles and cobbles, little sand		

## Profile 3

72 ft. to 5 ft. depth  
sand and gravel

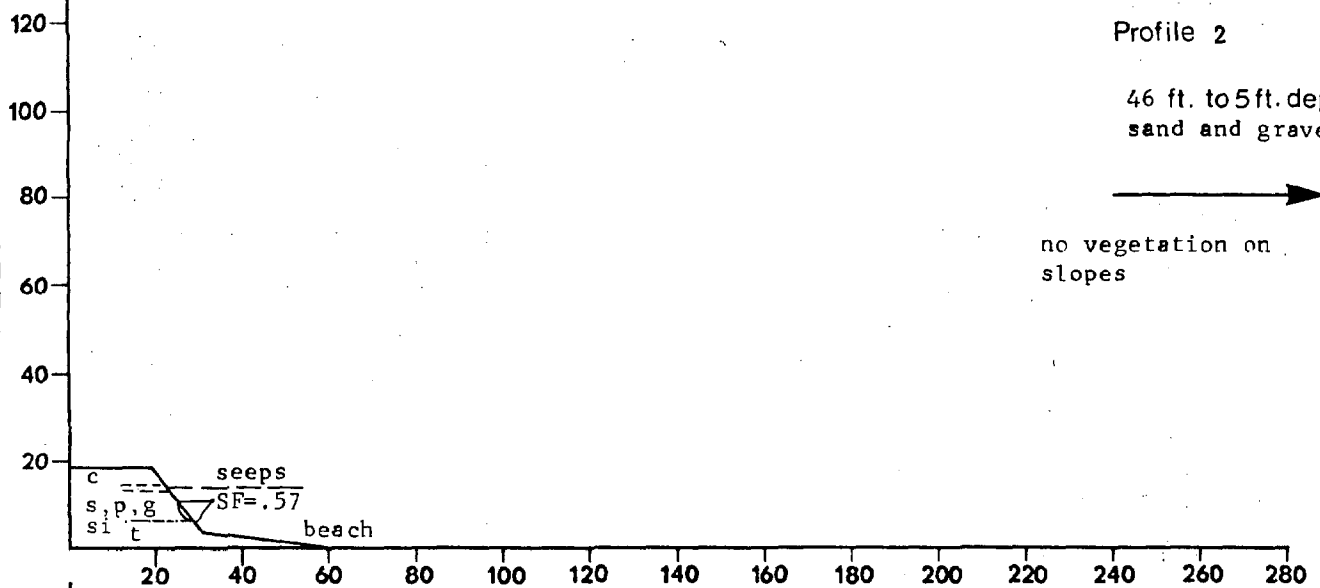
FEET



## Profile 2

46 ft. to 5 ft. depth  
sand and gravel

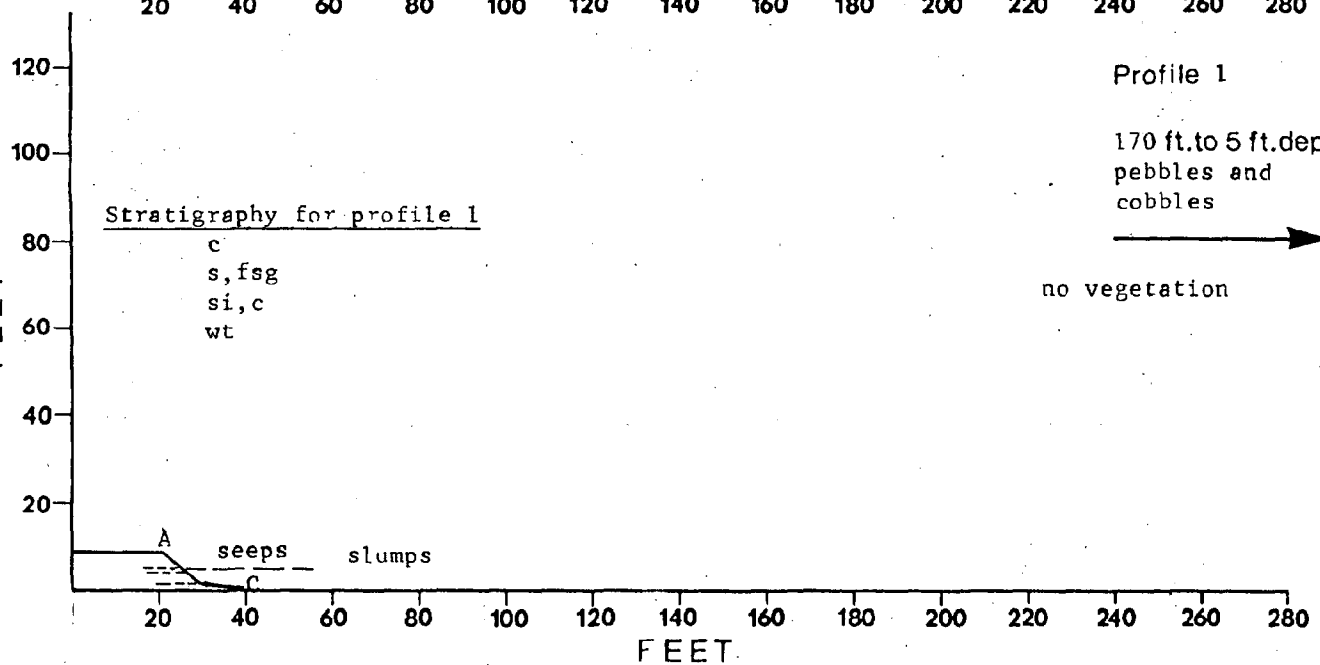
FEET



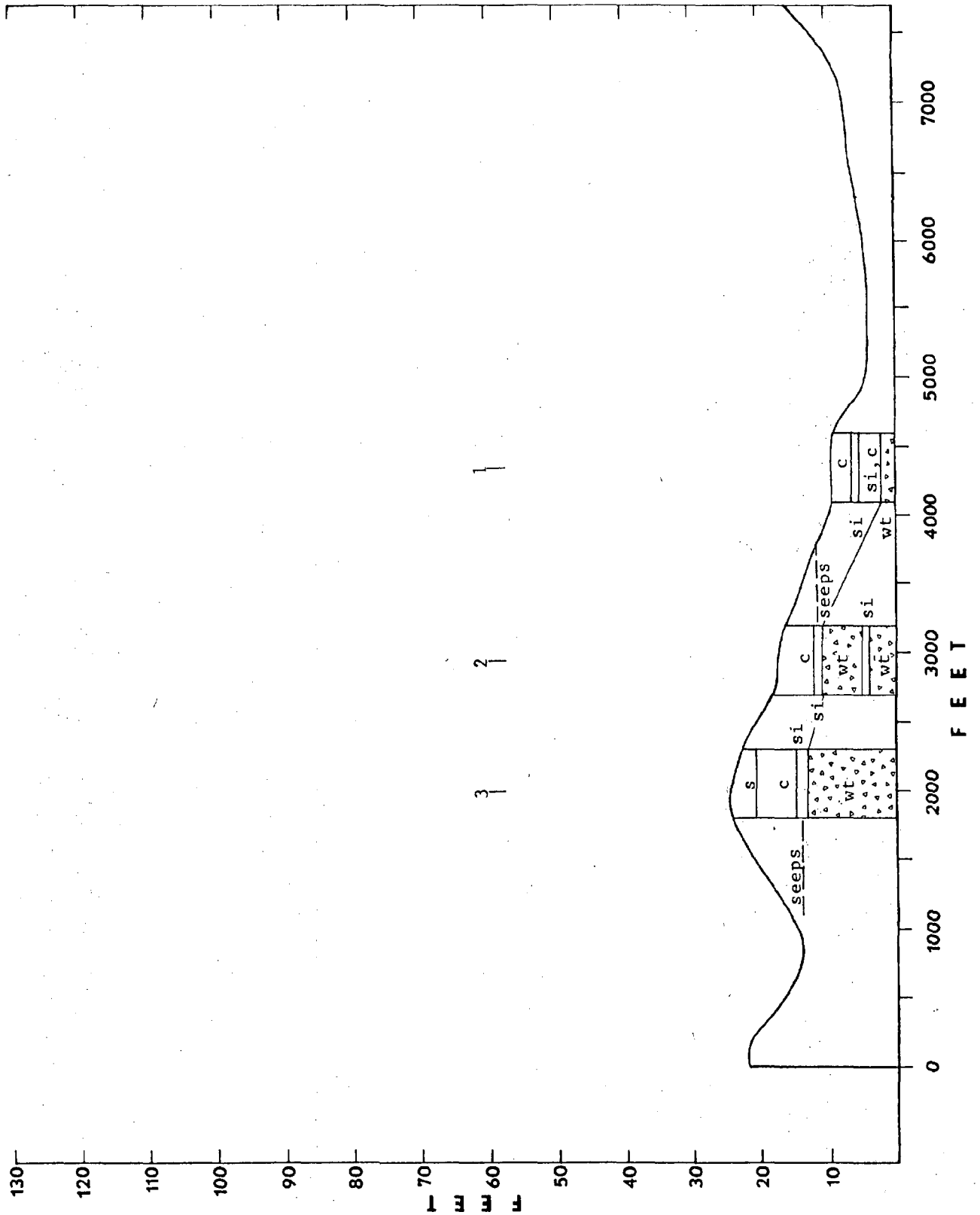
## Profile 1

170 ft. to 5 ft. depth  
pebbles and  
cobbles

FEET



T. 4 N., R. 22 E., Sec. 27



Reach 6

Erosion reach 6 is located in Townships 4 and 5 North, Range 23 East, in northern Racine County and southernmost Milwaukee County. It extends from the mid-line of the Wind Point headland in section 27 (T. 4 N.) northwestward to the north end of the bulkhead that protects the coal stockpile for the Oak Creek power plant in section 31 (T. 5 N.). Although the north-south grid distance of the reach is about 4.6 miles, the coastal distance is fully one-third again as long — more than 6.1 miles — due to the northwest-southeast orientation of the coastline.

Reach 6 has one of the highest priorities of the entire Lake Michigan shoreline, ranking third in the listing of critical erosion areas, with a value per mile of 25. Land use and shoreline characteristics cover a wide range. Much of the land is residential property, but some is used for agricultural purposes, some is undeveloped to partially developed recreational land (including both County of Racine and Town of Caledonia park properties in sections 7 and 8), some is industrial land, and some of the shoreline is owned by educational institutions.

Beach width ranges from 0 to 75 feet; much of the beach is between 10 and 40 feet wide. The beach is widest just south of the mouth of a small valley near the middle of the reach in section 17, where a compound shore-protection structure consisting of four on-shore beach-accretion groins attached to a dolomite stone revetment is responsible for active sedimentation. In contrast, numerous segments exist where either no beach whatever is present or where the beach is less than 10 feet wide. Beach materials also exhibit a wide range in caliber, from nearly pure sand to nearly pure gravel. The coarsest beach in all of Racine and Kenosha Counties is that at Wind Point just north of the lighthouse, where beach sediments consist almost entirely of pebbles and cobbles.

Much of the coastline in Reach 6 lacks shore protection structures of any kind, some of it is moderately well protected, and part is marked by a fair abundance of protective devices. Except for the compound structure that protects the Oak Creek power plant at the north end of the reach, only three protective structures, none of which is effective, are present in the entire north half of the reach. The density of structures is therefore about one per mile — in contrast to segments of several other reaches farther south, where the density is 40 or more per mile. Structures are much more abundant and generally well constructed, however, in the southern part of Reach 6.

Bluff height ranges from 5 to 85 feet. The bluff is highest in the northern part of the reach where the shoreline intercepts the proximal slope of the innermost Lake Border moraine in sections 6 and 31; in this area the bluff nearly everywhere is very steep and in excess of 70 feet high. In the southern part of the reach, on the other hand, at and just north of Wind Point a low terrace that separates the shoreline from the main upland surface is generally 8 to 14 feet above lake level, and in most places no real bluff exists along the shore; where present, the bluff is only 5 to 10 feet high. The terrace is also present as a narrow belt half a mile upshore. Throughout most of the reach, between the north end of this low terrace and the Lake Border moraine, the bluff is moderately to very steep and ranges from 30 to 70 feet high, progressively increasing in height from south to north. The upland surface behind the bluff in this segment is a lacustrine terrace that represents the Glenwood stage of glacial Lake Chicago.

The materials in the bluff consist mainly of fine-textured sediments, including compact silty clay till and also silt and clay of lacustrine origin, with lesser amounts of fine-grained sand. Individual till and lacustrine units range in thickness from less than a foot to about 55 feet, but unit thicknesses appear to be highly variable. The upper part of the bluff

commonly exposes sand or sandy gravel or sand and laminated lacustrine silts and clays, which overlie the much thicker till and lacustrine deposits below. Except for this general relationship, no very consistent stratigraphy is apparent, at least in the northern part of the reach. In many places relatively thick lacustrine sediments overlie till (see profile 2, section 6; profile 2, section 8; and profiles 3 and 4, section 16), whereas at other sites the relationship is reversed (see profile 1, section 8), and at still other localities the deposits are interbedded (see profile 4, section 7; profile 3, section 8; and profile 4, section 16).

Two discrete units of silty clay till are present near the north end of the reach, one at the toe of the bluff and one that makes up much of the upper two-thirds of the bluff (see profile 1, section 6). As much as  $4\frac{1}{2}$  feet of the lower unit is exposed above lake level, and it is overlain by about 20 feet of lacustrine deposits, which consist mostly of well bedded silts but which include some thin clay layers and some sand layers. The contact between the basal till and the lake deposits is very sharp and is marked by a prominent seep zone that reflects the differential permeability of the two units. The contact between the lacustrine sediments and the thick (45 feet) upper till, on the other hand, is gradational and marked by a zone of interbedded layers of till and lake sediment.

Throughout most of the reach only one till unit appears to be present, however, and in the southern part no till whatever is exposed in the bluff face (see profile 1, section 21 and profile 2, section 22). The pink lake clay that is present below sand in the upper part of the bluff near the south end of the reach (see profile 2, section 22) is undoubtedly the same pink to pinkish-brown clay that occurs farther south in Reaches 4 and 5; it may also form a thin cap on the bluff at a few places farther north in Reach 6 (see profile 2, section 6). This clay is believed to be correlative with the oldest

pink clay till that is exposed in the Lake Michigan bluff in northern Milwaukee and Ozaukee Counties.

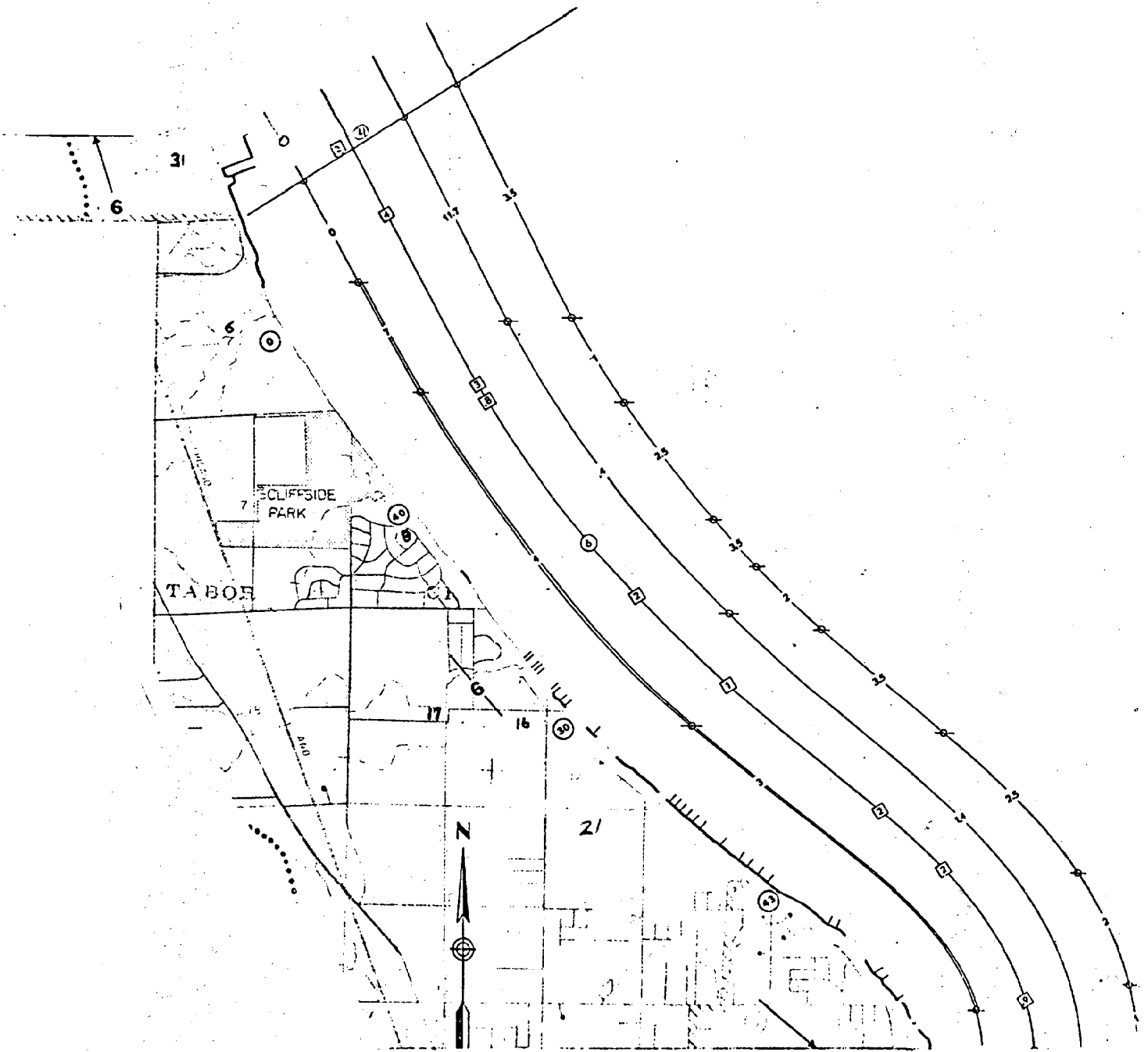
Slope stability also shows a range in conditions. In places where the bluff has been terraced or graded and sodded, the slope appears to be quite stable. In a great many other places, however, bluff failure is rapid and severe. Moderate-sized to massive slump blocks, commonly of a compound character, impart a distinctly scalloped pattern to the raw, sharp bluff edge through much of the reach. Mudflow, debris slide, debris fall, seep sapping, gully cutting, and toe erosion are all significant processes causing bluff failure and shoreline recession. Single profiles commonly show evidence of slump at the bluff edge, flow in mid-bluff, and wave erosion at the base of the cliff.

Thus, in virtually all categories, the Reach 6 shoreline presents a wide variety of conditions — undoubtedly the widest range of conditions of any reach in Racine and Kenosha Counties.

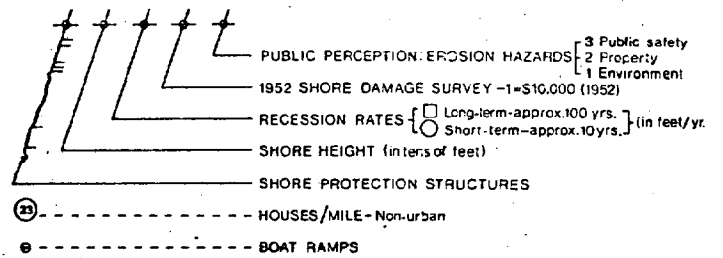
Evidences of shoreline recession and slope failure of the bluff face were observed throughout most of Reach 6. The general problem of coastal erosion is definitely more serious in the northern part of the reach, however, than near the south end. The greater severity of the problem in this stretch can be attributed to a combination of interrelated factors, which serve to reenforce one another and thereby complicate any analysis of a complex situation. The most important factors, not necessarily in order of their importance, are the following: (1) high lake level; (2) narrow beaches, which are a direct consequence of high lake level; (3) general absence of shore protection structures, such as groins, revetments, and seawalls; (4) constant, or at least repeated, attack upon the toe of the bluff by waves, due to both narrow beaches and general absence of protective structures; (5) northwest-southeast orientation of the coast and its gentle concavity to

the northeast, which make it particularly vulnerable to the ravages of winter storm waves from the northeast; (6) steep and moderately high to high bluffs, which are susceptible to rapid failure by debris fall and debris slide when undercut by wave action at the toe; (7) high content of fine-grained constituents (i.e., silt and clay) in the bluff sediments, which when wet are susceptible to failure by slump and flow processes; (8) presence of coarser-grained and more permeable layers in the bluff sediments, through which water can move laterally and issue at the bluff face in the form of seeps; and (9) location of the reach (especially the northern part) just to the south of the Oak Creek power plant and its massive groin-like structure that interrupt the north-south longshore current, thereby trapping sand to the north and resulting in sediment starvation of the beach area to the south. In this last regard, the situation in Reach 6 is analogous to that in Reach 3 south of Racine and to that in Reach 1 south of Kenosha.



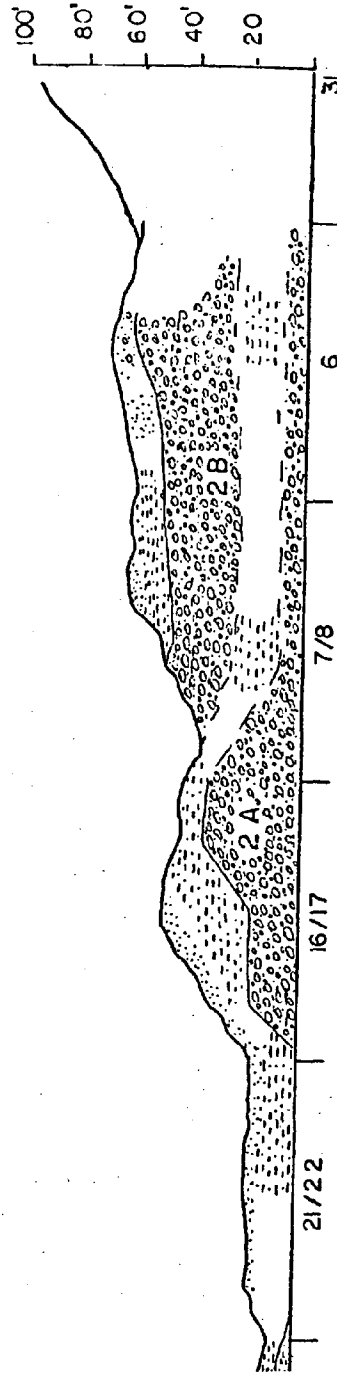


Reach 6



T. 4 N.

Racine Co., Milwaukee Co.



## LEGEND

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

Generalized longitudinal section showing bluff stratigraphy in Reach 6. Numbers along base of diagram are geographic (1 mile) sections.

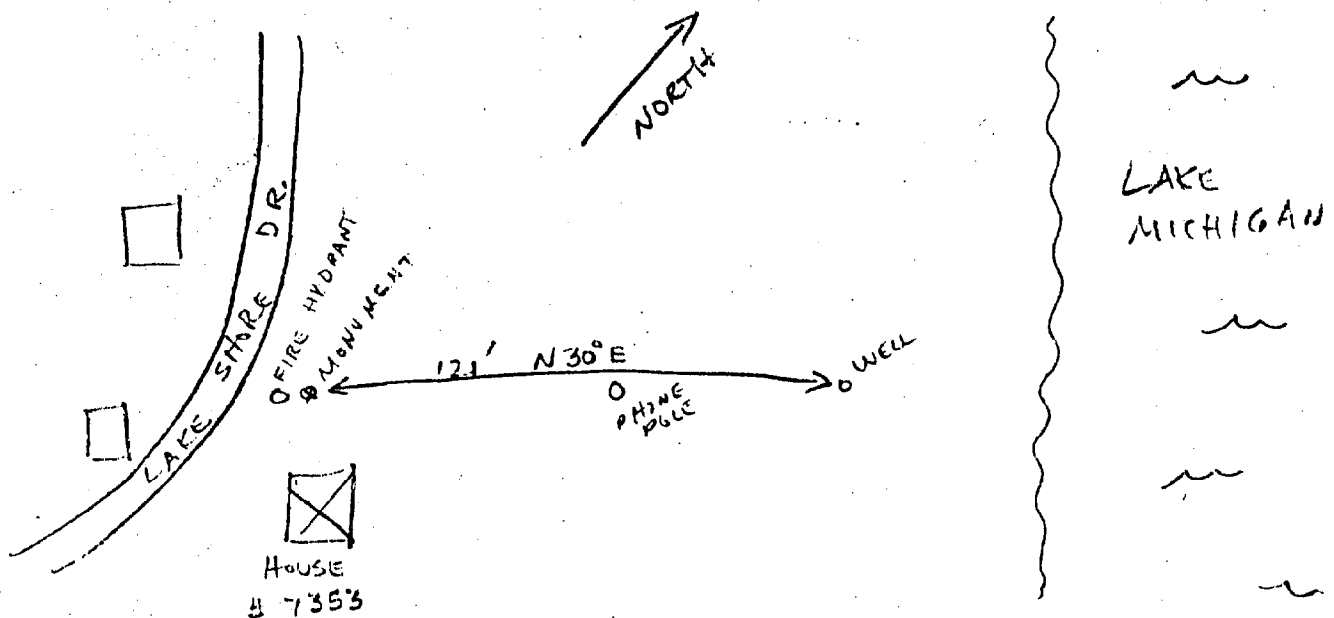
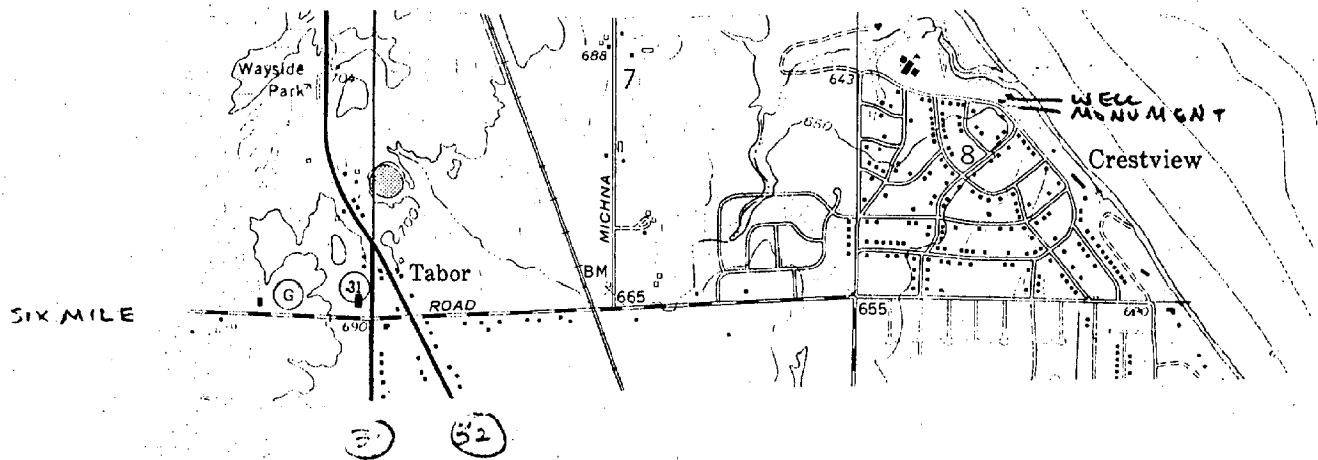
University of Wisconsin--Extension  
Geological and Natural History Survey  
1815 University Avenue, Madison, Wisconsin 53703

LOCATION AND MONUMENTATION SKETCHES

Boring No. GT-5 RACINE CO., RACINE NORTH QUAD. (BURNT OUT SCHOOL)  
NE 1/4 SW 1/4 SEC. 8 / T. 4 N. / R. 22 E

Date

Drawn by



Borehole: GT-5      Location: Crestview, Racine County, Sec. 8, T4N

Depth (feet)	Blow Counts (Split spoon) Standard Penetration	Pocket Penetrometer	w <sub>n</sub> %	γ <sub>d</sub> (psf)	w <sub>L</sub> %	I <sub>p</sub> %	% Clay & Silt	φ°	c (psf)	c <sub>vane</sub> (psf)	USCS class.
5											
10											
15											
20			15.9	120	28.5	11.9	31.4	28.0	818	1535	
25											
30											
35											
40											
45			15.3	120	27.5	10.7	30.8	28.0	818	2578	
50											
55											
60			13.3	122	21.2	8.3		28.0	818		
65											

no split spoon  
sampled

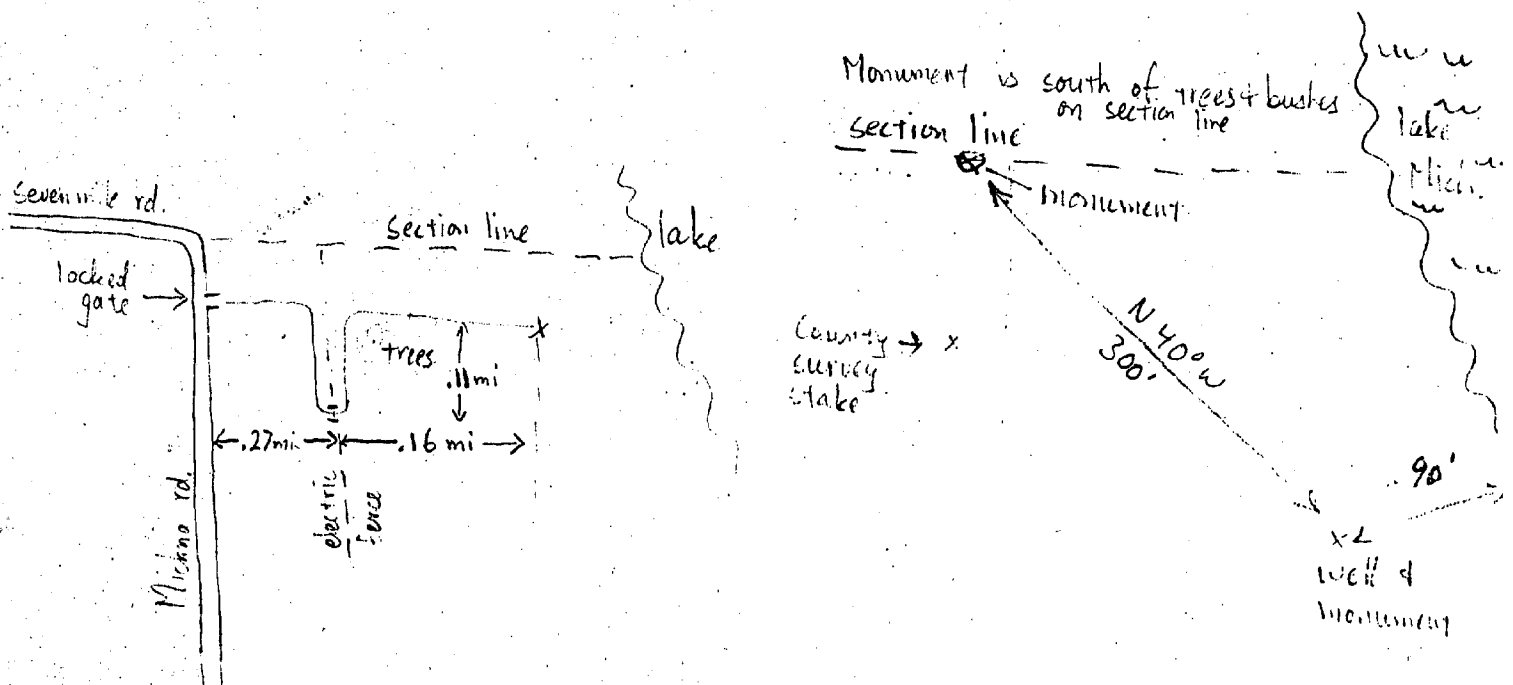
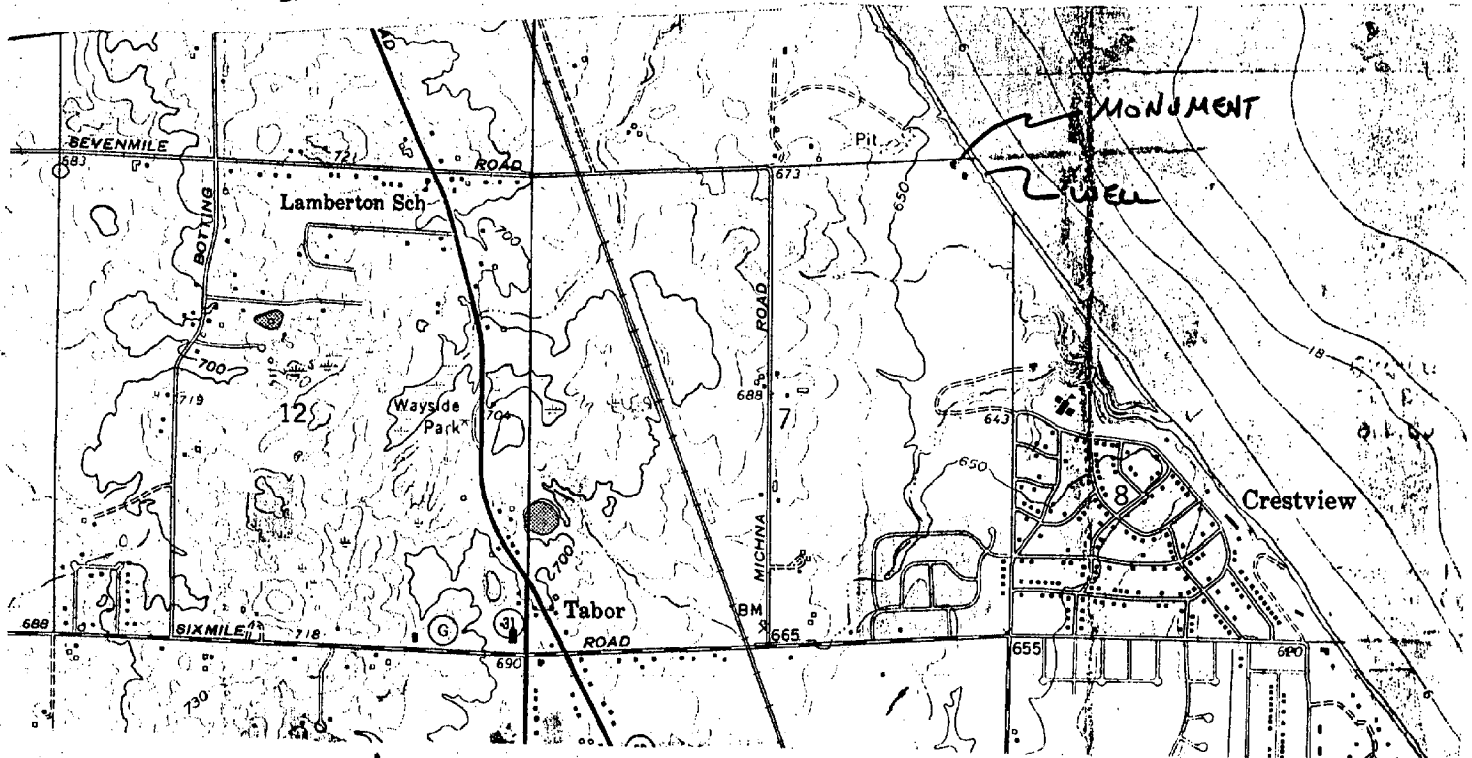
University of Wisconsin--Extension  
Geological and Natural History Survey  
1815 University Avenue, Madison, Wisconsin 53703

LOCATION AND MONUMENTATION SKETCHES

Boring No. GT-4 Key for gate - Frank Michna 7518 Michna road, 639-2999  
Racine North Quad, Racine Co. NE 1/4 / NE 1/4 / Sec. 7 / T. 4 N. / R. 23 E.

Date

Drawn by



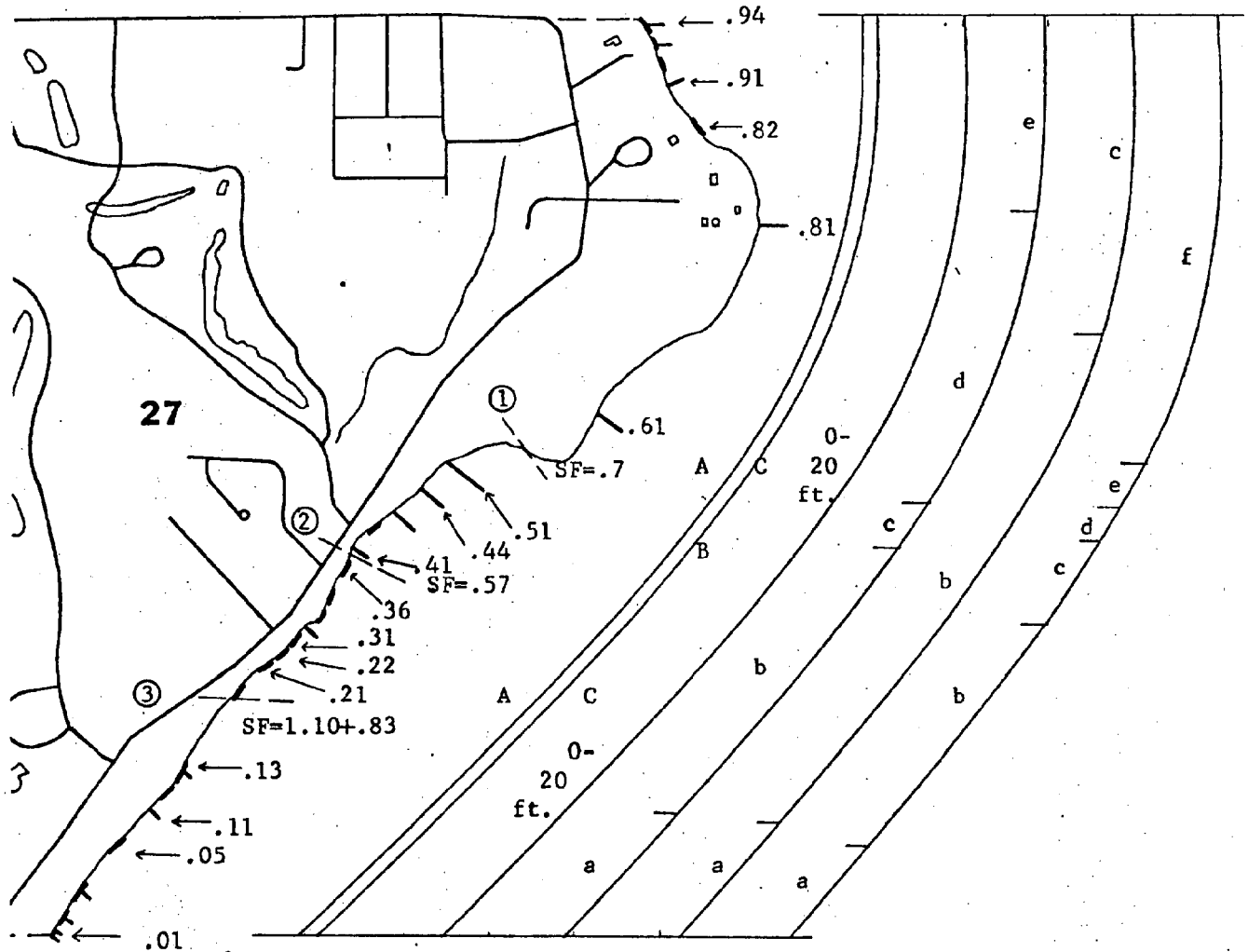
Borehole: GT-4 Location: Crestview, Racine County, Sec. 7, T4N

Depth (feet)	Flow Counts (Split spoon) Standard Penetration	Pocket Penetrometer	w %	$\gamma_d$ (psf)	w <sub>L</sub> %	I <sub>P</sub> %	% Clay & Silt	% Clay & Silt	$\phi^\circ$	c (psf)	c <sub>vane</sub> (psf)	USCS class.
5			18.8	108	32.2	14.0		86.5				CL
10			13.0	128	17.6	5.0	12.5	54.2	29	0.0		CL-ML
15			15.7	121			23.0	77.8	27.0	0.0		ML
20												
25			13.1	119	29.5	12.8		76.1				
30			22.3		22.3	10.1						
35												
40			12.6	121	23.3	9.1	29.6	89.3				CL
45			14.6	118	23.9	9.6		88.6				
50												
55			13.9	119	24.9	10.6	33.4	91.1				
60			14.2	120	22.7	9.2	27.7	85.7				
65												
70			13.7	124	22.2	8.1	27.8	92.1	31.2	0.0		
75												

tan  
sandy,  
silty  
clay

grey  
clay  
till

20'



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

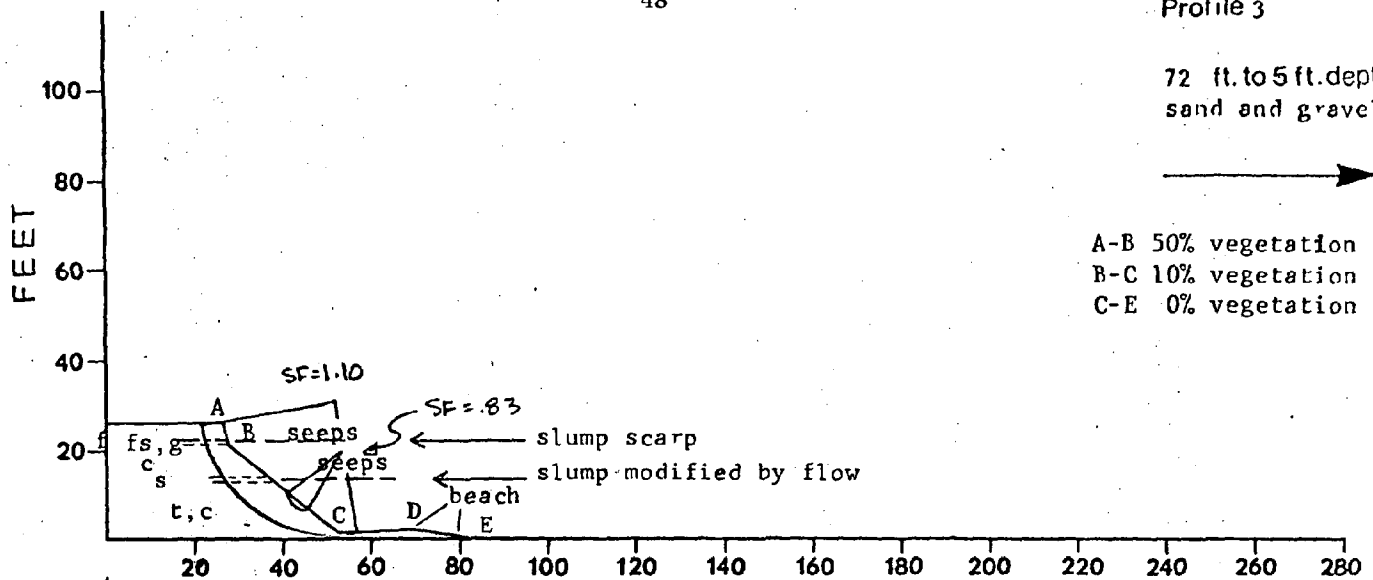
- A-boreholes (high confidence)
- B-near boreholes  
Stratigraphy visible
- C-no stratigraphy  
visible (low confidence)

1. BLUFF	a-mostly man-made material forms bluff face, small slump blocks in places.	b-stabilized by vegetation in some places, marked by small slump blocks and scalloped bluff edge in other places, seep zones present at and above mid-bluff	c-bluff behind wide beach grassed and stable	d-low bluff, subject to slump and toe erosion
	e-virtually no bluff present, minor toe erosion at upper edge of beach			
2. TOE	a-concealed by artificial fill, debris dumped along shore and over bluff (broken concrete, asphalt, dolomite blocks, etc)	b-clayey till, concealed in most places by debris, revetments, and bulkheads.	c-appears mostly sand, largely concealed by vegetation	
3. BEACH	a-0 to 5 ft. generally absent, covered by dumped debris	b-beach width variable, 5 to 65 ft. dependent on structures, sand, pebbles, cobbles	c-no beach, protective structures to water's edge	d-10 to 100 ft., sand accretion due to groins, some gravel
	e-5 to 10 ft., mostly gravel	f-10 to 30 ft., mostly pebbles and cobbles, little sand		



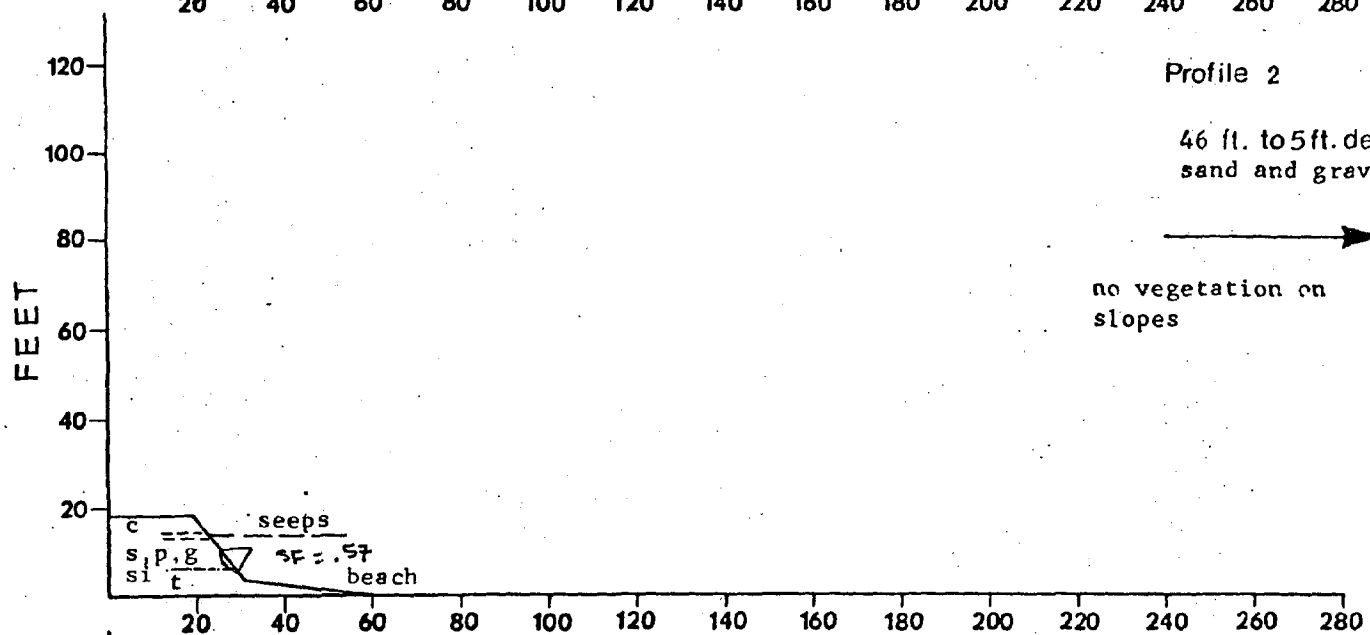
## Profile 3

72 ft. to 5 ft. depth  
sand and gravel



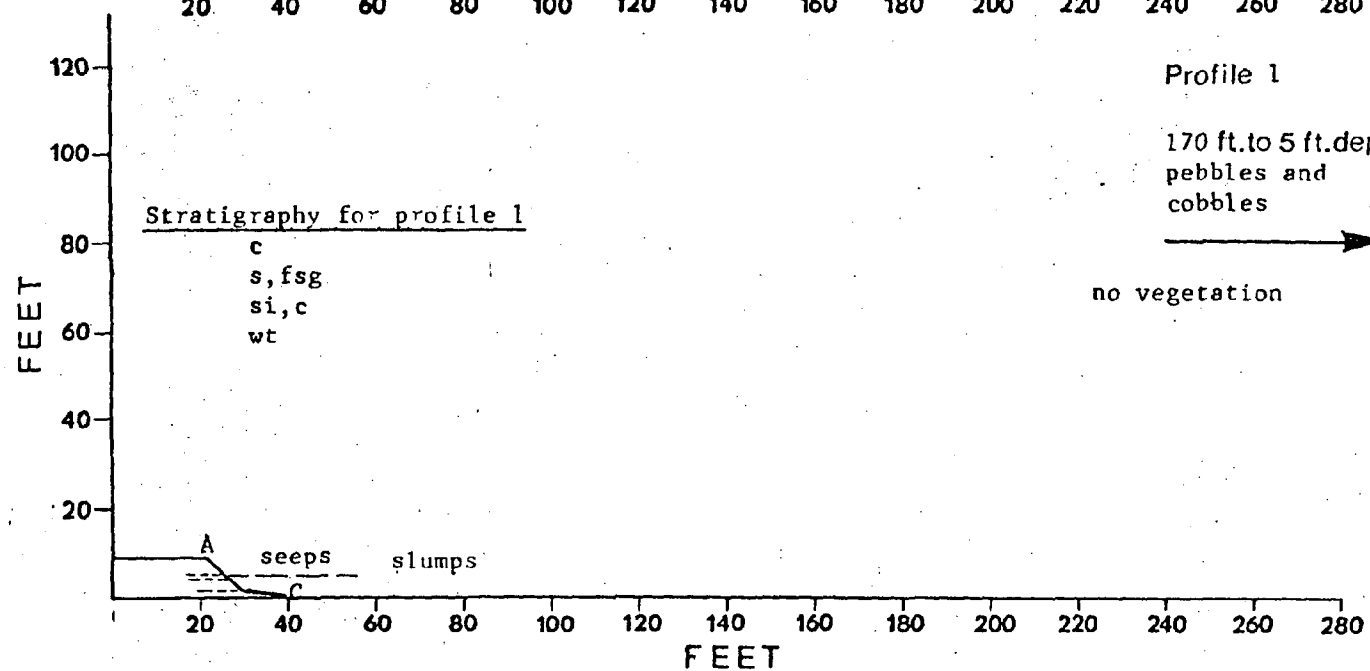
## Profile 2

46 ft. to 5 ft. depth  
sand and gravel

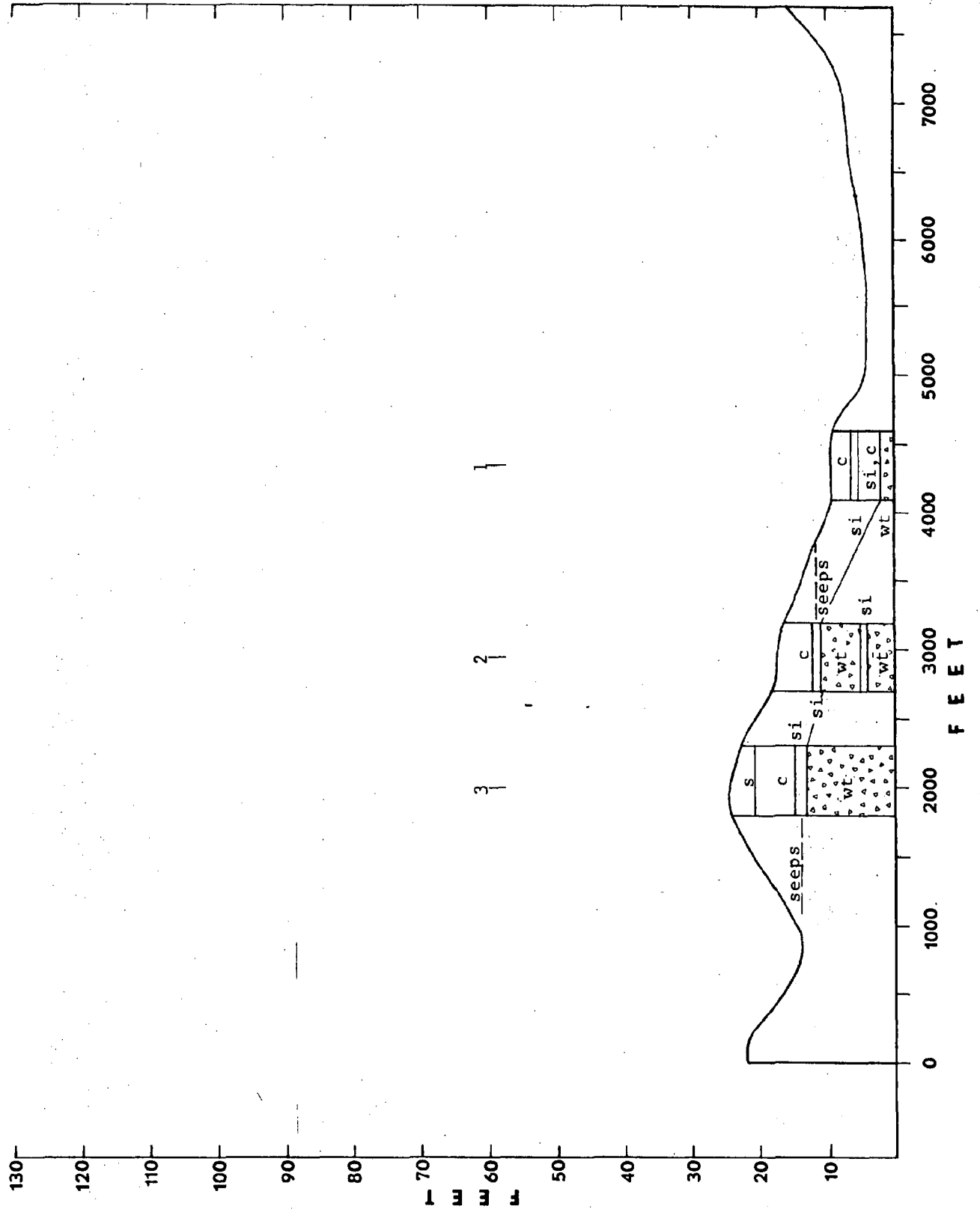


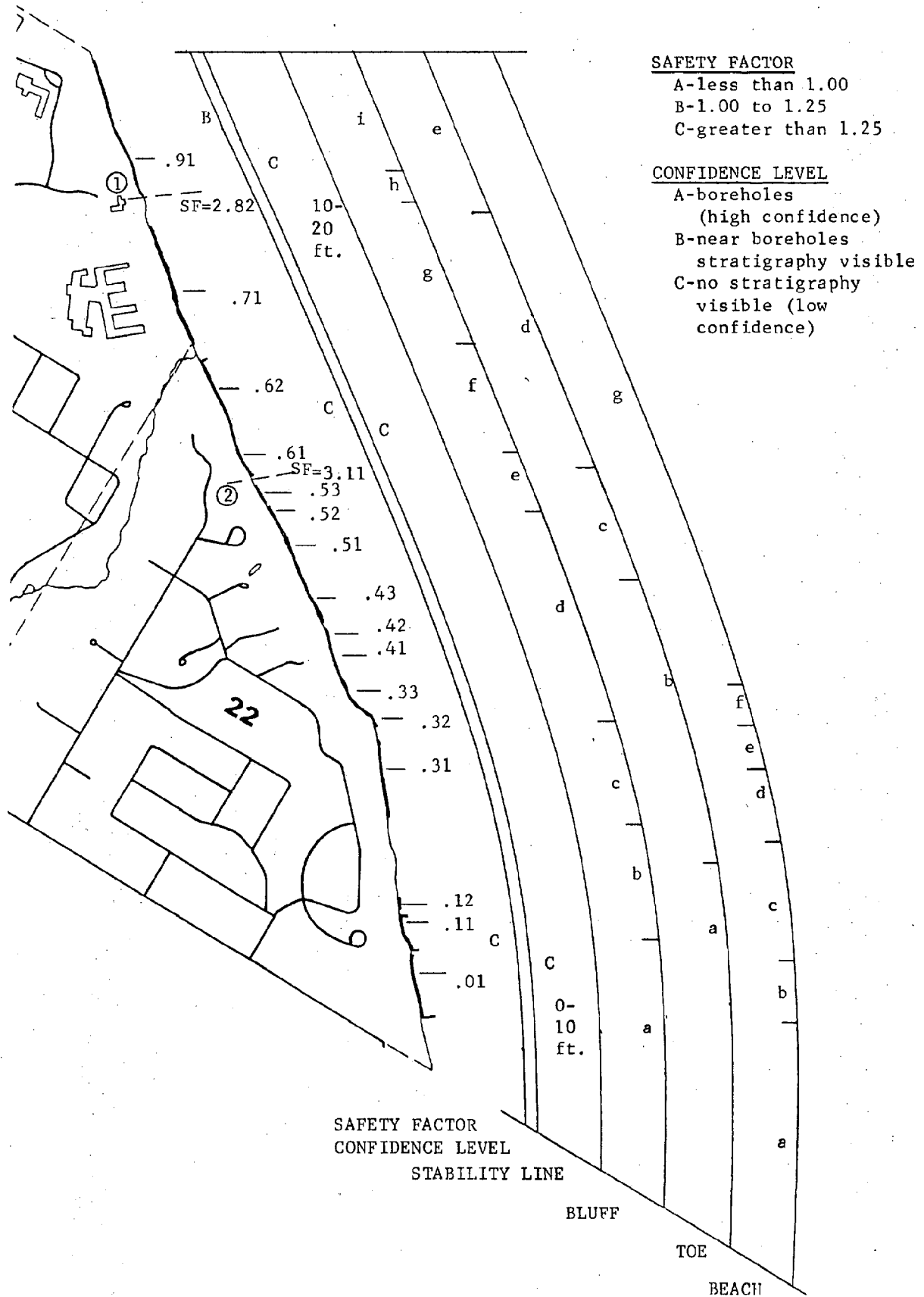
## Profile 1

170 ft. to 5 ft. depth  
pebbles and cobbles



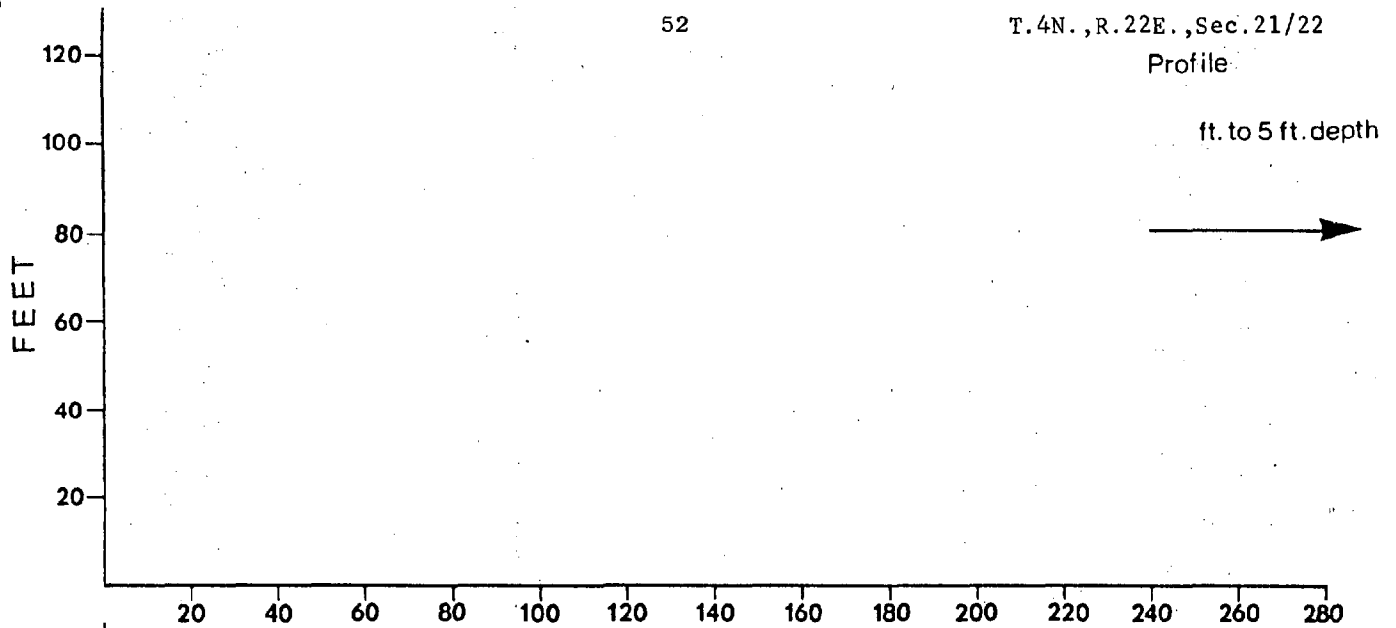
T. 4 N., R. 22 E., Sec. 27



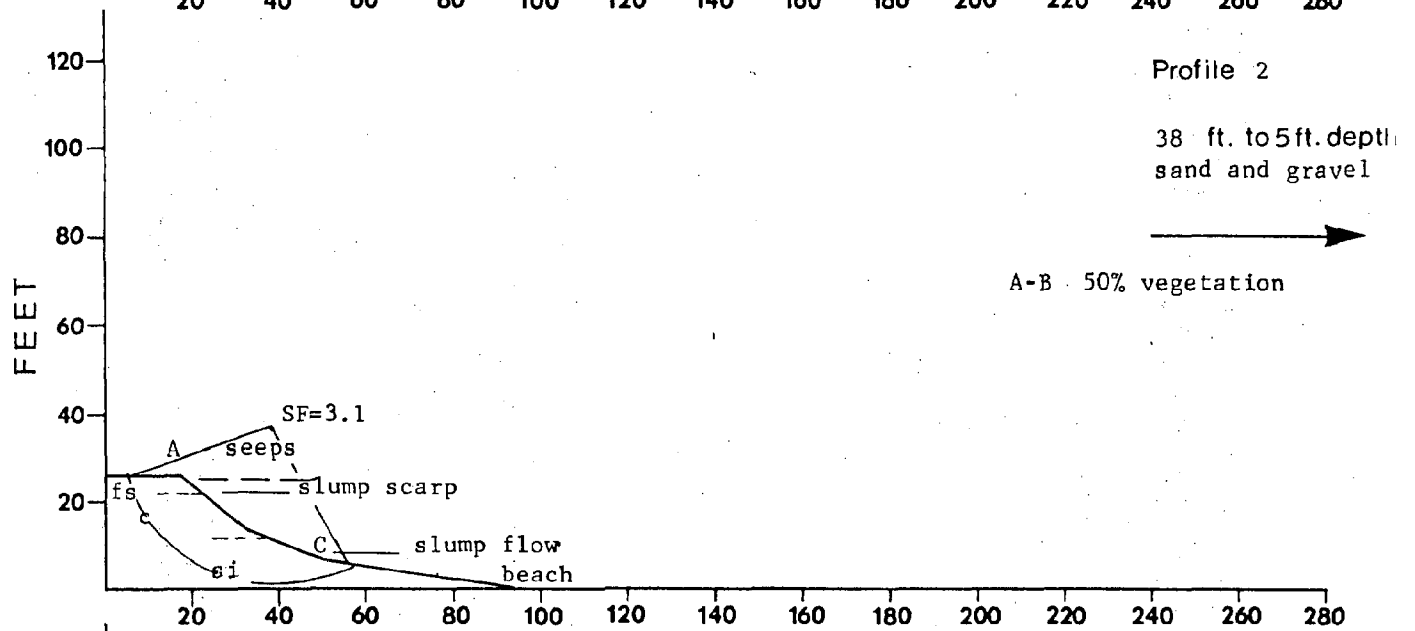


1. BLUFF	a-slopes stable	b-slump blocks; fresh slump scars at bluff edge	c-slump blocks in some places; scars partially healed.	d-a few small slumps now; some evidence of past slumps through old slump scars; not much active slumping or other slope failure. Bluff is fairly low, vegetated and protected by shore protection structures.
	e-partly stabilized, partly failing by small slumps.	f-low bluff; sodded, but failing due to small debris falls at base.	g-bluff terraced and sodded. stable. some toe erosion.	h-some active slumping.
	i-fairly stable bluff edge moderately straight, little failure, minor erosion			
2. TOE	a-probably sand	b-pinkish brown lacustrine clay and some sand	c-massive gray lacustrine silt	d-this slope is stabilized by terracing and sodding, exp. stabilization project.
	e-lacustrine silts and clays			
3. BEACH	a-20 to 40 ft., pebbles, little sand	b-0-10 ft., stone revetment on beach, pebbles and cobbles	c-20 to 60 ft., sand and pebbles	d-5 to 20 ft.,
	e-0 to 5 ft., junk revetment	f-10 to 20 ft., sand to cobbles	g-25 to 55 ft., 30 to 40 ft. wide in most places, sand and pebbles	

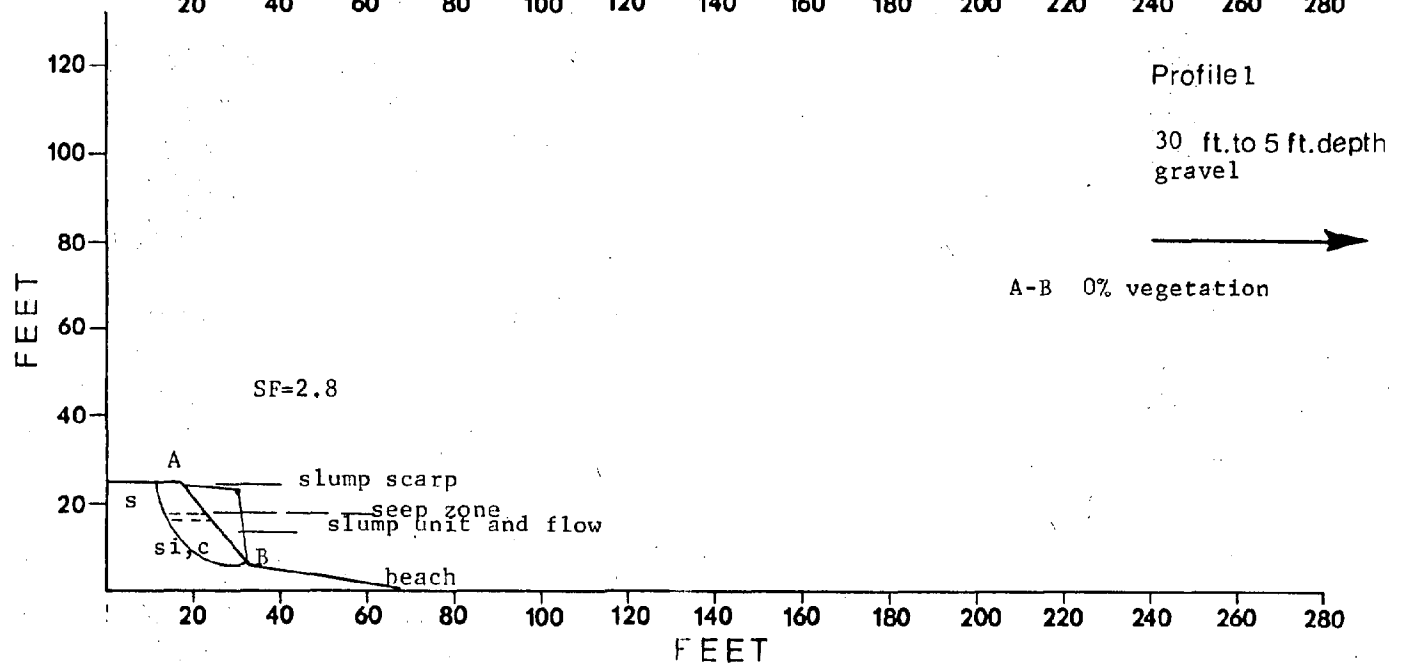
## Profile



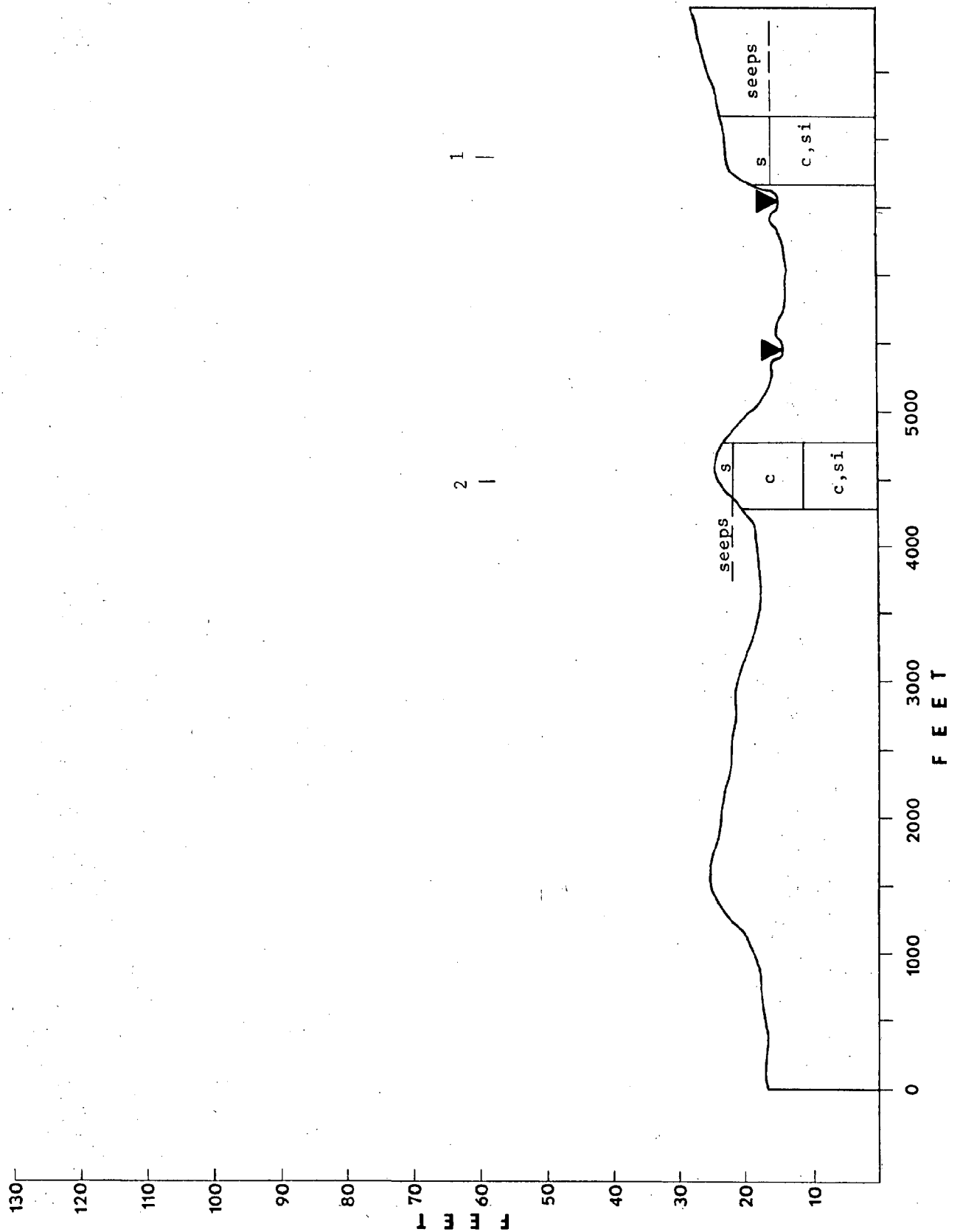
## Profile 2



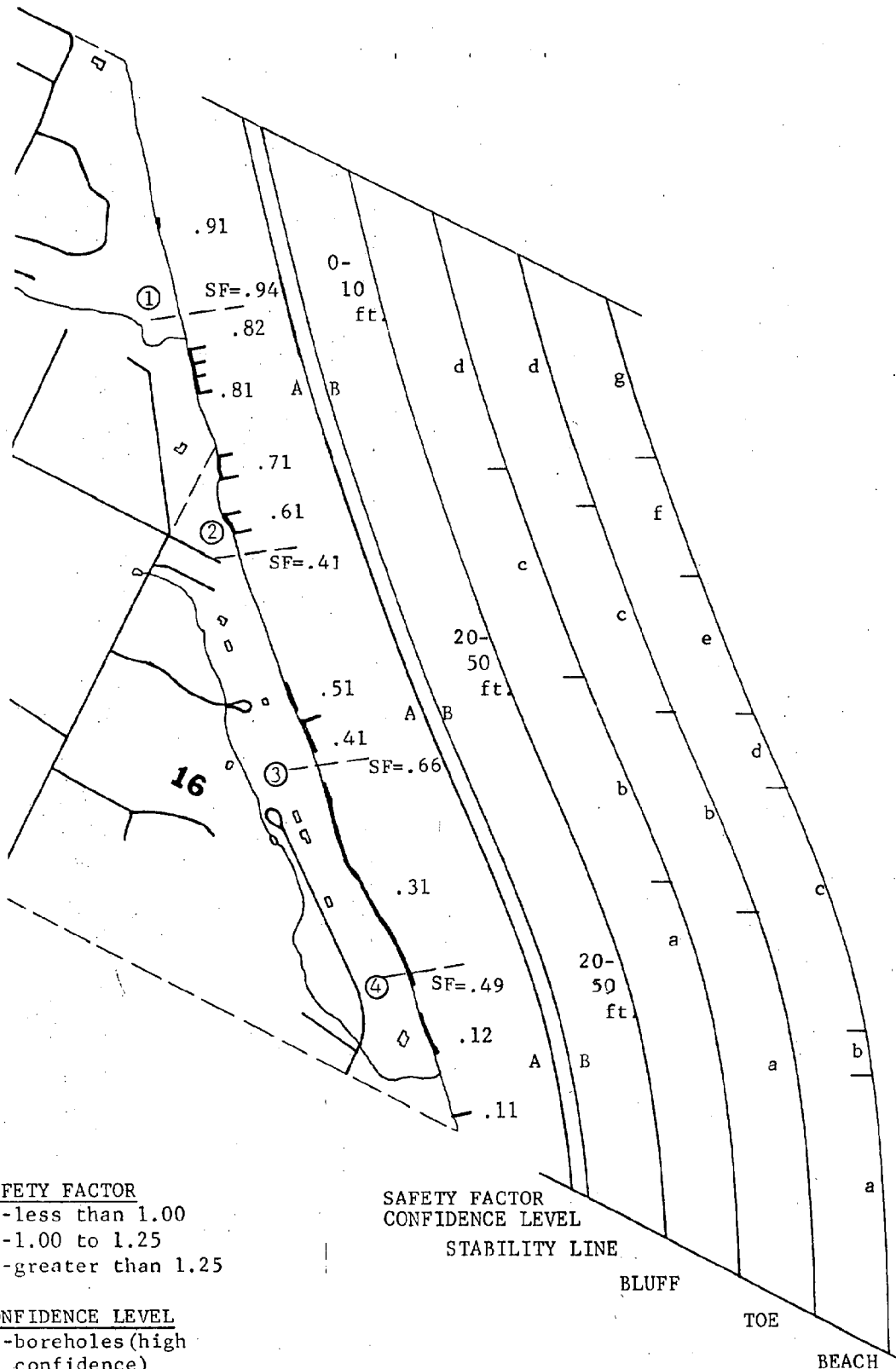
## Profile 1



T. 4 N., R. 23 E., Sec. 21/22



N



SAFETY FACTOR

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

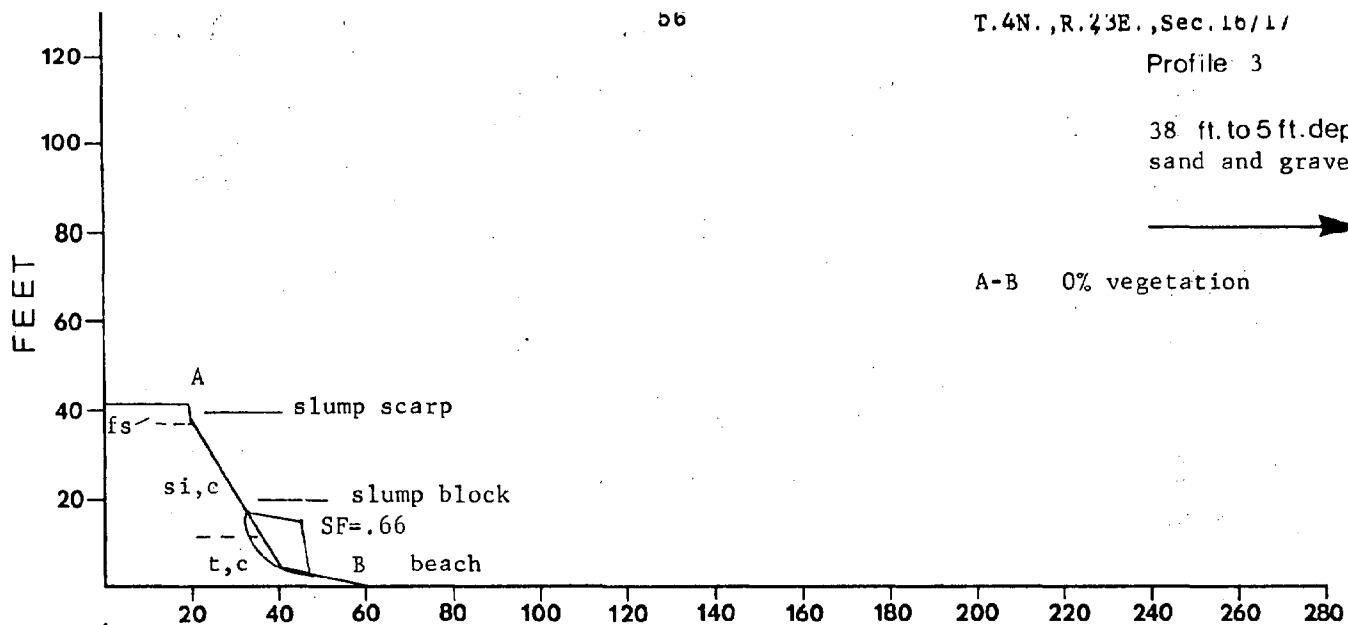
CONFIDENCE LEVEL

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

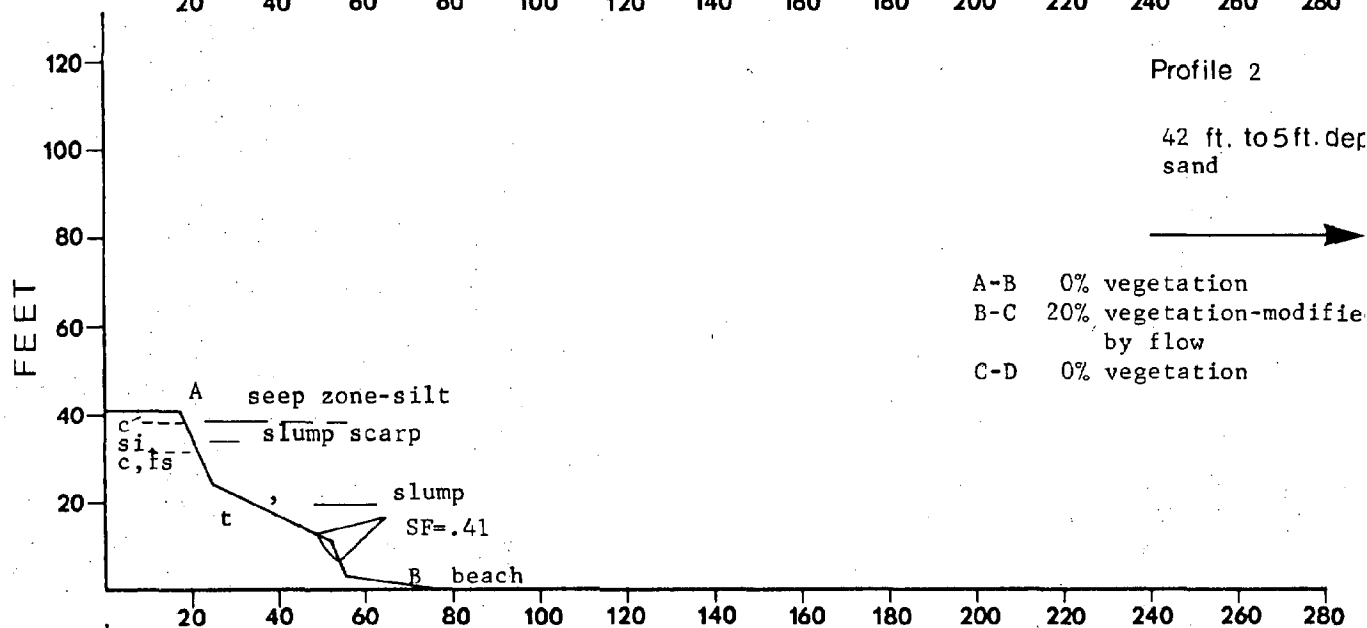
1. BLUFF	a-slump and flow	b-some slump blocks, very little vegetation, considerable flow evident	c-large slump blocks; vegetation scant and confined to slumps, are also modified by flow.	d-slump blocks and earth flow
2. TOE	a-massive lacustrine silts and clays	b-till, gray clayey	c-till, gray clayey	d-till, gray clayey-Wadsworth
3. BEACH	a-mostly about 35-40 ft. wide, but narrower at north end north of creek mouth. sand, pebbles, and cobbles	b-no beach; terraced gabion structure	c-beach 20-30 ft. wide. sand and gravel	d-beach 15-20 ft. wide
	e-beach 30-40 ft. wide. sand and gravel	f-beach 20-30 ft. wide. sand accretion around groins	g-beach is mostly 30-75 ft. wide. narrows to about 5 ft. at northern extremity of section. widest at end just south of stream mouth where groins have resulted in accretion. sand, pebbles, and cobbles.	



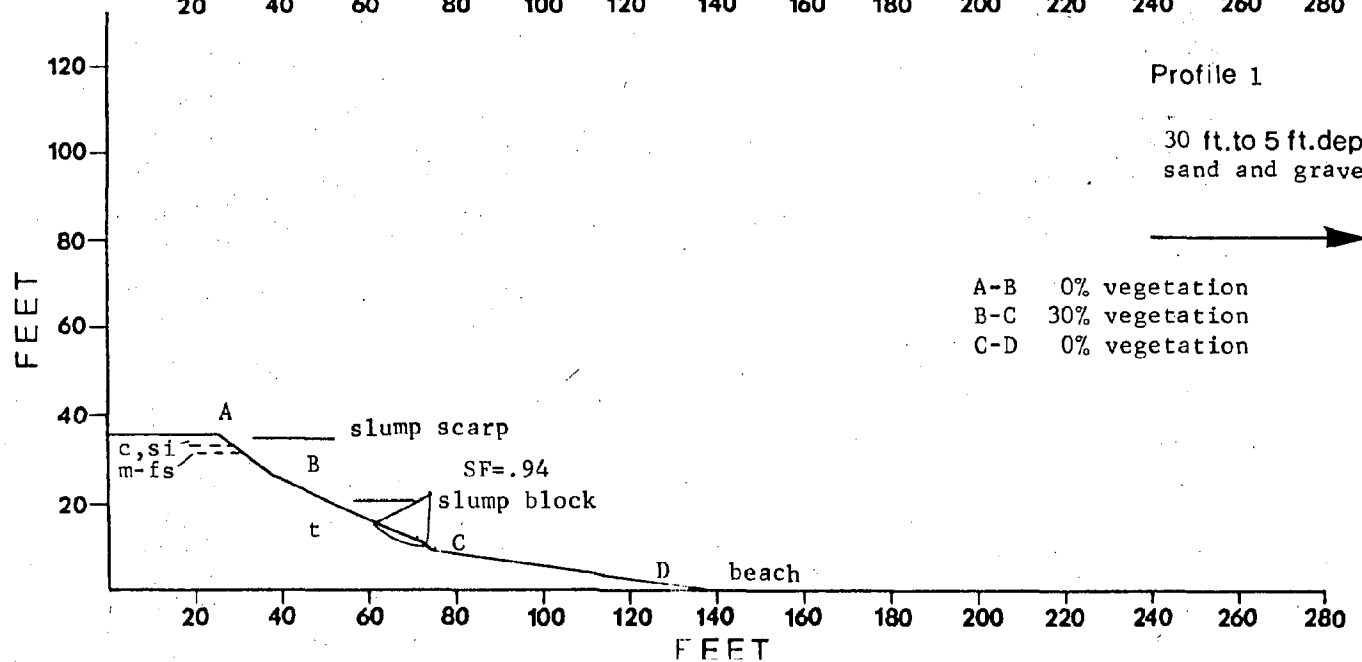
## Profile 3

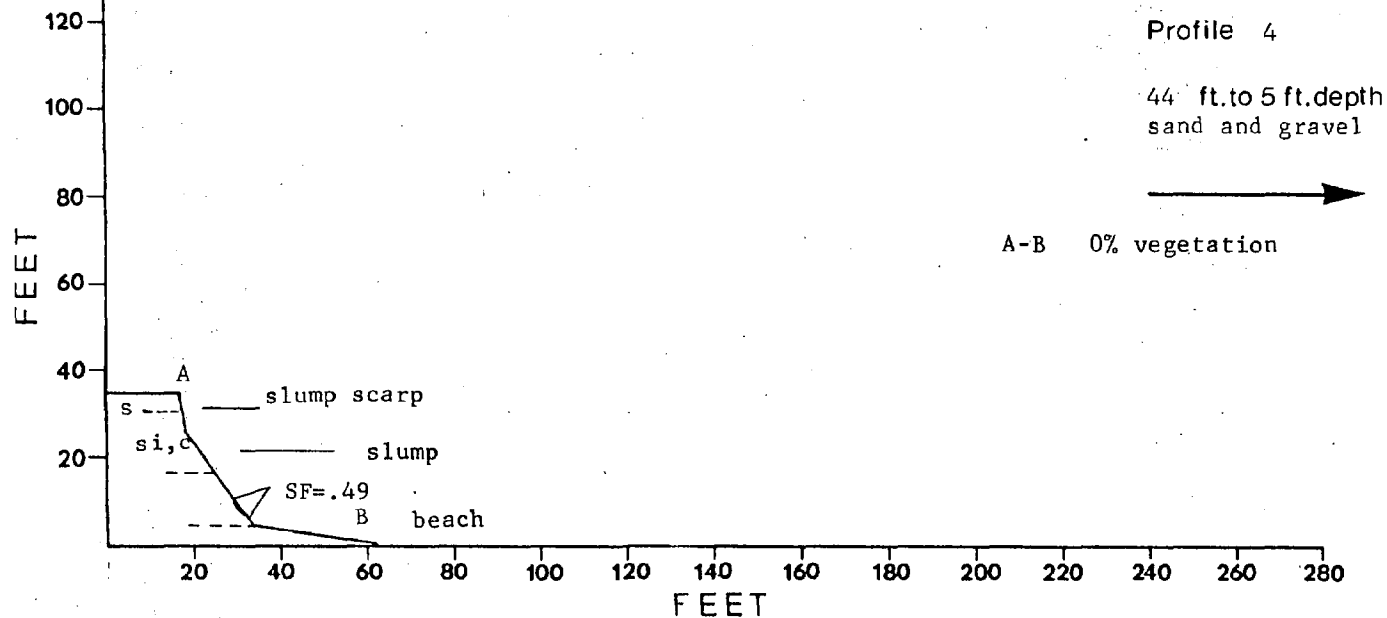
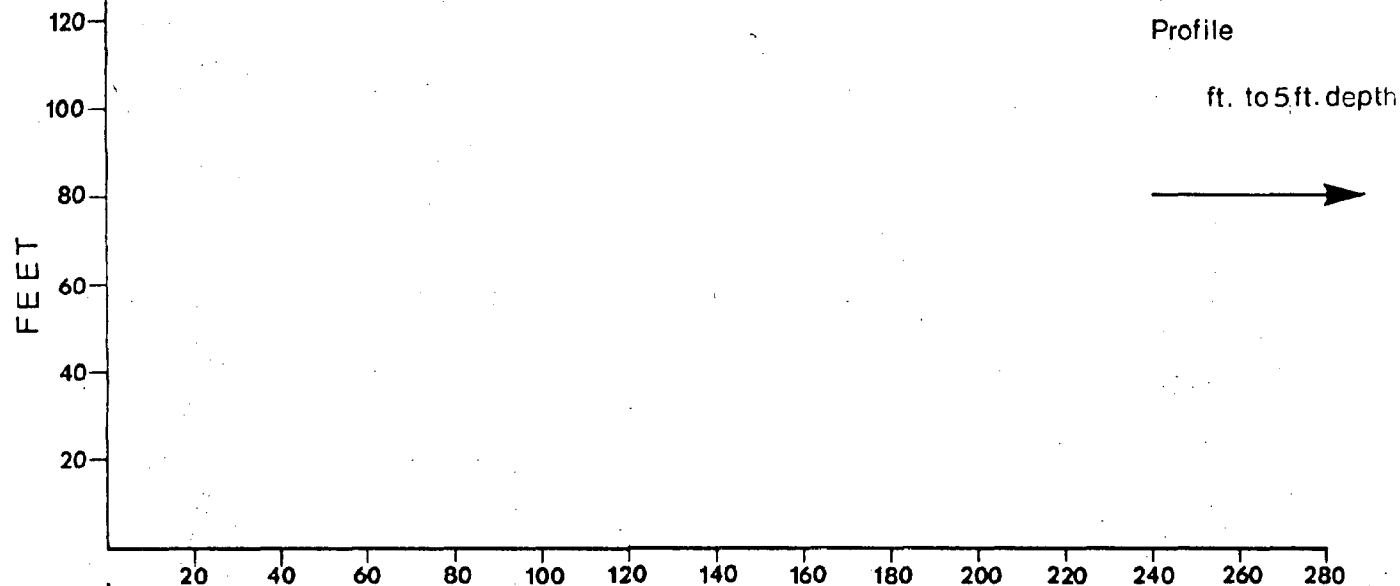
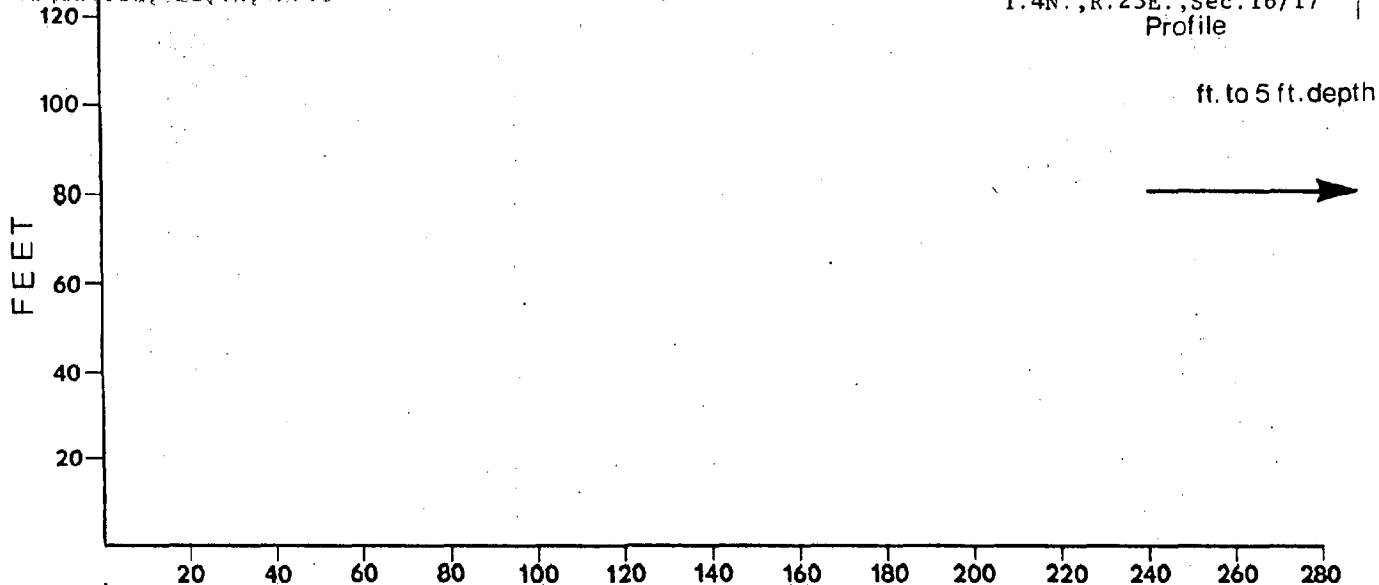
38 ft. to 5 ft. depth  
sand and gravel

## Profile 2

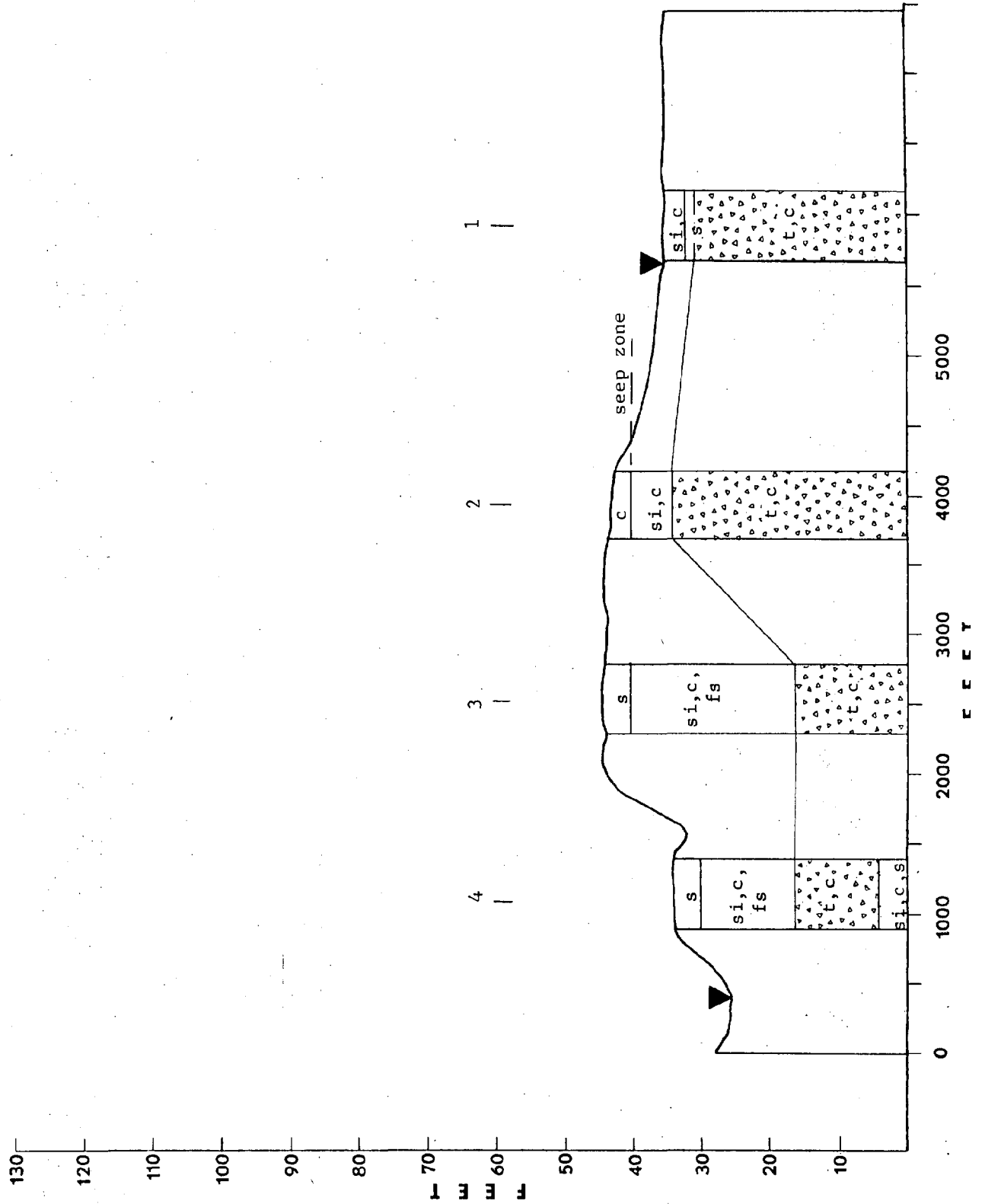
42 ft. to 5 ft. depth  
sand

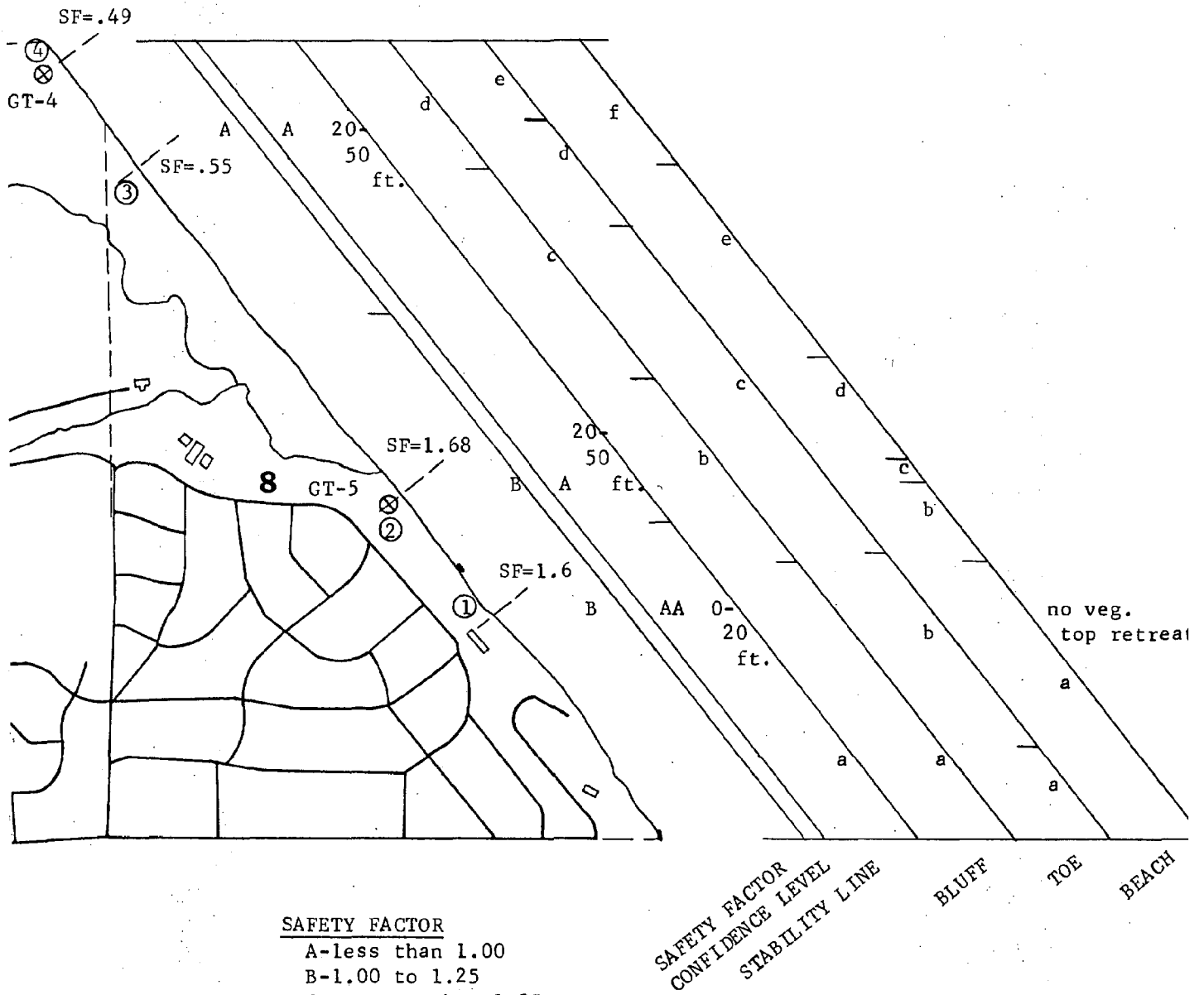
## Profile 1

30 ft. to 5 ft. depth  
sand and gravel



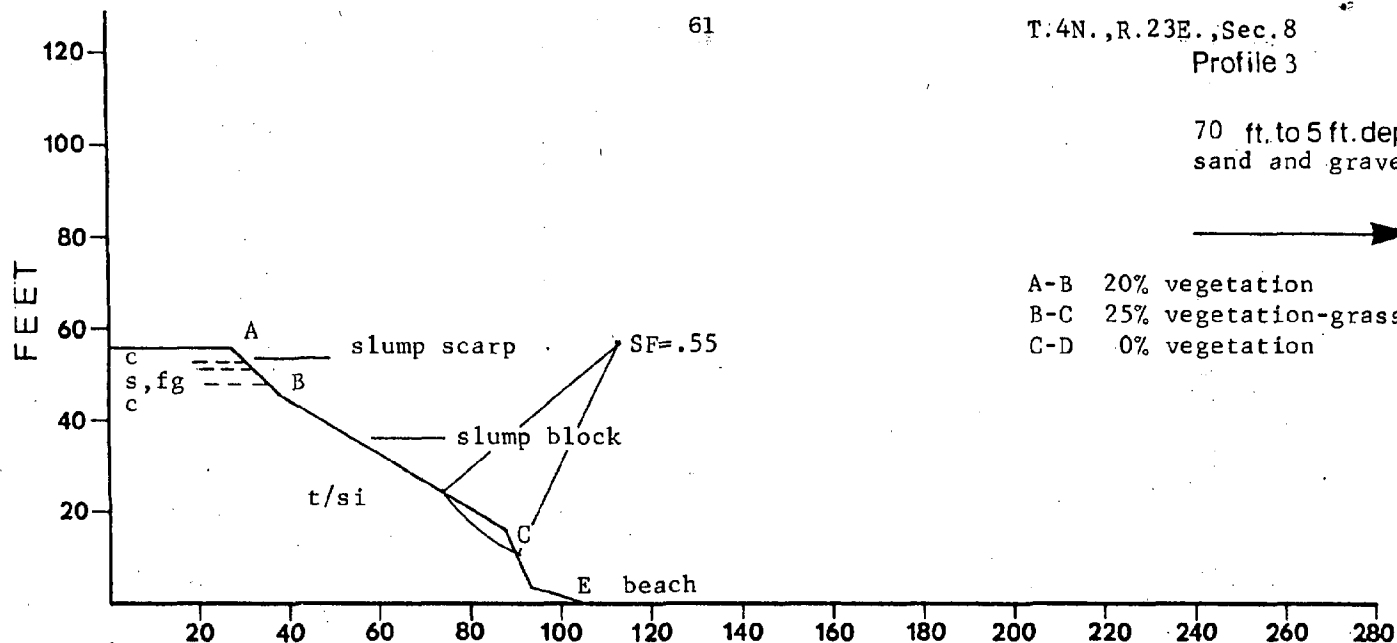
I.4 N., R. 23 E., Sec. 16/17



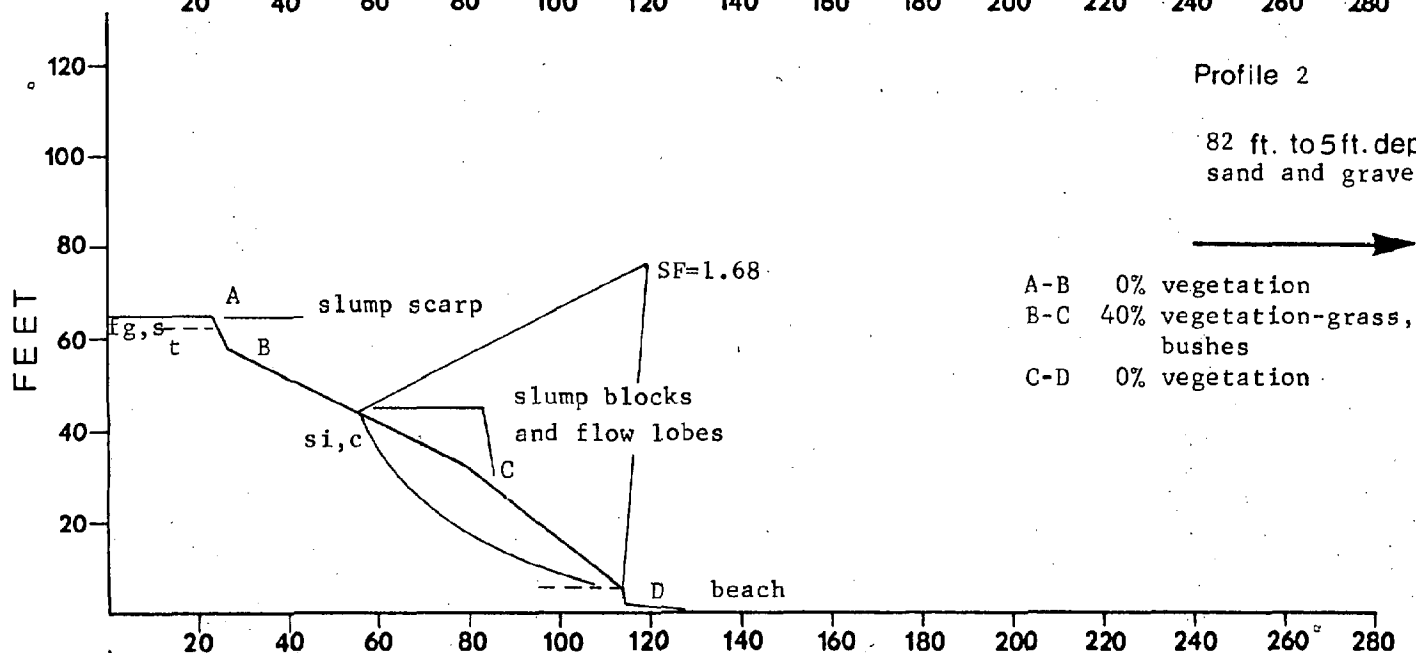


1. BLUFF	a-smaller slump units	b-larger slump units modified by secondary slumps and flows	c-large, massive slump blocks produce distinctly scalloped bluff edge, modified by smaller slumps and flows, compound slumps.	d-bluff steepens, recent debris fall and slide, seep in sand 8 ft. above beach, toe erosion
2. TOE	a-mostly covered; smaller slump units, mainly till	b-lacustrine silts and clays in place, and slump units	c-till, concealed in many places by slump blocks, both simple and compound, and by debris flows which also act as toe materials	d-till with some interbedded lacustrine silts
	e-till, mostly in place			
3. BEACH	a-generally 15 to 20 ft., except at extreme south end of section where less than 5 ft. wide, sand and gravel	b-beach width variable, 0 to 20 ft., compound slump blocks cover part of beach.	c-20 to 30 ft., stream mouth	d-beach width fairly uniform 15 to 20 ft., sand and gravel
	e-beach width variable, 0 to 15 ft., slump block and debris flow materials cover beach sediments at several places.	f-beach 10 to 20 ft., sand and gravel		

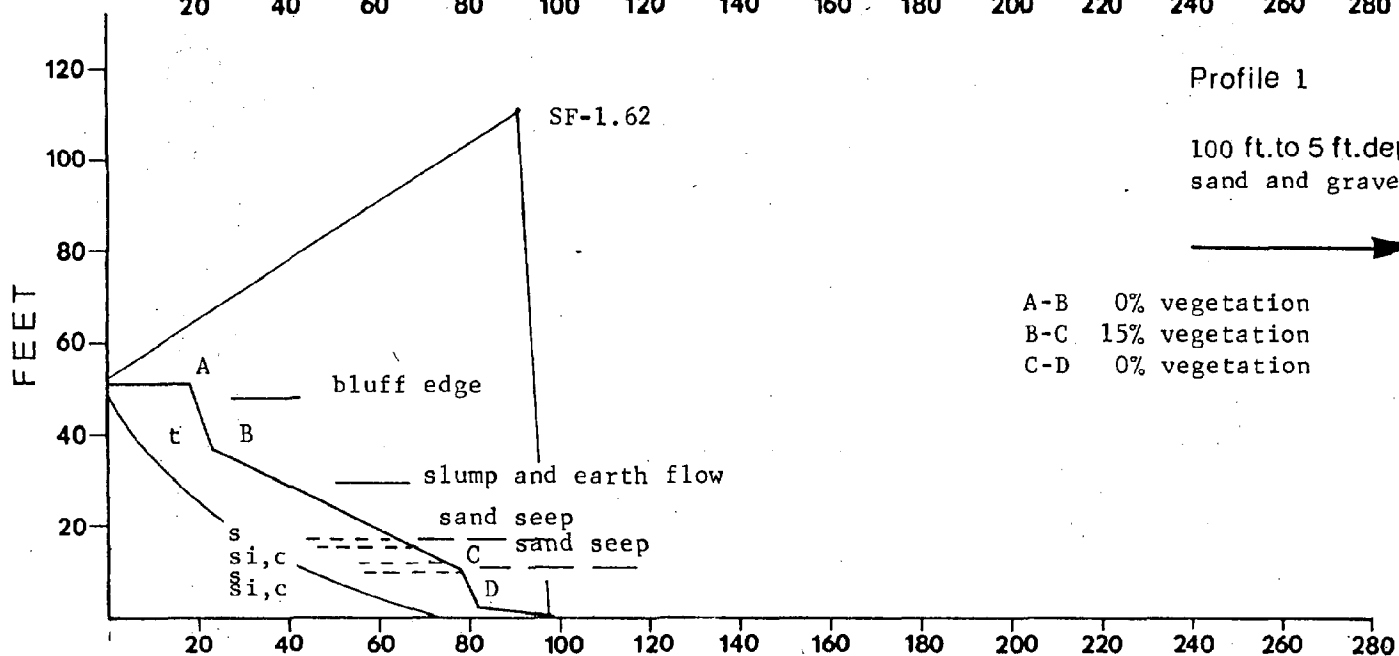
## Profile 3

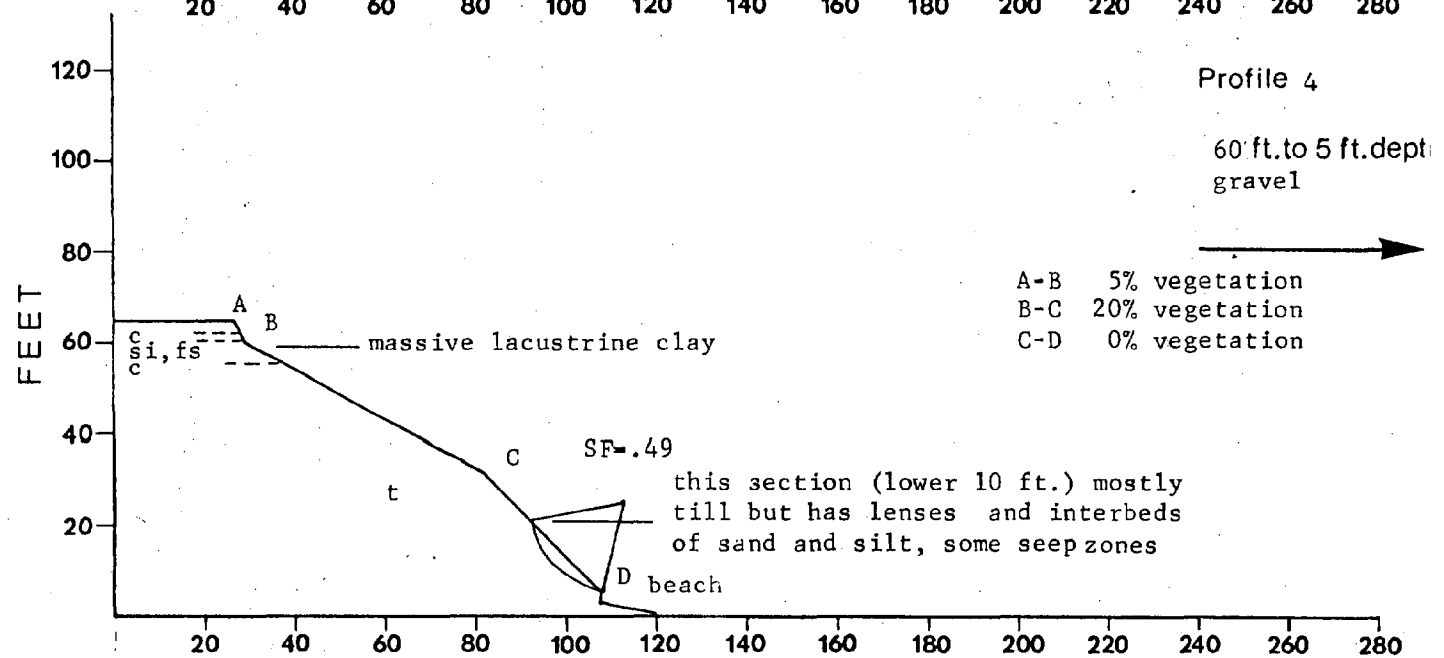
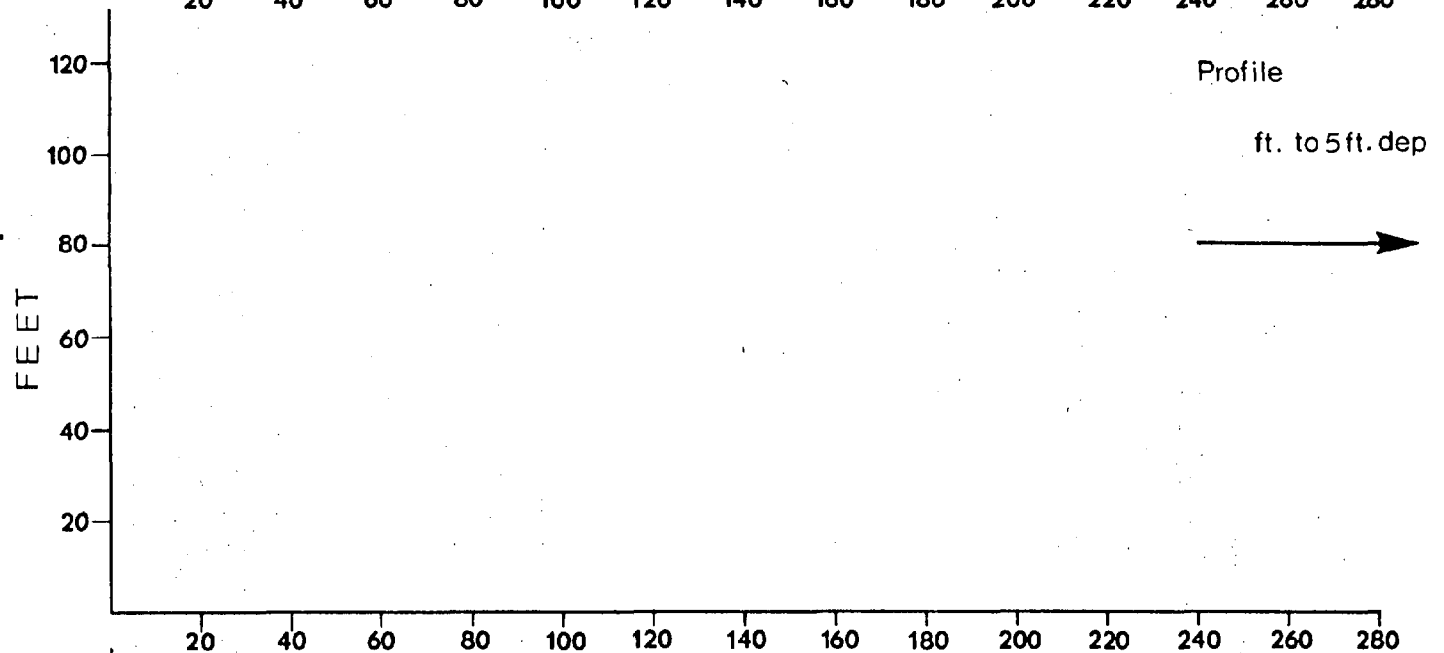
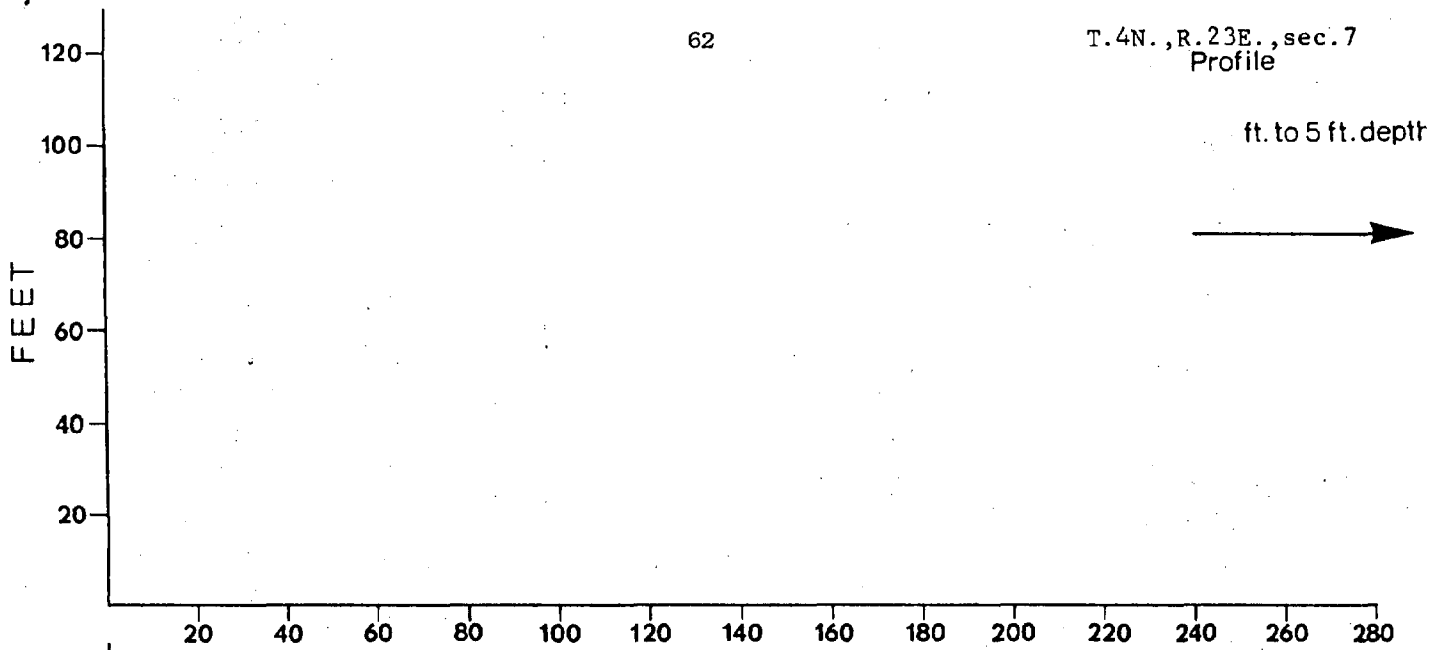
70 ft. to 5 ft. depth  
sand and gravel

## Profile 2

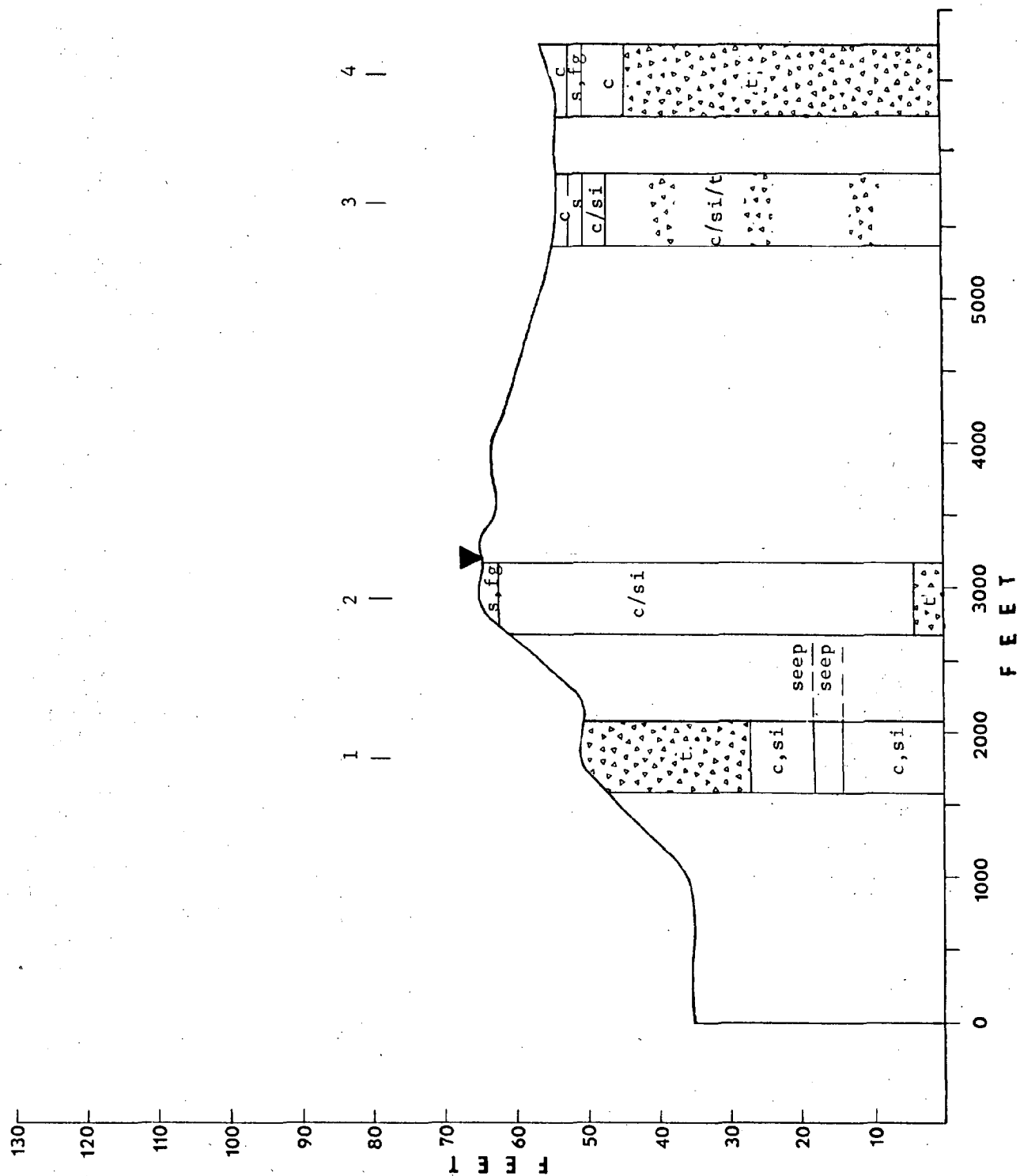
82 ft. to 5 ft. depth  
sand and gravel

## Profile 1

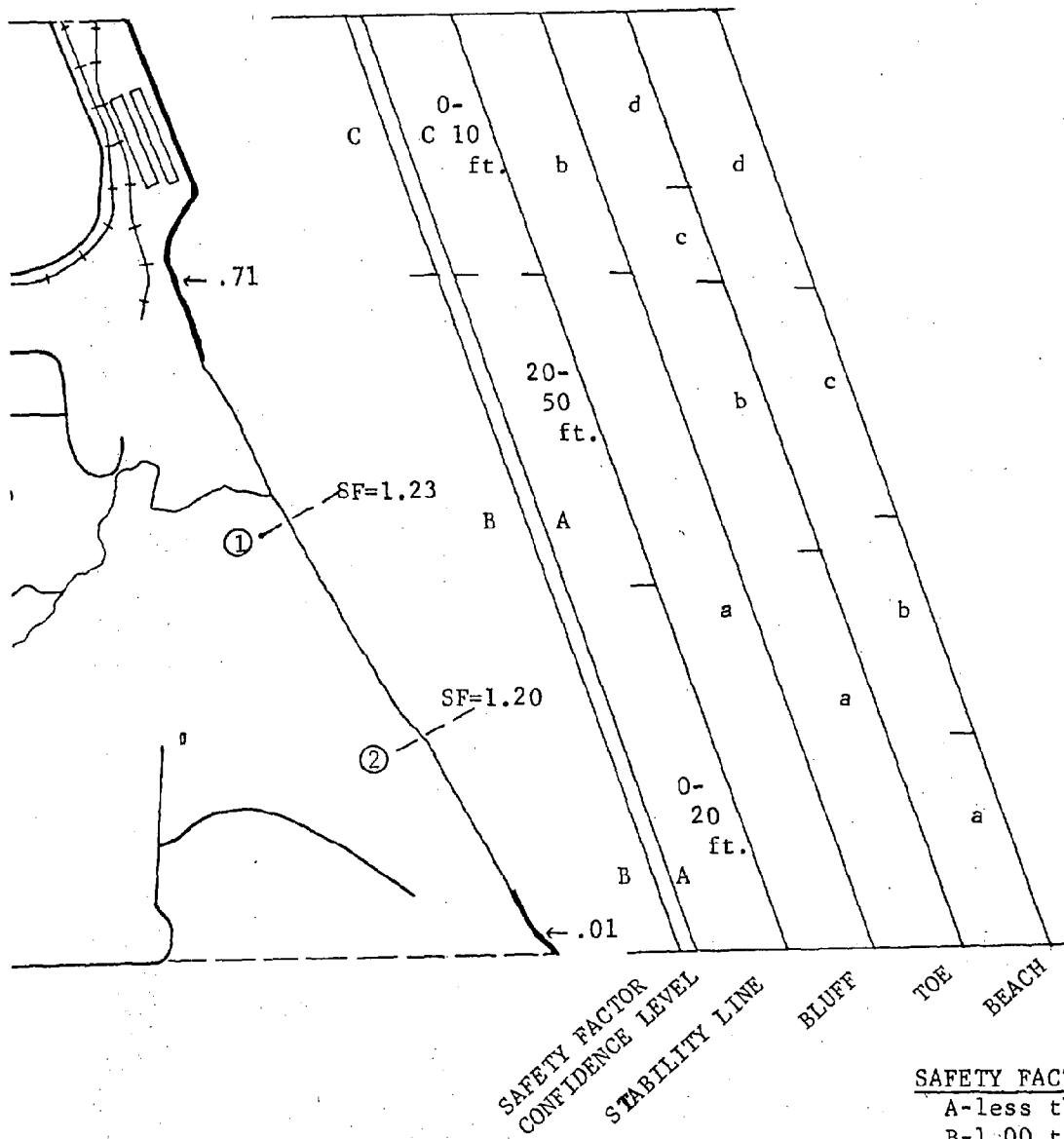
100 ft. to 5 ft. depth  
sand and gravel



T. 4 N., R. 23 E., Sec. 7/8





SAFETY FACTOR

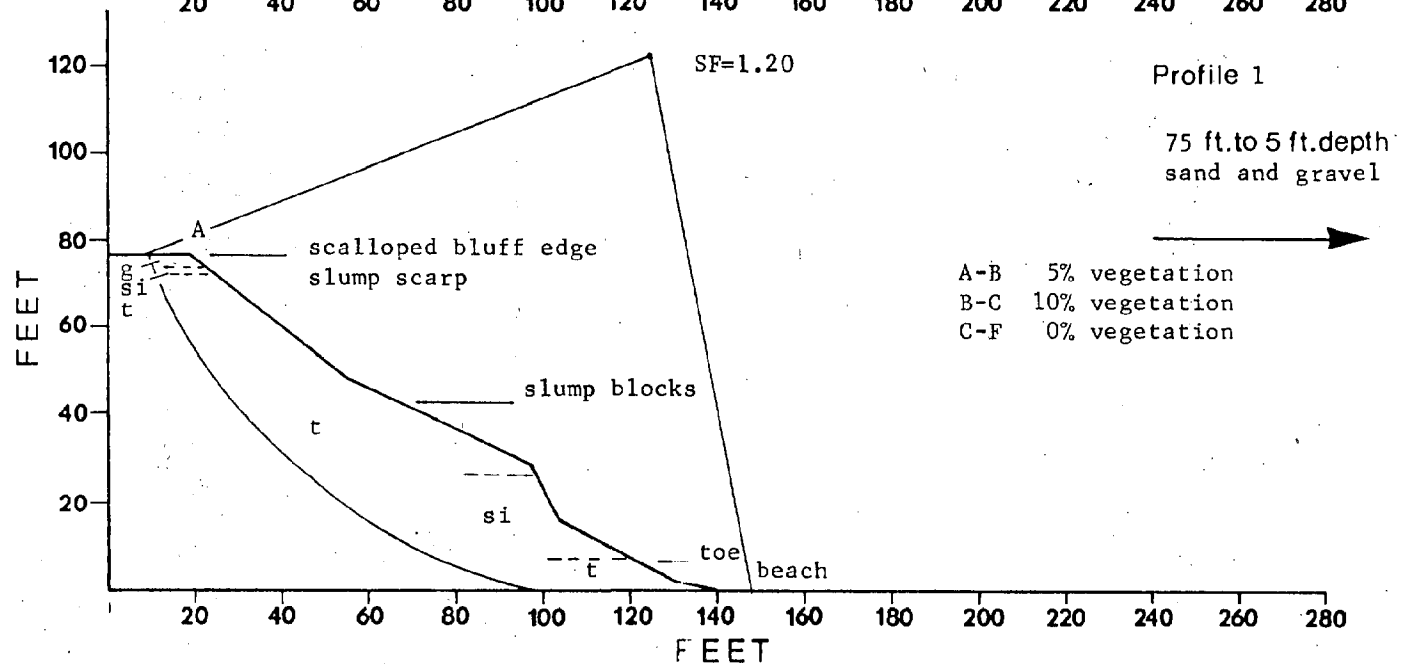
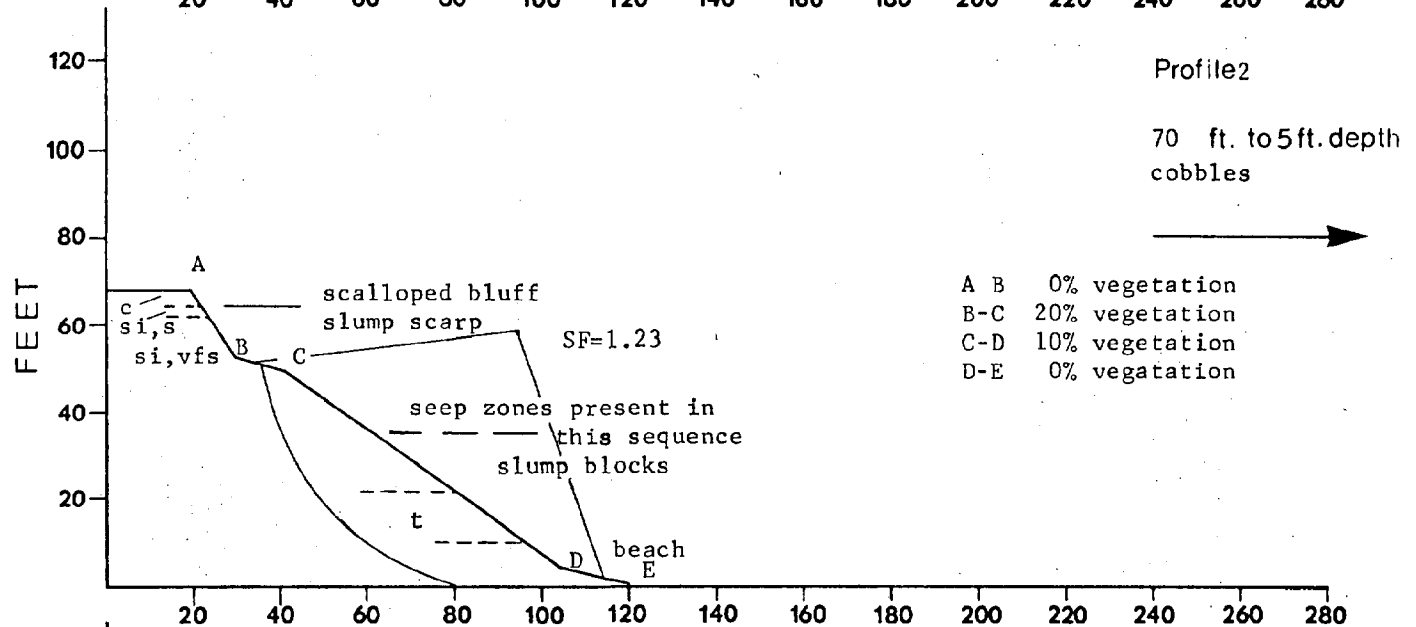
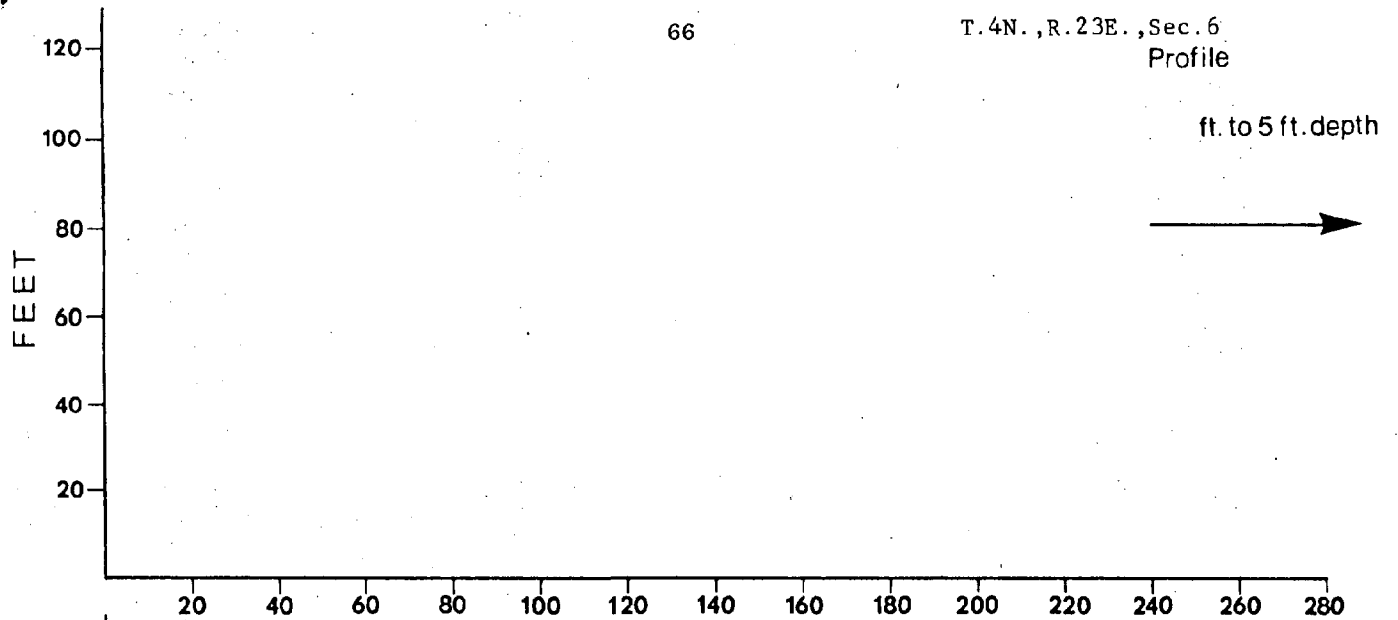
A-less than 1.00

B-1.00 to 1.25

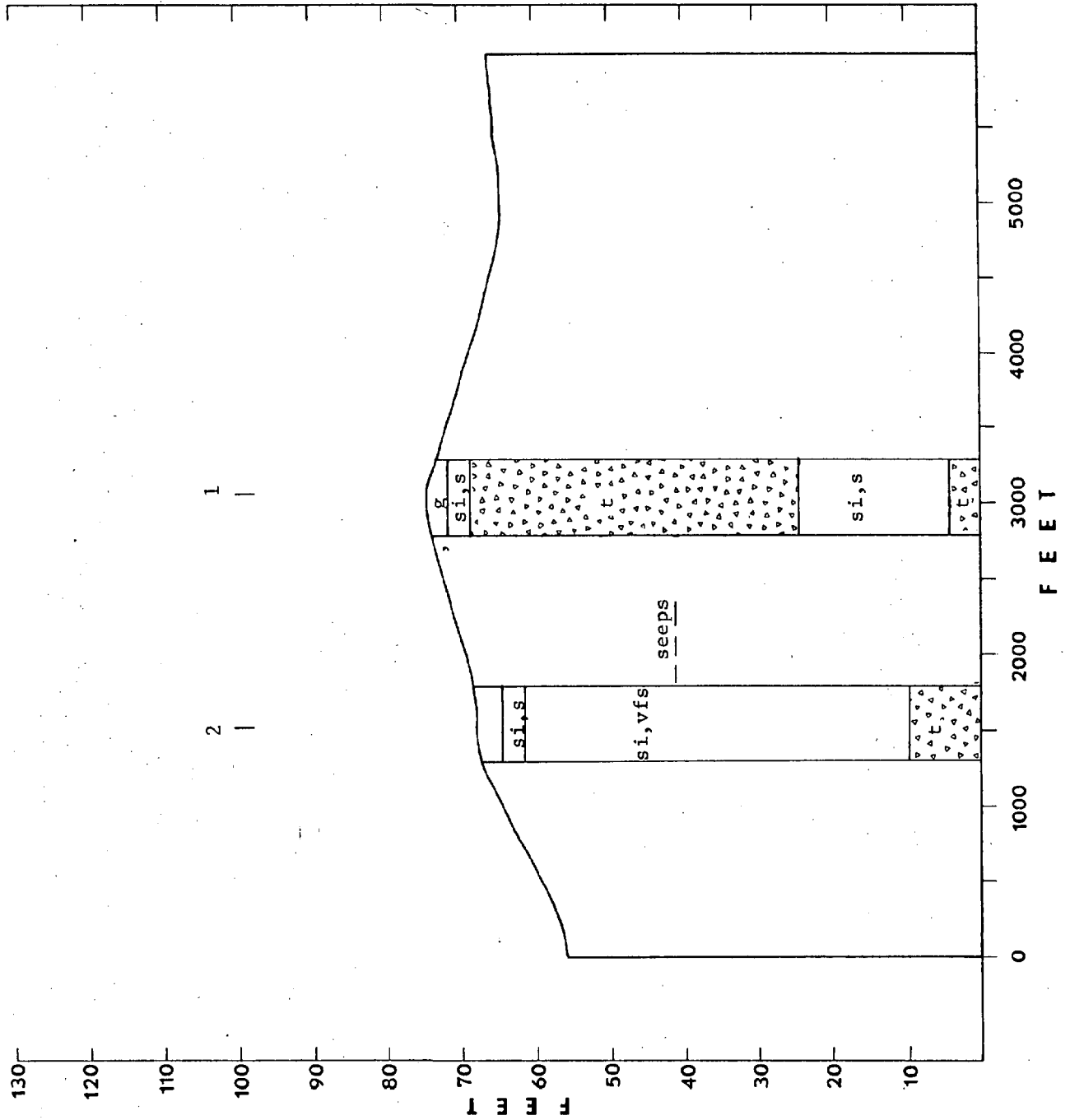
C-greater than 1.25

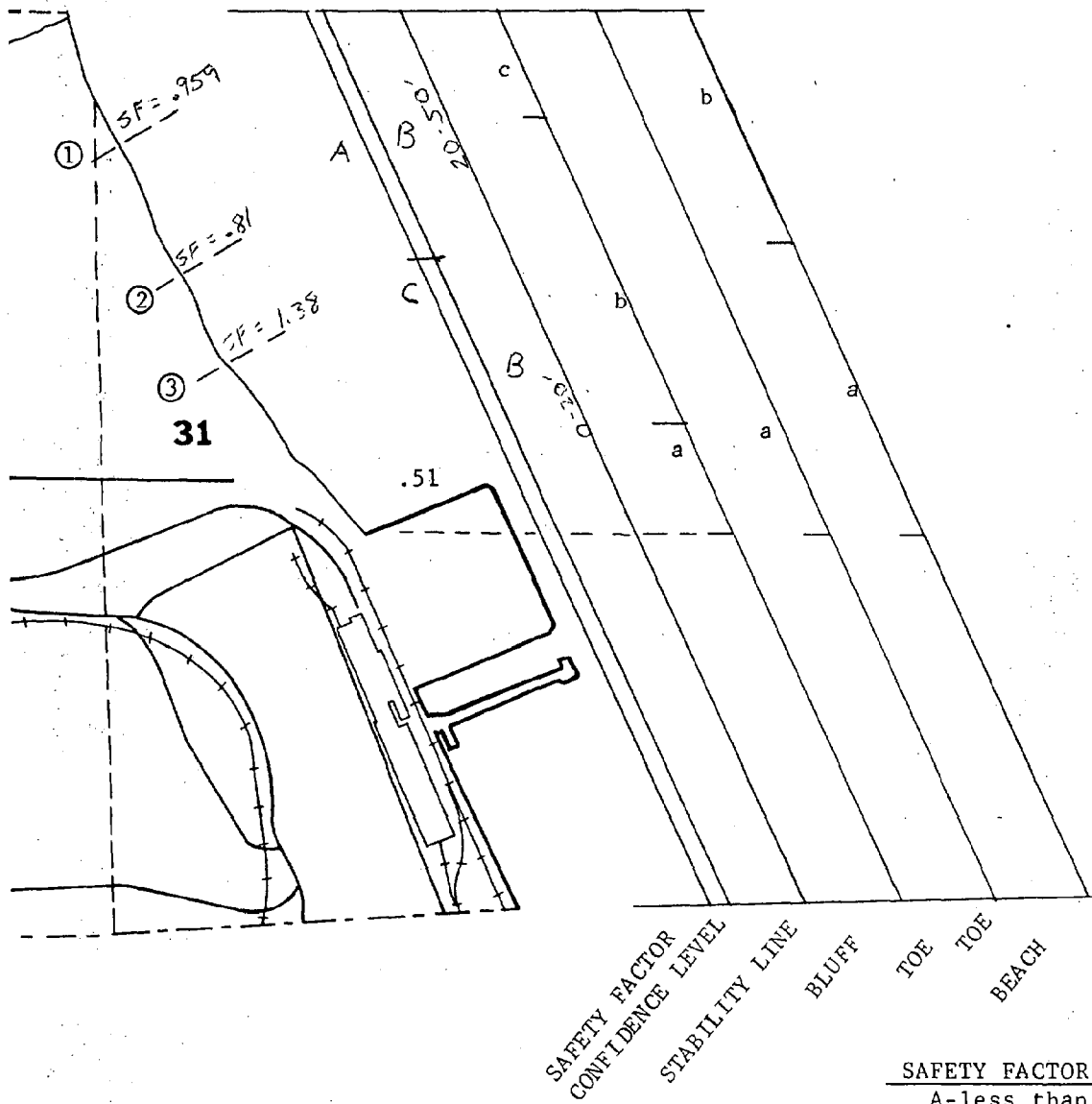
CONFIDENCE LEVELA-boreholes  
(high confidence)B-near boreholes  
stratigraphy visibleC-no stratigraphy  
visible (low  
confidence)

1. BLUFF	a-entire bluff is unstable, lacks vegetation, and is subject to slope failure. edge of bluff distinctly scalloped throughout; upper part of bluff face marked by numerous slump scarps; middle part of bluff covered with simple and compound slump blocks, mainly of rotational variety; failure also taking place by toe erosion and consequent debris fall, particularly north of stream mouth near middle of section, where large debris falls are present; debris slides also present at several places.		b-bluff behind area of artificial fill is graded and sodded; appears fairly stable	
2. TOE	a-till mostly in place, but also in slump blocks, also some lacustrine silts in slump blocks	b-till; some in place, some in slump blocks, some in debris falls	c-dolomite blocks (revetment)	d-dolomite blocks and corrugated sheet-steel piling (bulkhead)
3. BEACH	a-10 to 15 ft., sand and gravel	b-generally 5 to 10 ft., but less than 5 ft. in some places, sand and gravel	c-0 to 5 ft., except 10 to 15 ft. at mouth of stream, sand and gravel, boulders	d-no beach



**T. 4 N., R. 23 E., Sec. 6**



SAFETY FACTOR

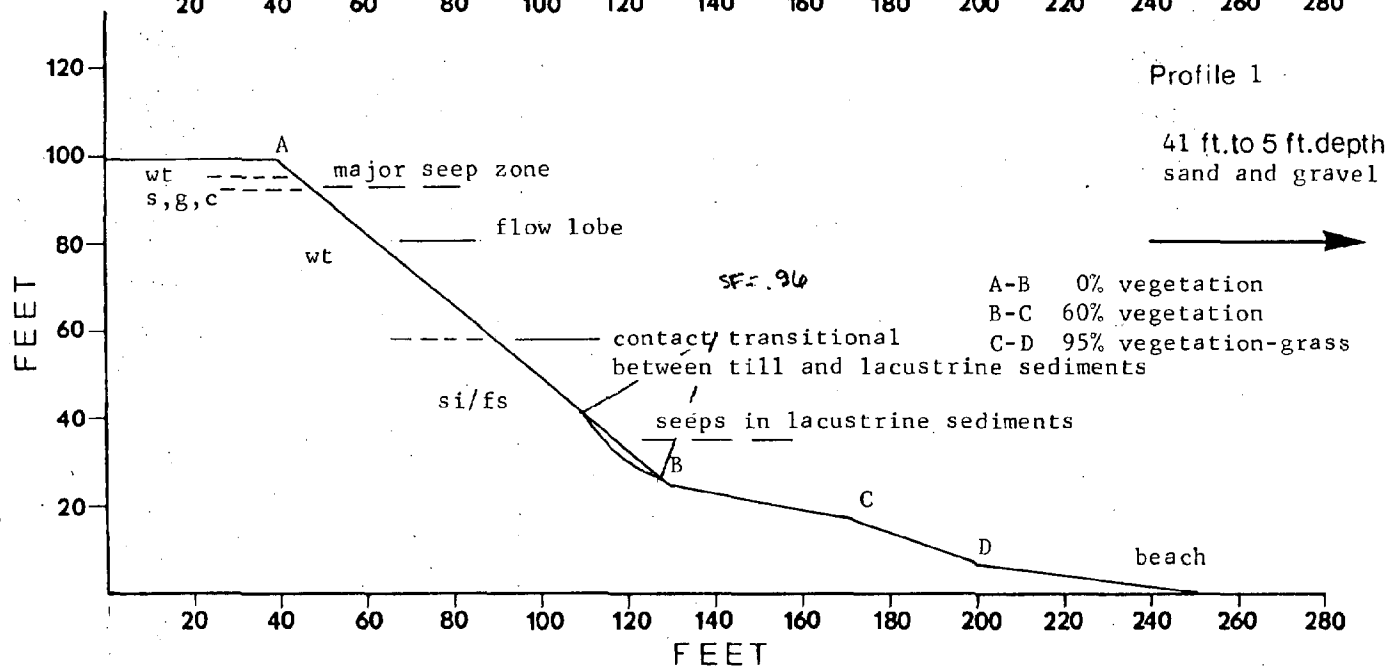
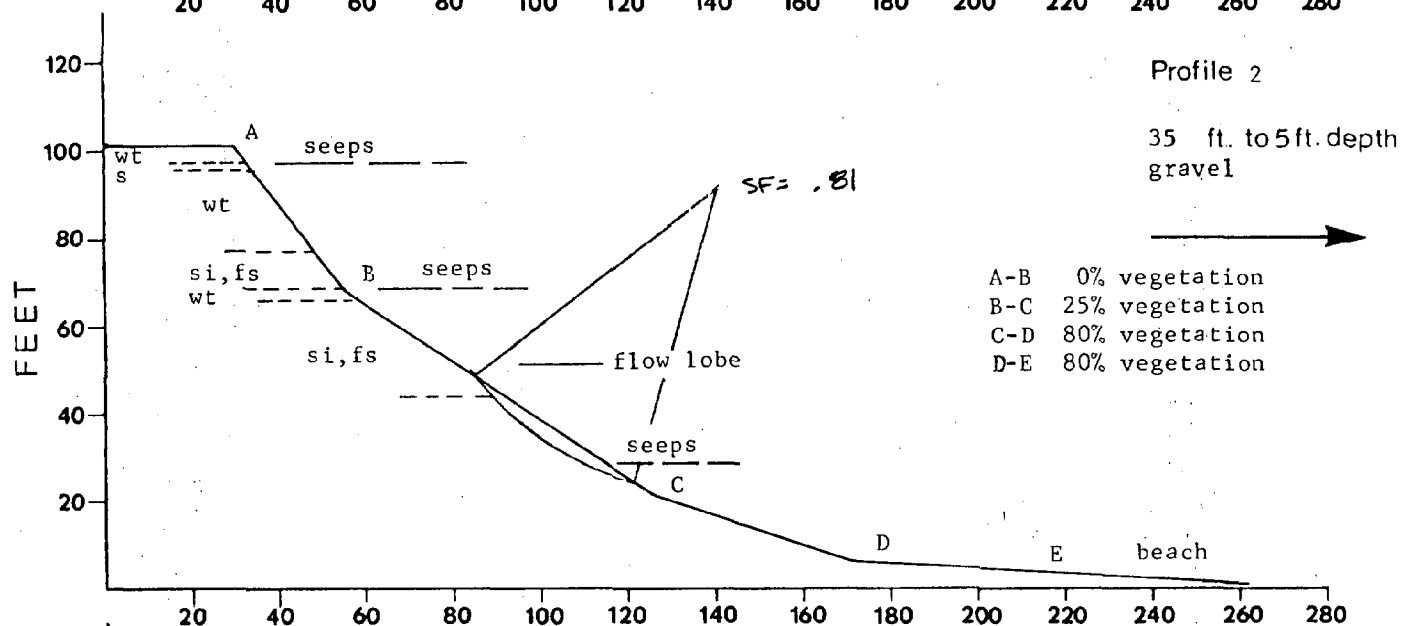
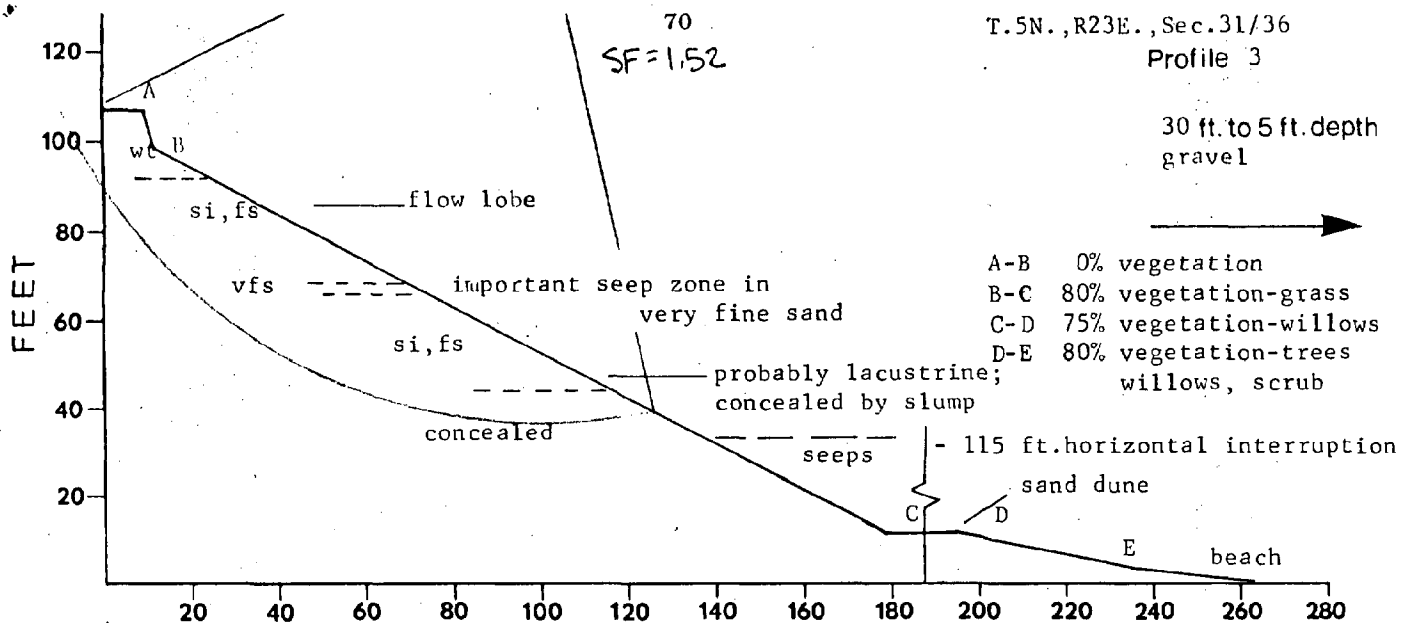
A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

CONFIDENCE LEVELA-boreholes  
(high confidence)B-near boreholes  
stratigraphy visibleC-no stratigraphy  
visible (low  
confidence)

1. BLUFF	a-steeper slopes; middle portion of bluff less modified by flow units, smaller flow units	b-primarily earth flowage in two major recognizable episodes; tops of older flows form more or less continuous terrace, younger units cover lower 2/3 of bluff face	c-compound slope failure, slump debris fully modified by flowage
2. TOE	a-mostly consisting of slumped lacustrine sediments		
3. BEACH	a-less than 20 ft. sand and gravel	b-10 to 20 ft. sand and gravel, widens southward	







COASTAL ZONE  
INFORMATION CENTER

