COLORADO RIVER INVESTIGATIONS VI

July - August, 1987

By
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Northern Arizona University

Under the Supervision of

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Submitted To

Mr. Richard W. Marks, Superintendent
Grand Canyon National Park
Grand Canyon, Arizona

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CHAPTER I

INTRODUCTION

This report presents results of a five-week, six-semester hour course (GLG 538-626) for graduate students on the Geology, Hydrology, and Biology of the Grand Canyon. The course was offered during the period July 23 through August 12, 1987. This program was conducted through Northern Arizona University in collaboration with the National Park Service, Grand Canyon National Park. The program involved about two and a half weeks of laboratory class and short field trip experiences as an introduction to the natural history of northern Arizona, and culminated in an 11-day river trip through Grand Canyon. This was followed by about four days of intense class work to summarize the results of the field investigations and prepare them for this report. Additional editing and finalizing of the project reports was necessary during the following academic year, 1987-1988.

The field investigations conducted on the river trip were run under the supervision of Stanley S. Beus and Steven W. Carothers, Department of Geology, Northern Arizona University.

The research project reports here submitted were prepared either entirely, or in part, by the student investigators in the course. Some final editing has been done by the editors and the report is herewith submitted to Superintendent Richard W. Marks of the Grand Canyon National Park. The data collected and the conclusions presented deal with a number of on-going studies and questions or problems of concern to the National Park Service in the management of Grand Canyon as both a natural history laboratory and a recreational experience for those who visit.

CHAPTER II

CHANNEL ORIENTATION OF THE TEMPLE BUTTE FORMATION IN MARBLE CANYON

Peter Van Valkenburg

INTRODUCTION

The Temple Butte Limestone of Devonian age is observed throughout much of the Grand Canyon. In the eastern section of the Grand Canyon, in what is known as the Marble Canyon Gorge, the Temple Butte Formation occurs as scattered lens-shaped channels between the Redwall Limestone and Muav Limestone. Farther to the west, the Temple Butte thickens to a continuous layer up to 450' thick (McKee, 1937, p. 341; Beus 1973, p. 30). The type section is at Temple Butte on the west side of the Colorado River a few miles below its junction with the Little Colorado River (Walcott, 1883, p. 438). The formation was first recognized by Walcott in 1880 from exposures in Kanab and Nankoweap Canyons, (McKee, 1939) and others have extended the name to the thicker deposits in Western Grand Canyon (Beus, 1988).

Age determinations have been by fish plates indentified as Bothreolepis (Noble, 1922) and various corals, gastropods, and crinoid plates dated to late Devonian age. The most diagnostic fossils were the conodonts identified by D. Schumacher (1978) which puts the age at latest middle Devonian to early late Devonian for most of the Temple Butte in central Grand Canyon.

In the Marble Canyon section the Temple Butte fills channels that were cut into the underlying Muav Limestone in middle Devonian time as the sea was transgressing onto the land (see Figure II-1, Figure II-2). During that transgression the Temple Butte was deposited. The sea again withdrew and erosion stripped off materials during latest Devonian and earliest Mississippian time leaving only the channel-filled deposits (Billingsley, 1970, p. 76, 77). During early Mississippian the Redwall limestone was deposited on top of the eroded Temple Butte. This gap in the geologic record represents some 100 million years.

OBJECTIVES

The purpose of this study was to identify the channels of the Temple Butte Formation in the Marble Canyon Gorge and to measure the orientation of the separate lens from about River Mile (RM) 38, where they first occur, to about RM 52.

METHODS

Data were collected as our party was rafting down the Colorado River. My assignment was to identify the lens of Temple Butte as we floated by, plot the position on a segment of a map of the area, take a picture of the channel, and then take a compass reading to determine the direction in which the channel was trending.

Materials used:
1 - Brunton compass
2 - Hamblins guide book part I
3 - camera

RESULTS

The total number of channels measured was 17 (see Figure II-3). The location and orientation of these channels are presented in Table II-1.

Table II-1. Temple Butte formation channel-fill site observed in Marble Canyon.

Channel #	Mile	Compass Direction	Side of Canyon*
1	37.6	310 degrees	left side
2	37.8	332 degrees	right side
3	37.9	330 degrees	left side
4	38.2	305 degrees	right side
5	38.7	220 degrees	both
6	39.9	245 degrees	both
7	40.1	302 degrees	right side
8	40.2	301 degrees	right side
9	40.7	320 degrees	both
10	41.3	240 degrees	left side
11	42.0	360 degrees	left side
12	43.0	341 degrees	right side
13	43.7	264 degrees	both
14	46.6	322 degrees	left side
15	48.5	225 degrees	right side
16	51.5	285 degrees	left side
17	52.5	222 degrees	right side

* Orientation, facing down stream (see Figure II-1).

Number of reading between 290 and 340 (northwest direction)	8
Number of reading between 250 and 290 (westerly direction)	2
Number of reading between 250 and 200 (southwest direction)	5
Number of reading between 340 and 360 (northerly direction)	2

CONCLUSION

According to the data collected, it shows that in the channels that were measured most of the orientations trended in a Northwest-Southeast direction. These data support the observations made by Hamblin and Rigby (1968).

If this study is to continue, more time will need to be taken in side canyons. Also, it would be helpful to have another person on the project to help collect the data.

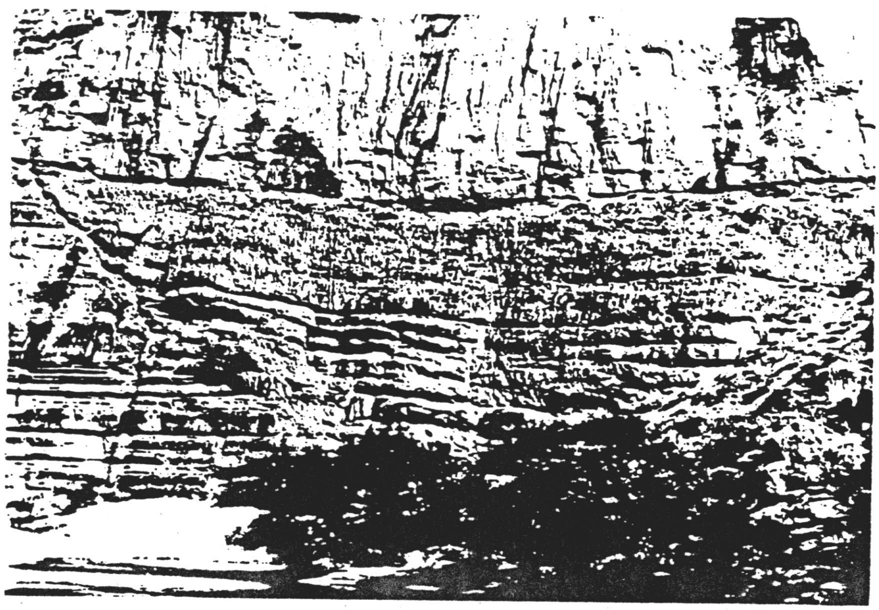

Figure II-1. Lens-shaped outcrop of Temple Butte Formation at mile 38, right bank, in Marble Canyon.

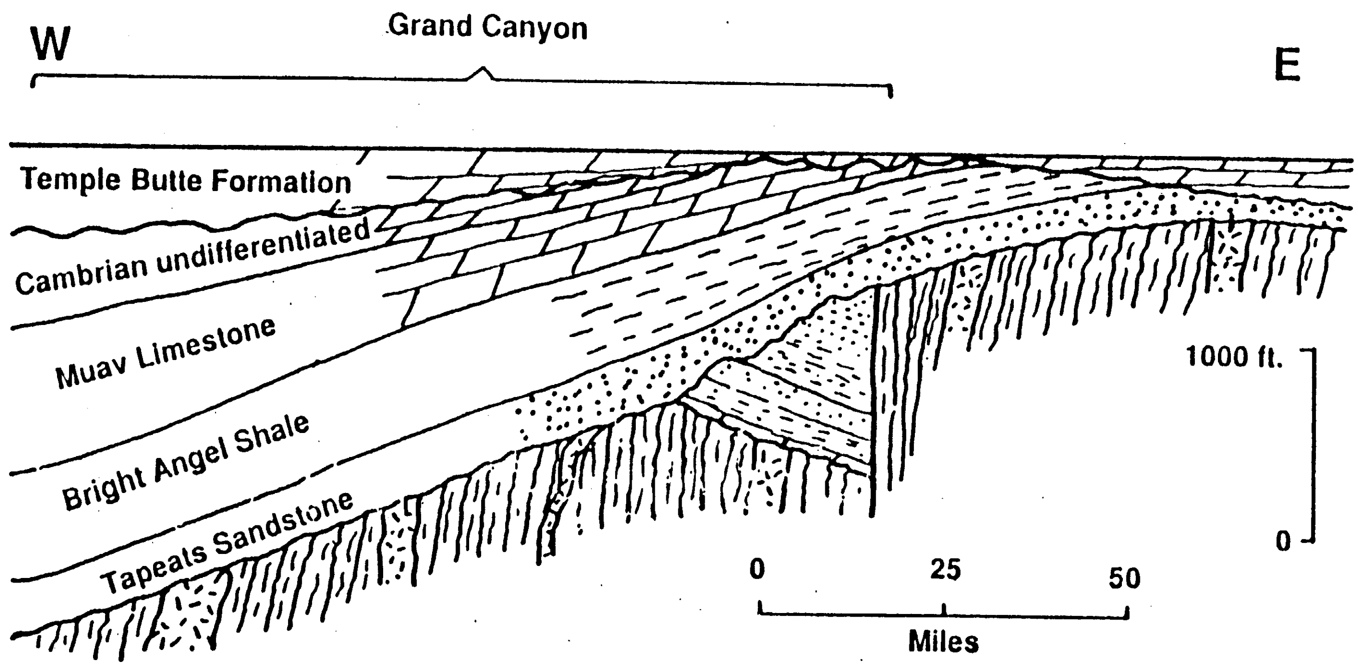

Figure II-2. Regional pattern illustrating angular discordance of Temple Butte Formation strata truncating Cambrian rocks.

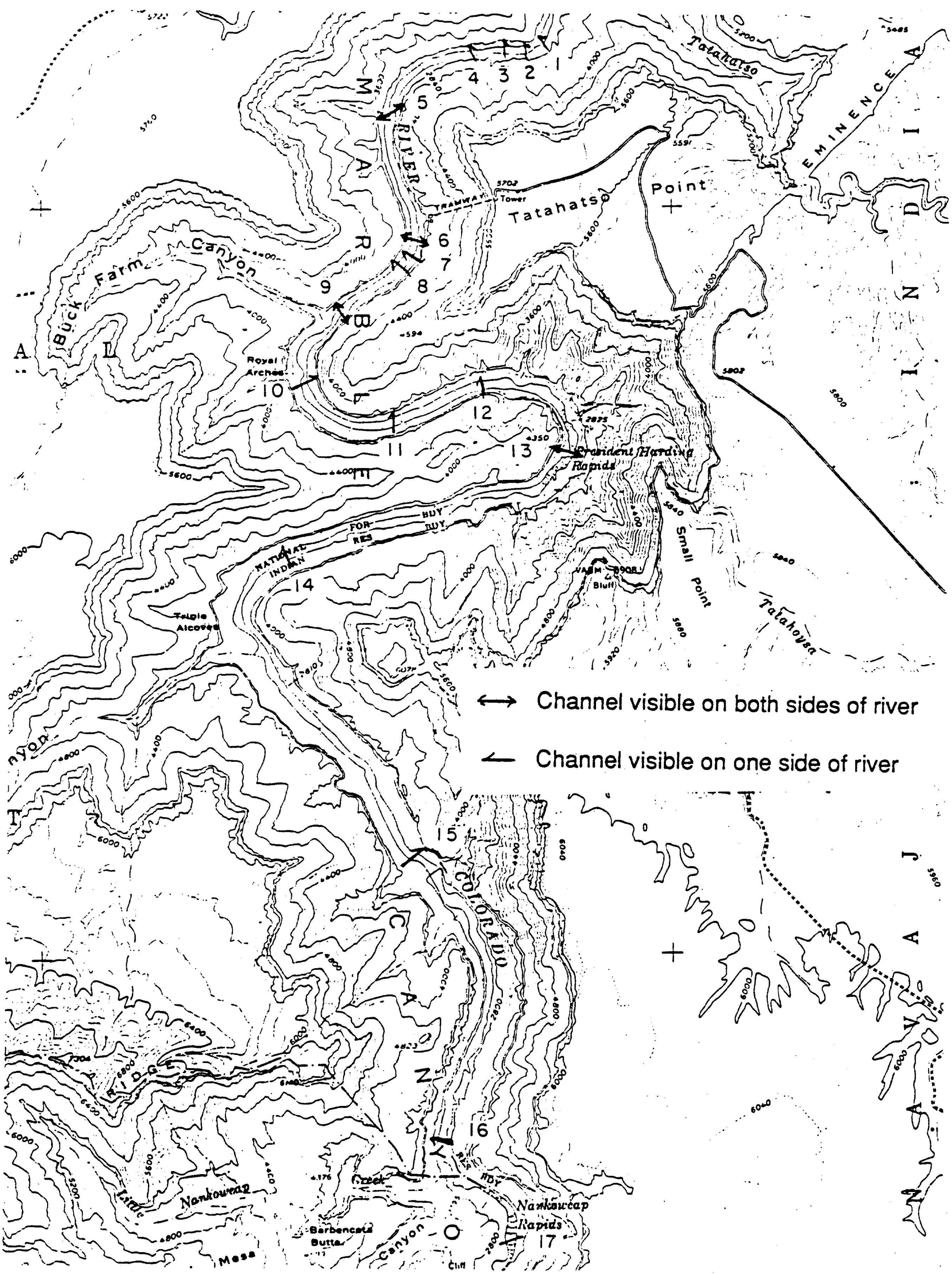

Figure II-3. Location and approximate orientation of channels filled by Temple Butte Fomation in Marble Canyon. Base from USGS topographic map of Nankoweap quadrangle, 1:24,000.

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CHAPTER III

SEDIMENTARY STRUCTURES IN BEACHES AND BARS OF THE COLORADO RIVER IN THE GRAND CANYON

Stephen Lee and John Zanazzi

INTRODUCTION

Examination of sedimentary structures provides information on the transportational and depositional history of beaches and bars of the Colorado River in the Grand Canyon. The conditions under which these beaches and bars were formed can be reconstructed by examining the sedimentary structures found in cross-sections of the beach and bar deposits. Common sedimentary structures found in river deposits include laminae bedding, cross-bedding, convoluted bedding, ripple marks, forset beds, and mud cracks. These structures are formed under various depositional conditions. Some of the structures, especially ripple marks and mud cracks, can be seen presently forming along the water's edge. Previous studies have been done by students at Northern Arizona University in the GLG 538-626 river course over the past six years. Laboratory studies (McKee, 1965) have also simulated conditions under which these structures are formed.

OBJECTIVES

There are three main objectives which this research project addresses. The first is to identify the various sedimentary structures found in the beach and bar deposits along the Colorado River. The second is to interpret these structures and reconstruct the conditions or environments under which they were formed. Lastly, this project tests methods for making peels of sedimentary structures in the field in order to examine them more closely in the laboratory.

METHODS

Materials:

- 2 shovels
- cement trowel
- 1 can of clear Krylon acrylic spray
- 2 packages of cheese cloth
- scissors
- dissecting needles
- 1 dozen disposable paint brushes
- 2 gallons Krylon latex acrylic
- plastic pail
- Brunton compass
- ruler

Procedure:

1. A site above the present river level was chosen on

the beach.

2. Trenches were dug parallel and perpendicular to the direction of flow of the main current of the river.

3. The sides of the trenches were smoothed with a cement trowel to expose the sedimentary structures.

4. The trenches were sketched and photographed. Scale was shown by adding a ruler and compass orientation,river mileage and trench #'s were recorded on a small (6" x 8") chalkboard.

5. Latex peels were made at selected sites (usually where we camped at night so that there was enough time for the peels to dry). The following method was used:

   a. Cheese cloth was cut at least 10 cm longer than the trench was deep.

   b. The cheese cloth was anchored on top of the trench by rocks or sand.

   c. The cheese cloth was then flipped back up off the smooth trench wall.

   d. Clear acrylic spray was applied evenly over the trench wall surface to be covered by the peel.

   e. The cheese cloth was flipped down over the trench wall and was pressed firmly to stick to the wall. Needles were then inserted along the edges of the cheese cloth to hold it in place.

   f. Krylon latex acrylic was then applied by paintbrush with light upward motions and allowed to dry.

   g. A second coat was applied after the first coat was dry.

   h. The next morning the peel was removed and compass orientation, river mile, and year was written on the back of the peel.

RESULTS AND DISCUSSION

During the eleven day raft trip, twenty-two beaches were surveyed (Table III-1) with forty-five trenches and nine peels completed. Sketches and photographs, recording compass orientation and river mile, were taken at each site. Sedimentary structures found included: laminae bedding, forset beds, ripple marks, cross-bedding, and convoluted bedding.

The most predominant structures found were planar laminae. Laminae (Figure III-1) are formed either by suspension or traction transportation and the sediments are laid down in a relatively calm environment. Upstream dipping forset beds are also common (Figure III-2, lower part) and provided evidence that many of the beaches were formed by back eddy currents depositing sediments in an upstream direction. Ripple marks occur in several deposits and can be clearly seen in the upper part of the trench at RM 61.8 (Figure III-2). Examples of cross-bedding were also present at a few sites (Figure III-2). Cross-bedding is a

Table III-1. Beaches examined for sedimentary structures.

BEACH NAME	MILE
Badger Creek Rapids	L 7.8
18.2 Mile	L 18.2
20.0 Mile	L 20.0
Nautiloid Canyon	L 34.7
Lower Nankoweap	R 53.0
Awatubi	L 58.1
Little Colorado River	R 61.8
Carbon Creek	R 63.5
Nevills Rapid	L 75.5
Grapevine	L 81.1
Cremation Canyon	L 87.0
Granite Rapid	R 93.2
99 Mile	L 99.0
Lower Bass	R 108.5
122 Mile	R 122.0
Forster	L 122.8
Bedrock	R 131.0
Poncho's Kitchen	R 137.0
Lower National Canyon	L 166.6
194 Mile	L 194.0
Granite Park	L 208.8
220 Mile	R 220.0

result of alternating current direction during deposition. Convoluted bedding was the last major sedimentary structure observed in the deposits. Convoluted bedding (Figure III-3) indicates plasticity and deformation of soft sediments after deposition.

There were some unexpected structures found in the deposits, mainly dark-colored heavy minerals and charcoal. The dark-colored heavy minerals (Figure III-4) were probably mica, hornblende, or pyroxene minerals. In some places these materials occur washed up on the present-day shoreline. Only one of the twenty-two beaches (Granite Park, L208.8) contained deposits of charcoal. This deposit (Figure III-5) was probably buried by recreationists who had a campfire on the beach. The deposit was found in a distinct band 20 cm below the surface and was 10-12 cm thick.

The trench dug at Lower National Canyon, L166.6, was extended to 12'long. Because of the extended exposure, a more accurate history of the beach formation was possible. Many structures, including ripple marks, forset beds, convoluted beds, cross-bedding, and laminae bedding were found. A series of photographs taken were put together to form a mosaic of the beach trench (Figure III-6) in order to study and reconstruct the history of the beach.

CONCLUSIONS

The predominant sedimentary structures found in the deposits of beaches and bars along the Colorado River were laminae bedding, forset beds, and ripple marks. By examining the trenches it is possible to conclude that with a few exceptions most beaches were formed by back eddy currents and are therefore

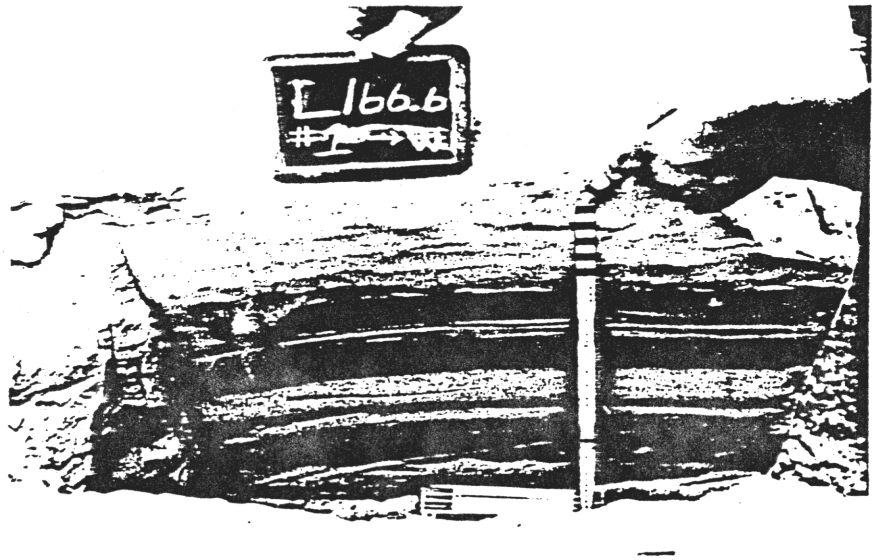

Figure III-1. Laminae bedding and ripple marks.

Figure III-2. Forset beds and cross-bedding.

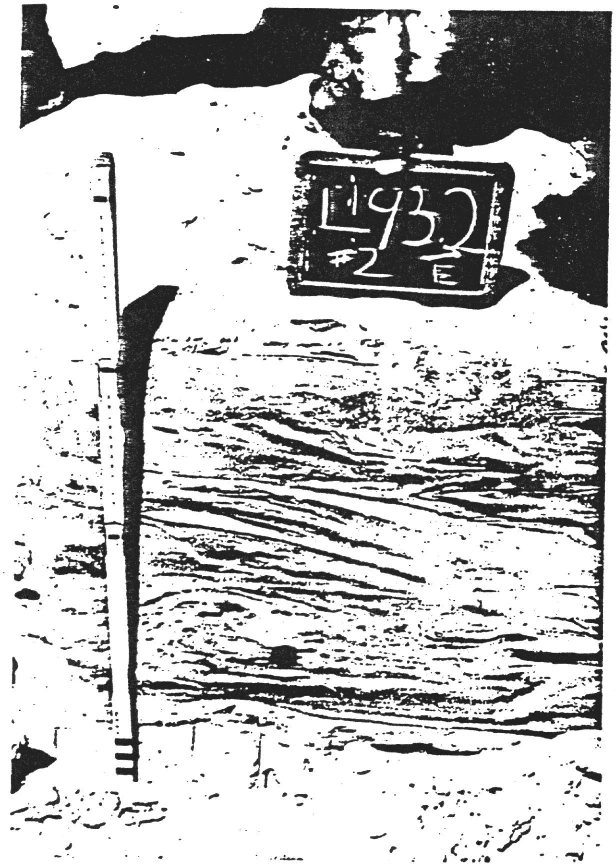

Figure III-3. Convoluted bedding.

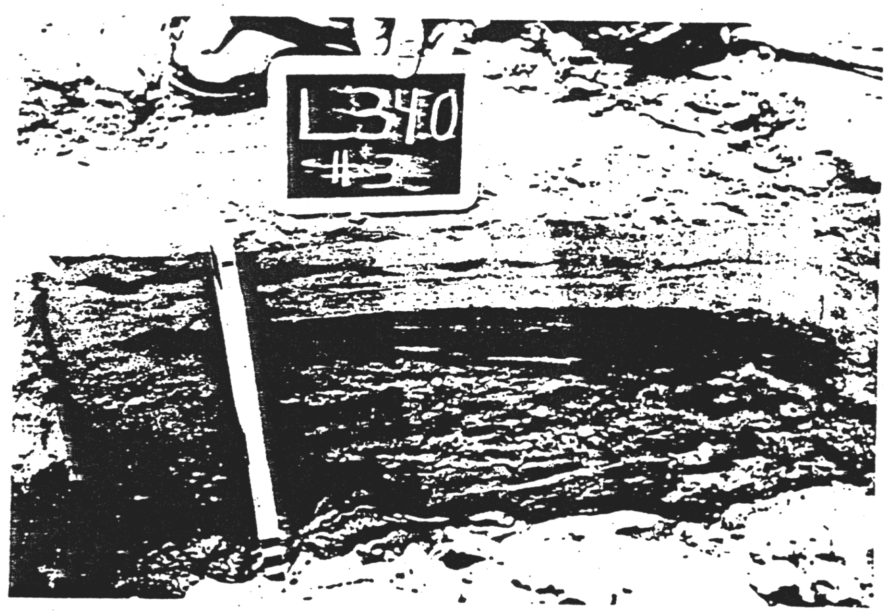

Figure III-4. Heavy minerals.

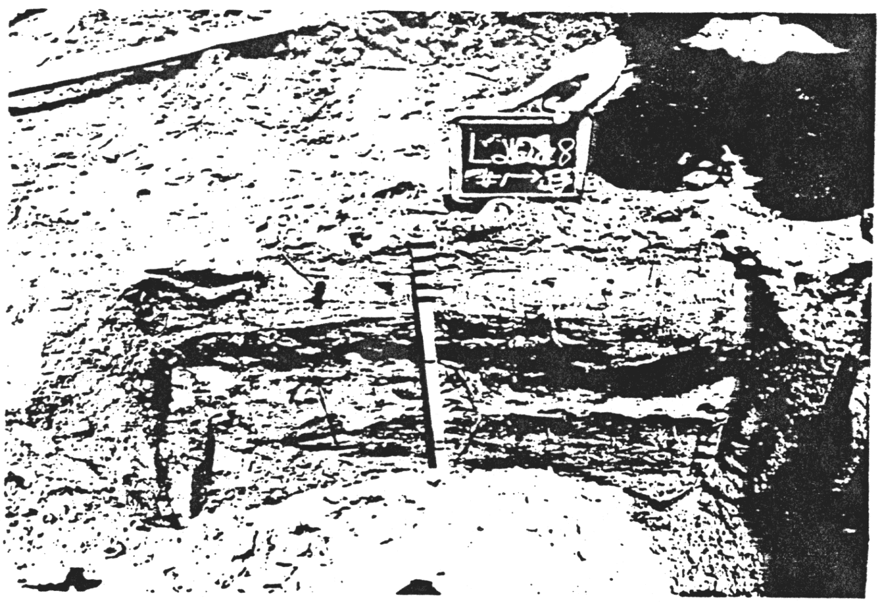

Figure III-5. Charcoal.

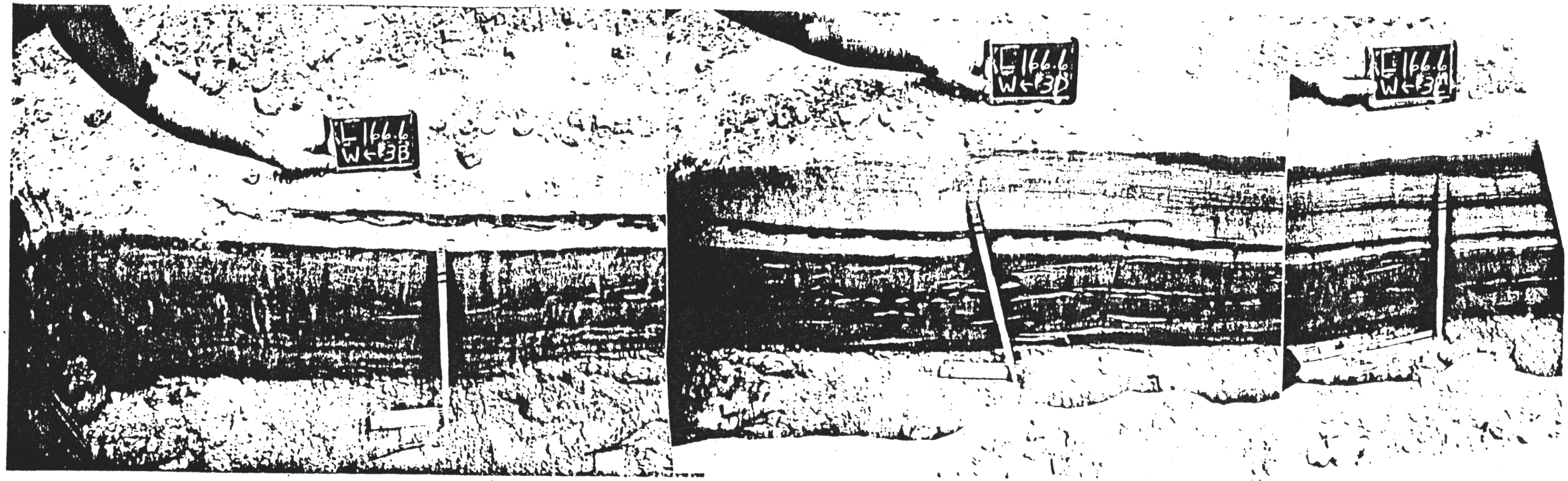

Figure III-6. Lower National Canyon.

referred to as back eddy beaches. This is evident mainly through the current direction indicated by the forset beds which pointed upstream.The structures found in the beaches and bars also indicate a low-energy depositional environment with periodic inundations of heavy sediment-laden flood waters. Through the examination of the sedimentary structures it was possible to reconstruct the transportational and depositional history of the sediments which form the beaches and bars of the Colorado River in the Grand Canyon.

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CHAPTER IV

TOPOGRAPHIC CHANGES ON SELECTED BEACHES IN THE GRAND CANYON, 1986-1987

Robert Bogart, Lillian Flick, Sheryl Brinkhuif, Beverly Possen, Sheila Ringhiser, Martin Kuhl

INTRODUCTION

On July 29, 1987 a research team of seven began a eleven-day continuation study on campsite beaches along the Colorado River in the Grand Canyon. The study involved a transit survey along previously fixed profile lines from established benchmarks. The team surveyed 40 profiles on 20 beaches.

The survey originated in 1974 & 1975 when Howard (1975) surveyed 37 profiles on 20 beaches. This year new benchmarks were set at 194 mile beach (L193.9) with three cross-sections. Tanner Mine Beach (L65.5) and CS2 of the Mouth of the Little Colorado River Beach (R61.8) were not surveyed this year. Table IV-1 shows the history of beach profiles from 1974-1987.

OBJECTIVES

There is concern for the Colorado River beaches in the Grand Canyon. Since the addition of Glen Canyon Dam on the Colorado River in 1963, the beaches have been altered. This study was implemented to determine the direction of this alteration. Final reports of this study may assist management agencies of the Grand Canyon Park in making important decisions for the area.

METHODS

In 1987, 40 profiles on 20 beaches were surveyed. A standard surveying transit was used for all profiles. Table IV-1 indicates the beach profiles from 1974 to 1987. Table IV-2 presents a comparison of the loss or gain of vertical feet of beach sand between 1987 and 1986. Selected individual beach profiles are shown in Figures IV-1 thru 14, and Figures IV-18 thru 22. The histograms in Figure IV-23 represent the amount of gain or loss in vertical fill of sand.

DISCUSSION

The results of the survey presented in Table IV-2 and Figure IV- 23 indicate a loss of sand on most of the beaches studied between 1986 and 1987. Eight profiles on seven beaches showed a slight gain of 0.25 to 1.5 feet of sand deposition on the inner beaches and twelve profiles on eight beaches showed a net gain of 0.5 to 2.75 feet of sand deposition on the outer beaches close to

Table IV-1. Beach Profiles surveyed.

River Mile	Beach Name	1974	1975	1980	1982	1983	1984	1985	1986	1987
				Number of Profiles Measured						
L18.2	Upper 18 Mile Wash		2			2	2	2	2	2
L19.3	19 Mile Wash		2	1		2		2	2	
L34.7	Nautiloid Canyon	2	2			2	2	2	2	2
R53.0	Lower Nankoweap	3	3	1		1	3	2	1	2
R58.1	Awatubi									1
R61.8	Mouth of Little Colorado	1		1		1	1	1	2	1
L65.5	Tanne Mine	2		2		2	2	2	2	
R72.2	Unkar Indian Village (gone)	1	1	3		2	1			
L75.5	Nevills Rapid (New 1984)						2	2	2	2
L81.1	Grapevine	2		2		2	1	2	2	2
L87.1	Lower Suspension Bridge		2	1				1		
L93.2	Upper Granite Rapid	2		1		2	2	2	2	2
R109.4	109 Mile (gone)	2				1	2			
R112.2	Waltenberg Canyon (gone)	1		1		1	1			
R120.1	Blacktail Canyon	2		2	1	2	2	2	2	2
R122.0	122 Mile Beach (New 1985)							2	2	2
R122.8	Forster Canyon (New 1983)					3	3	3	3	2
L124.4	Upper 124 1/2 Canyon (gone)	2				1	1			
R131.0	Bedrock Rapid	2		2		2	2	2	2	2
L151.6	The Ledges	2	2			1	2	2		1
L166.5	National Canyon		2	1		1	2	2		2
L166.6	Lower National (New 1985)							2	5	5
R180.9	Lower Lava Falls	2		2		2	2	2	2	2
L190.2	190 Mile		1	1			1	1	1	1
L193.9	194 Mile Beach (New 1987)									3
L208.8	Granite Park	2	2	2	1	2	2	2	2	2
L220.0	220 Mile Beach (New 1985)							2	2	2

1974, 1975 data from Howard (1975)
1980 data from Dolan (1981)
1982 data from Beus and others (1982)
1984 data from Beus and others (1985)
1985 data from Beus and others (1986)
1986 data from Beus and others (1987)
1987 data from this report

Table IV-2. Summary of loss or gain of beach sand.

Beach	Profile	Inner	Outer
L18.2	CS1	-1.0	-1.5
	CS2	+1.5	-3.5
L34.7	CS1**	0.0	0.0
	CS2**	0.0	0.0
R53.0	CS1	No data in 1987	
	CS2	+1.0	+0.5
	CS3**	-2.0	-3.0
R58.1	CS1	-3.0	-2.75
R61.8	CS1	-1.0	+0.75
	CS2	No data in 1987	
L65.5	CS1	No data in 1987	
	CS2	No data in 1987	
L75.5	CS1	-0.75	-1.0
	CS2	-0.5	-0.5
L81.1	CS1	0.0	-1.25
	CS2	-0.5	-1.25
L93.2	CS1	0.0	0.0
	CS2	0.0	-1.0
R120.1	CS1	0.0	-1.25
	CS2	+0.25	+0.75
R122	CS1	-1.75	-3.6
	CS2	-1.25	-4.0
L122.8	CS1	+1.0	-1.4
	CS2	+1.0	+1.25
	CS3	No data in 1987	
R131.0	CS1	0.0	+0.5
	CS2	0.0	+1.0
L166.5	CS1**	-0.5	+0.5
	CS2**	-1.13	+1.13
L166.6	CS1	-0.25	0.0
	CS2	+0.5	+0.5
	CS3	0.0	+2.75
	CS4	-2.5	-2.0
	CS5	-0.1	0.0
R180.9	CS1	-0.25	-1.0
	CS2	-0.25	-0.75
L190.2	CS1	0.0	0.0
L193.9	CS1, CS2, CS3.	New 1987	
L208.9	CS1	+1.25	-0.5
	CS2	0.0	-2.0
R220	CS1	0.0	+1.0
	CS2	+1.0	+0.5

** Compared to 1985 data

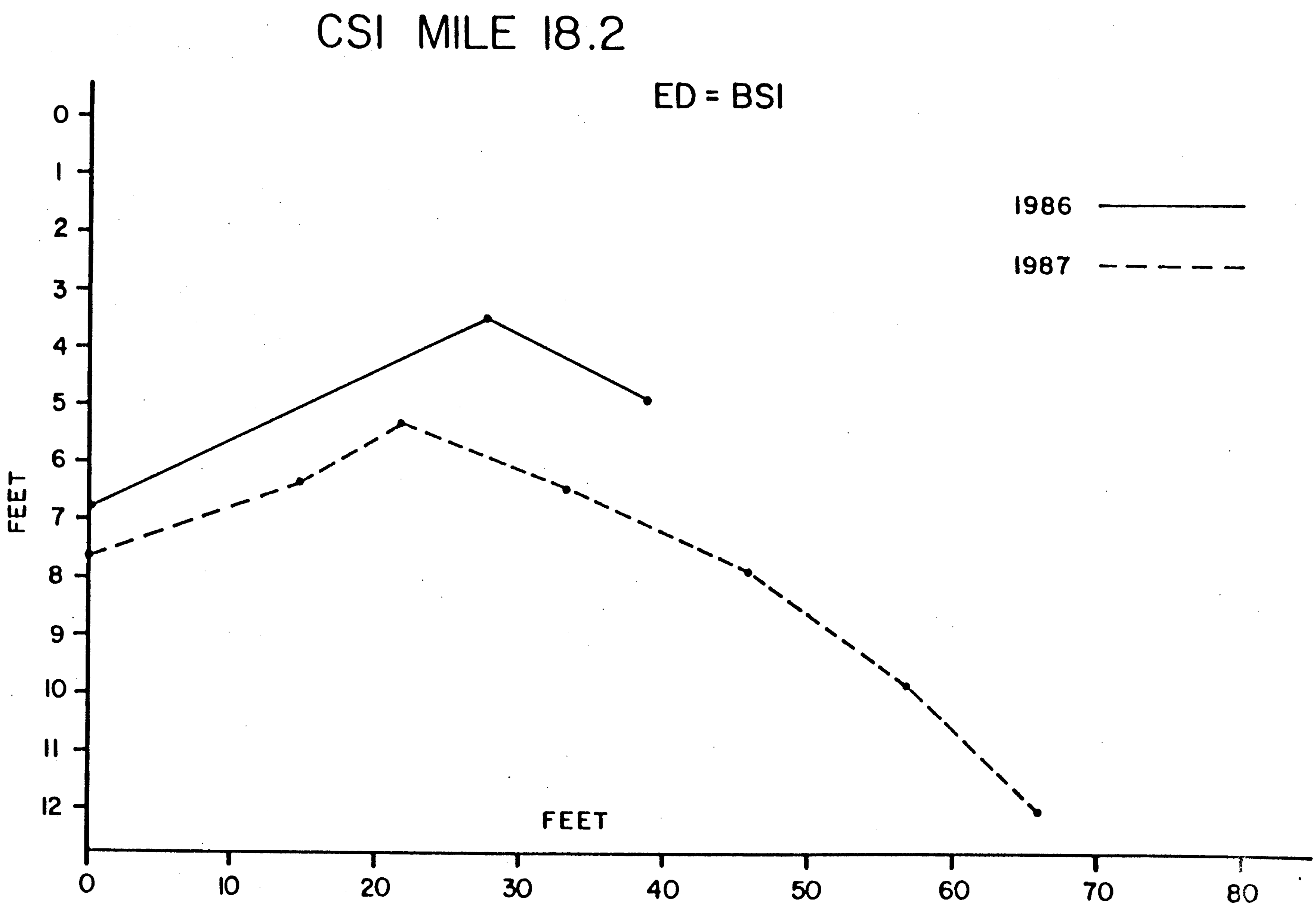


Figure 1. Cross-section 1 at 18-mile beach

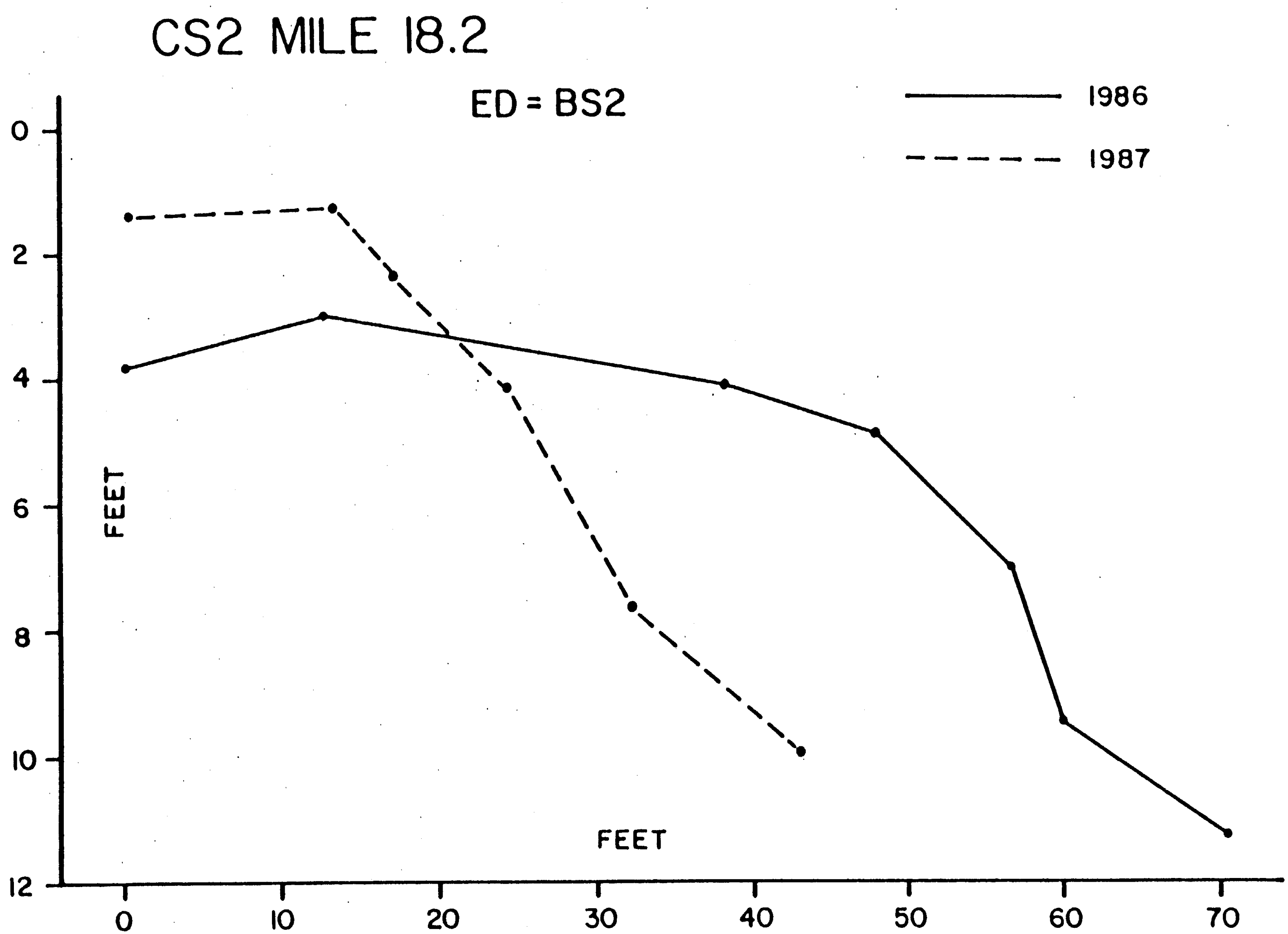


Figure 2. Cross-section 2 at 18-mile beach

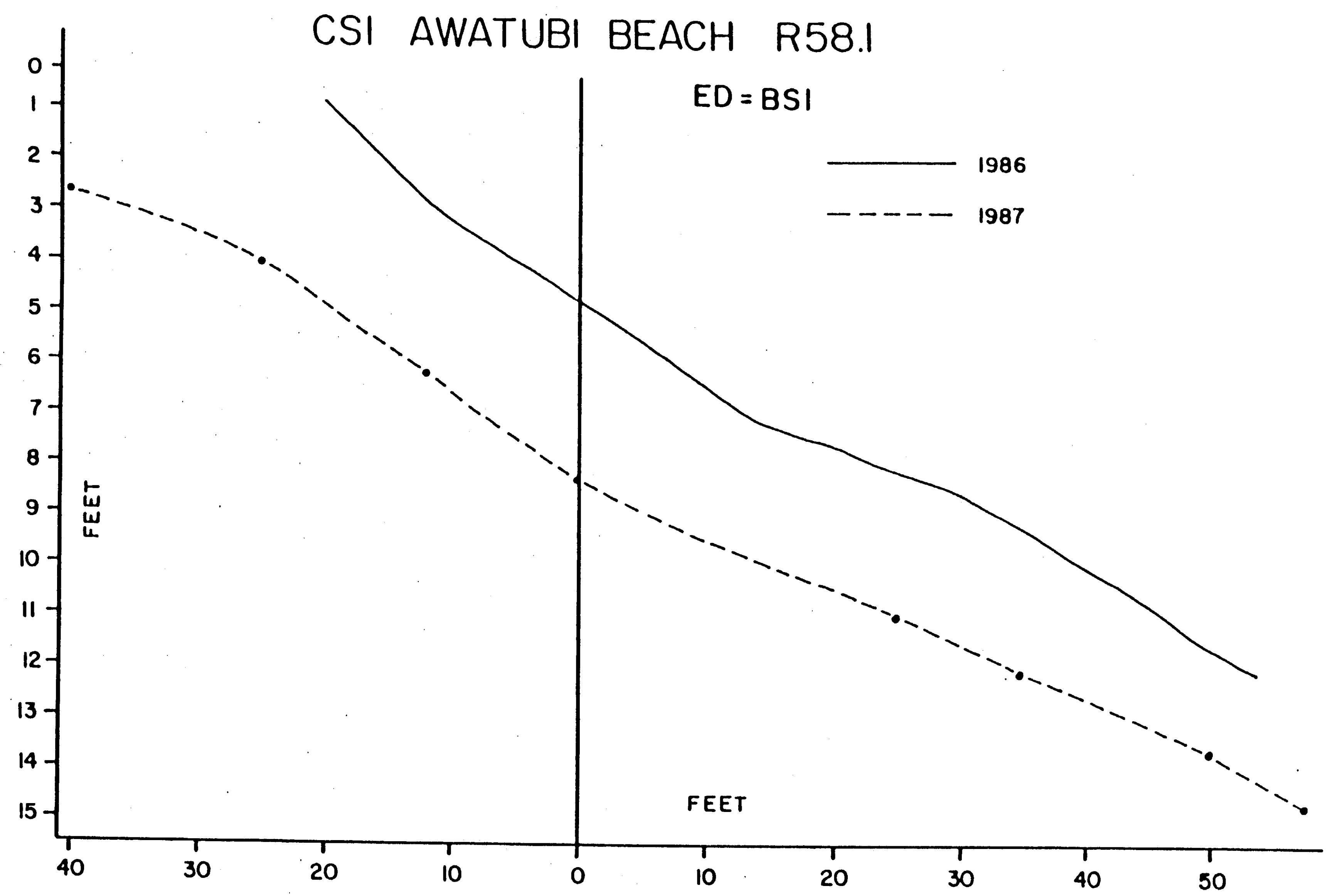


Figure 3. Cross-section 1 at Awatubi beach, mile 58.1

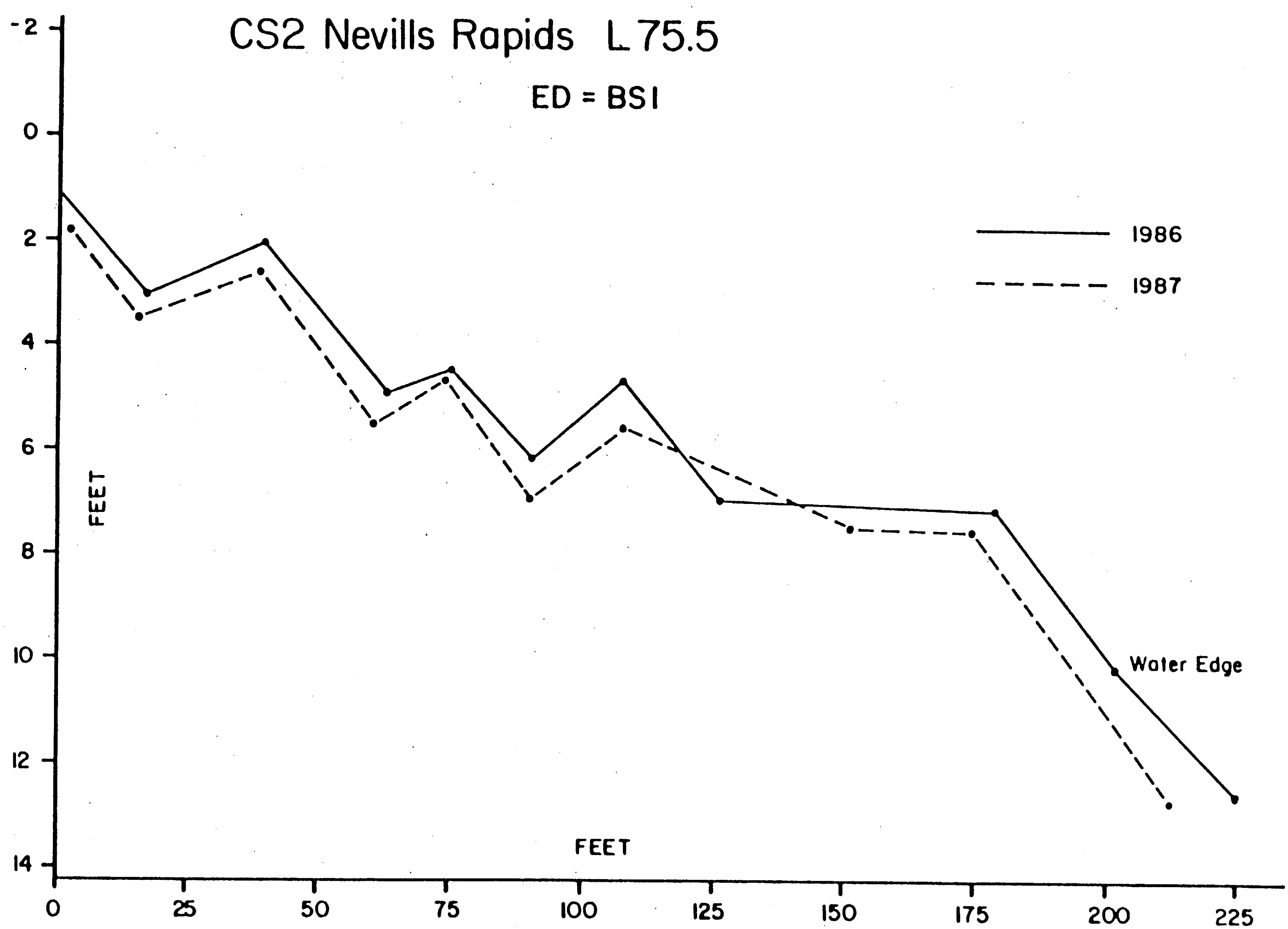


Figure 4. Cross-section 2 at Nevills beach, mile 75.5

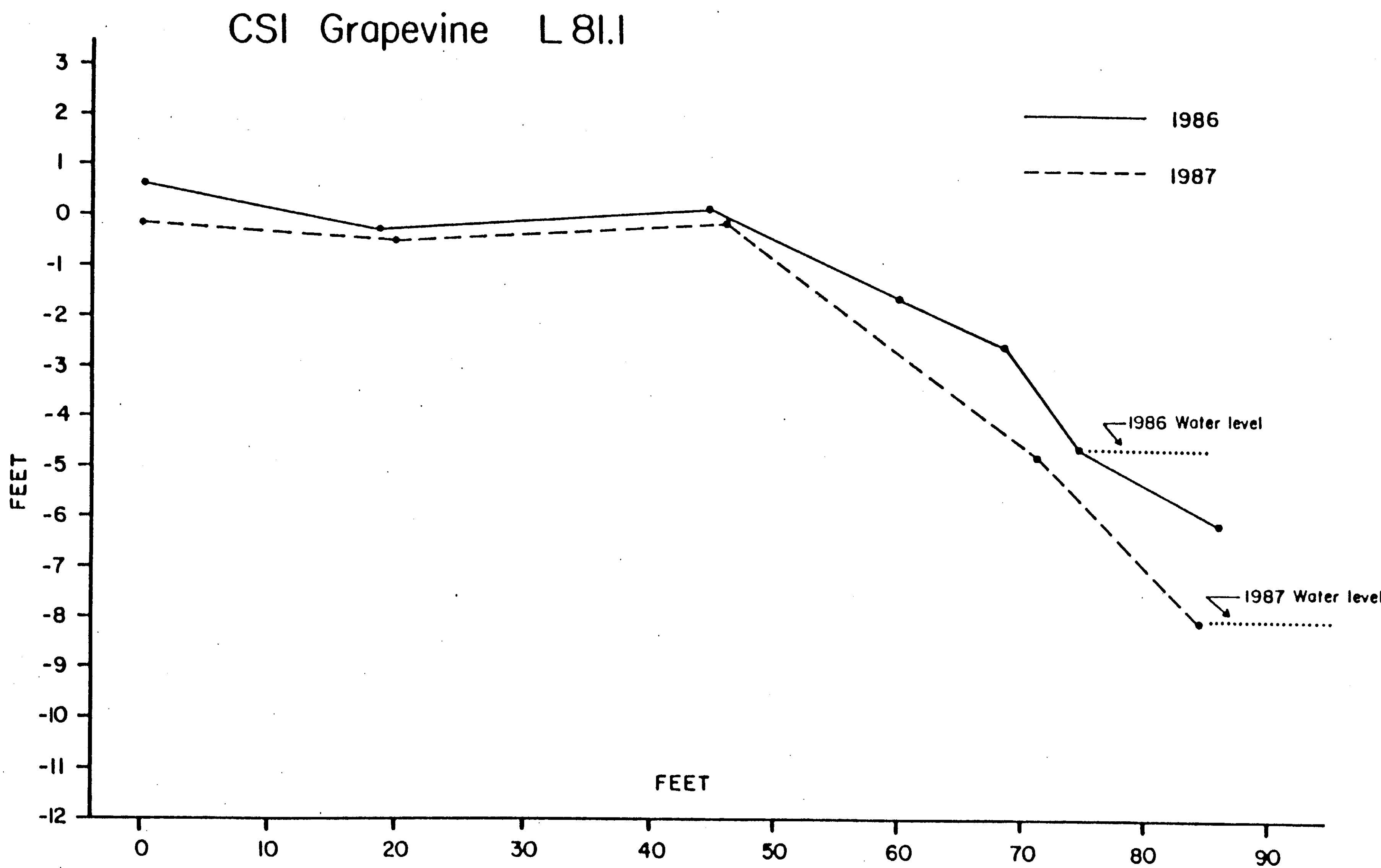


Figure 5. Cross-section 1 at Grapevine beach, mile 81.1

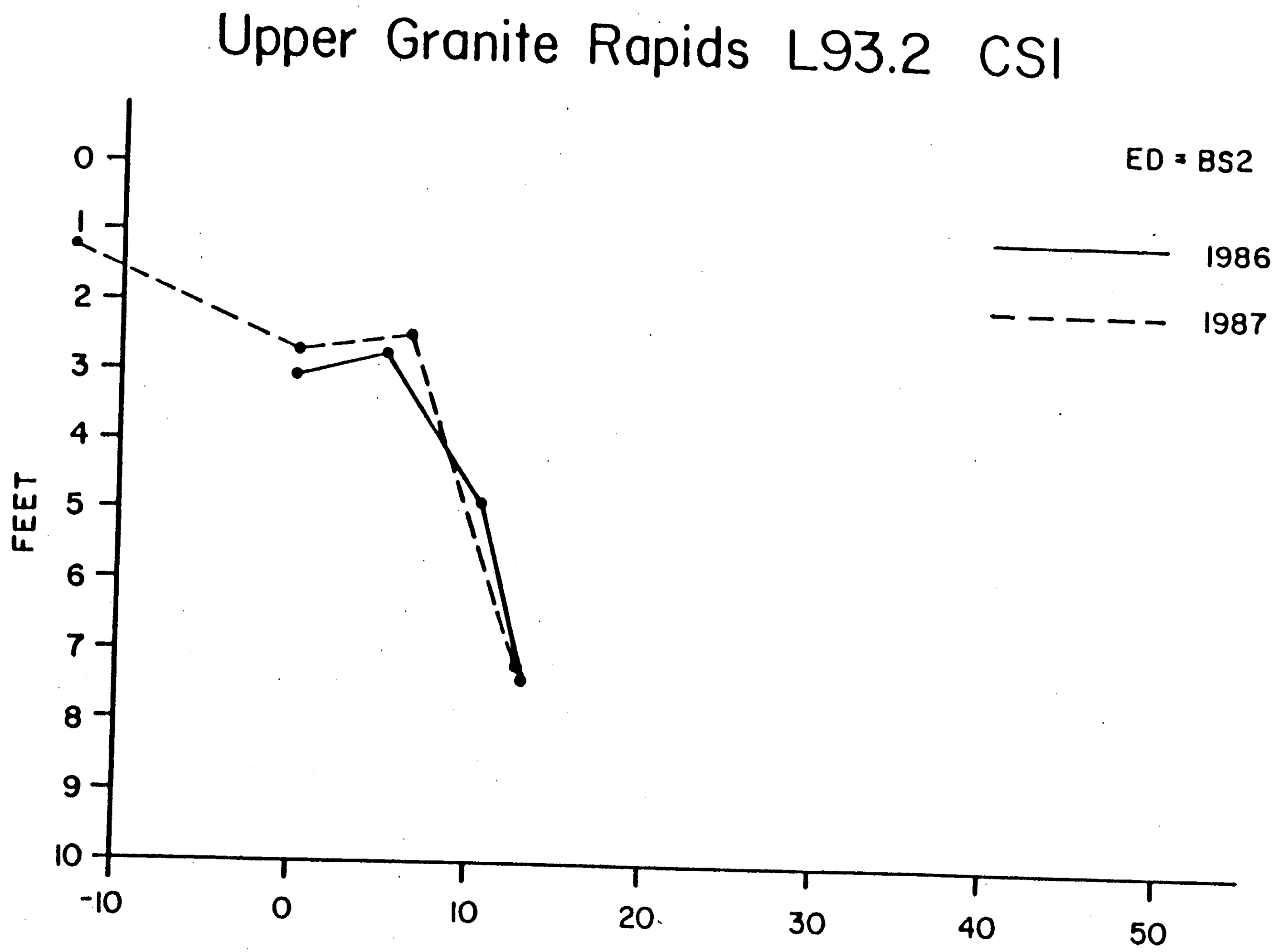


Figure 6. Cross-section 1 at Upper Granite beach, mile 93.2

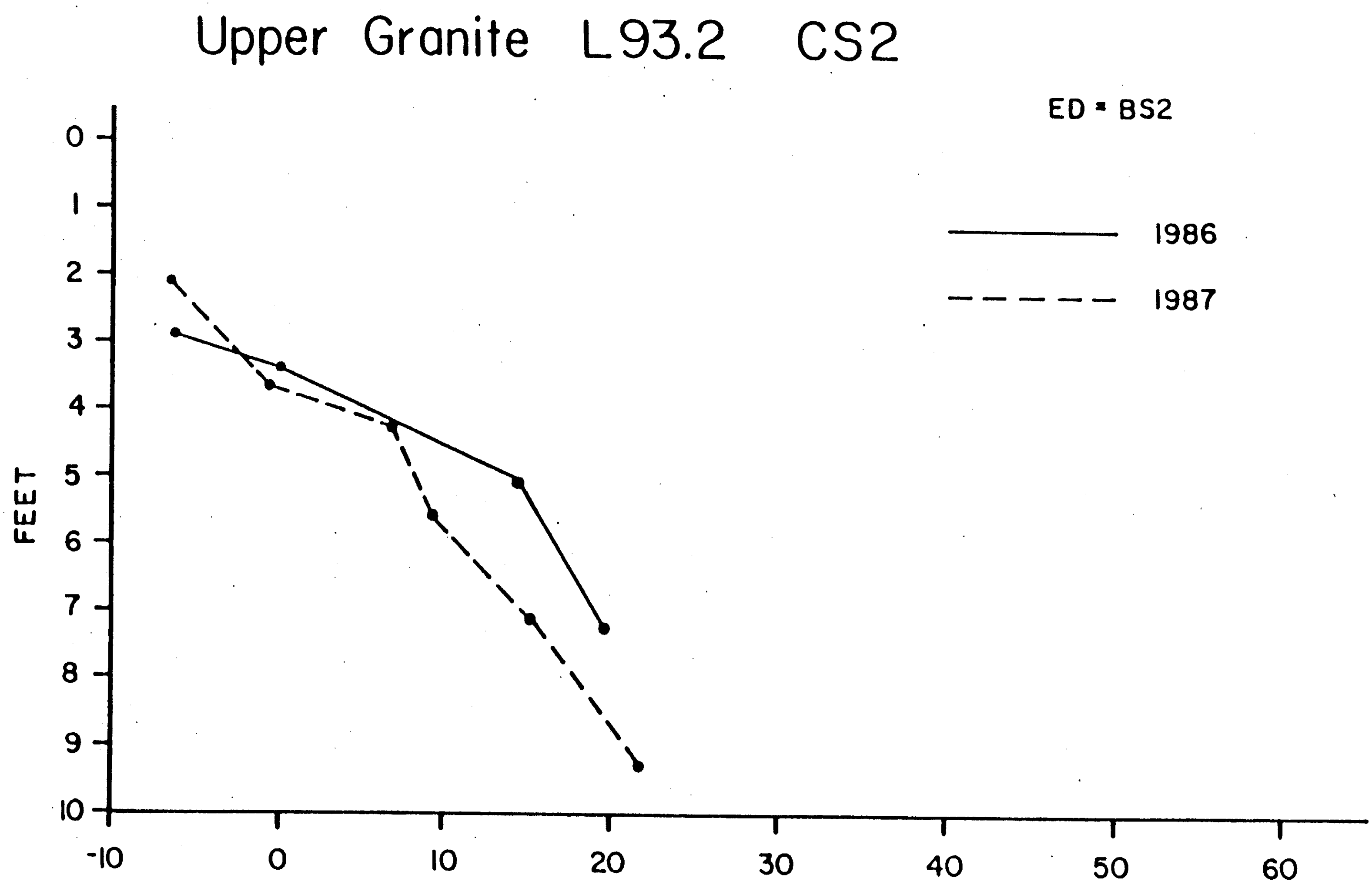


Figure 7. Cross-section 2 at Upper Granite beach, mile 93.2

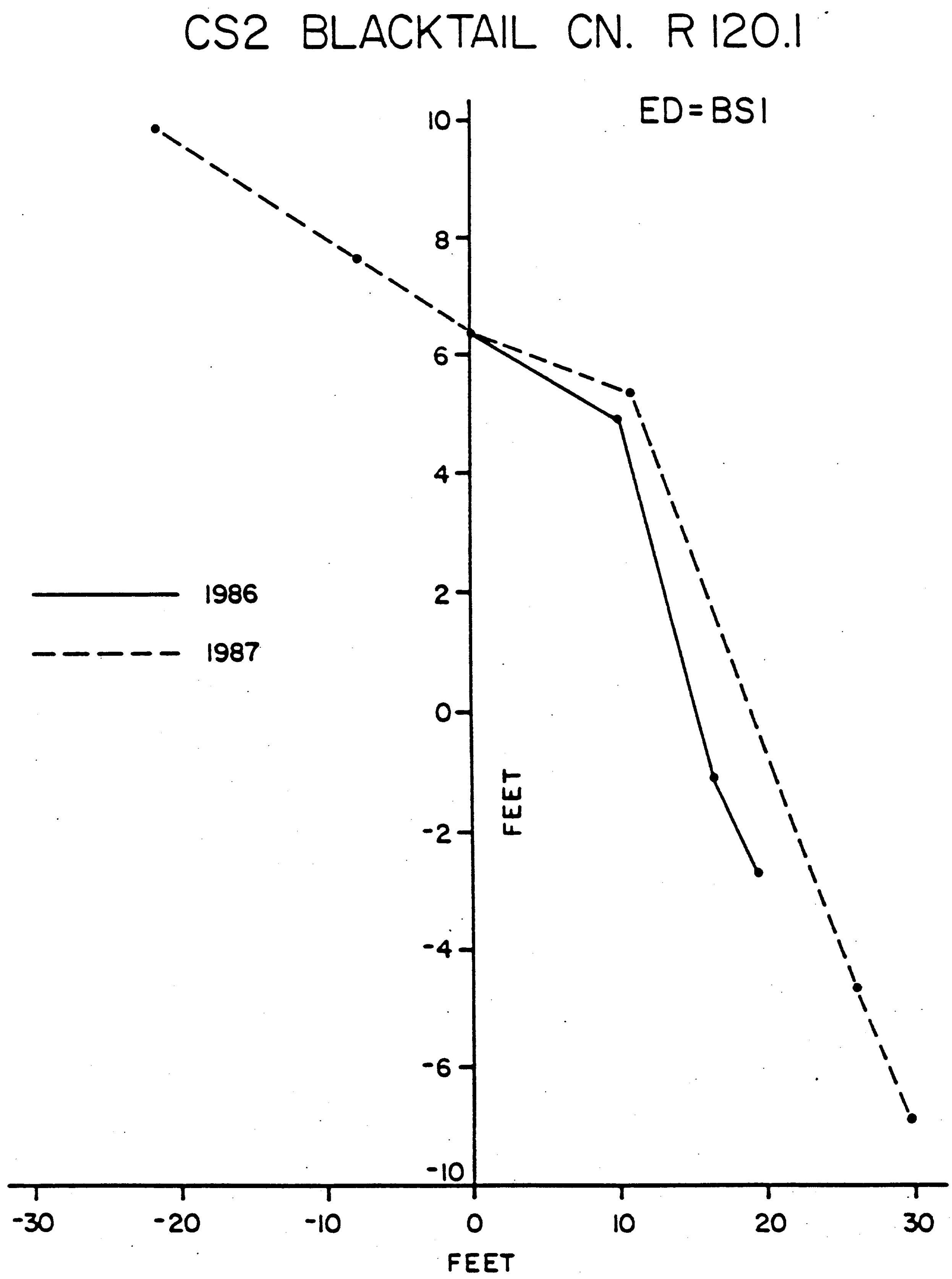


Figure 8. Cross-section 2 at Blacktail beach, mile 120.1

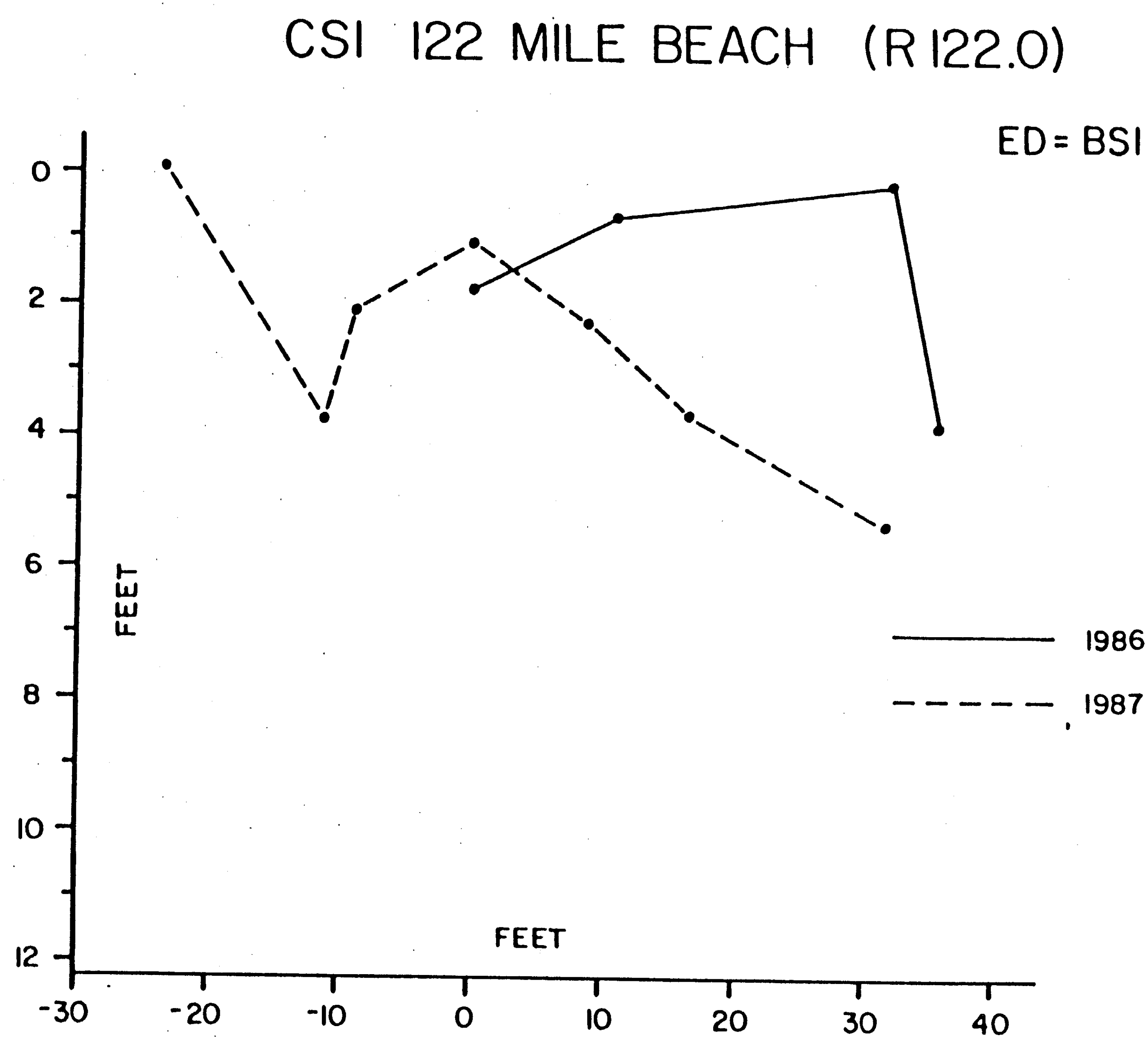


Figure 9. Cross-section 1 at 122-mile beach

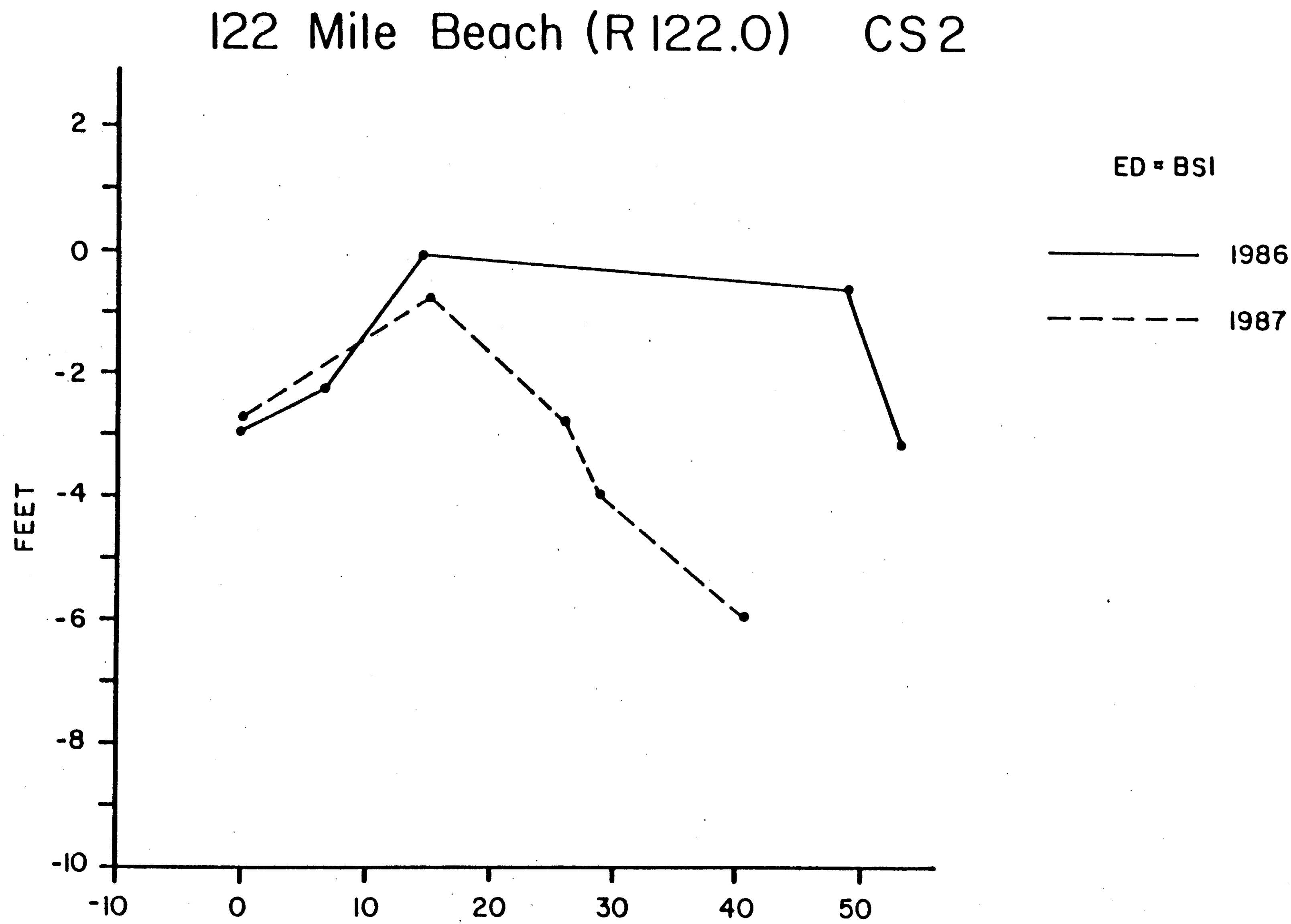


Figure 10. Cross-section 2 at 122-mile beach

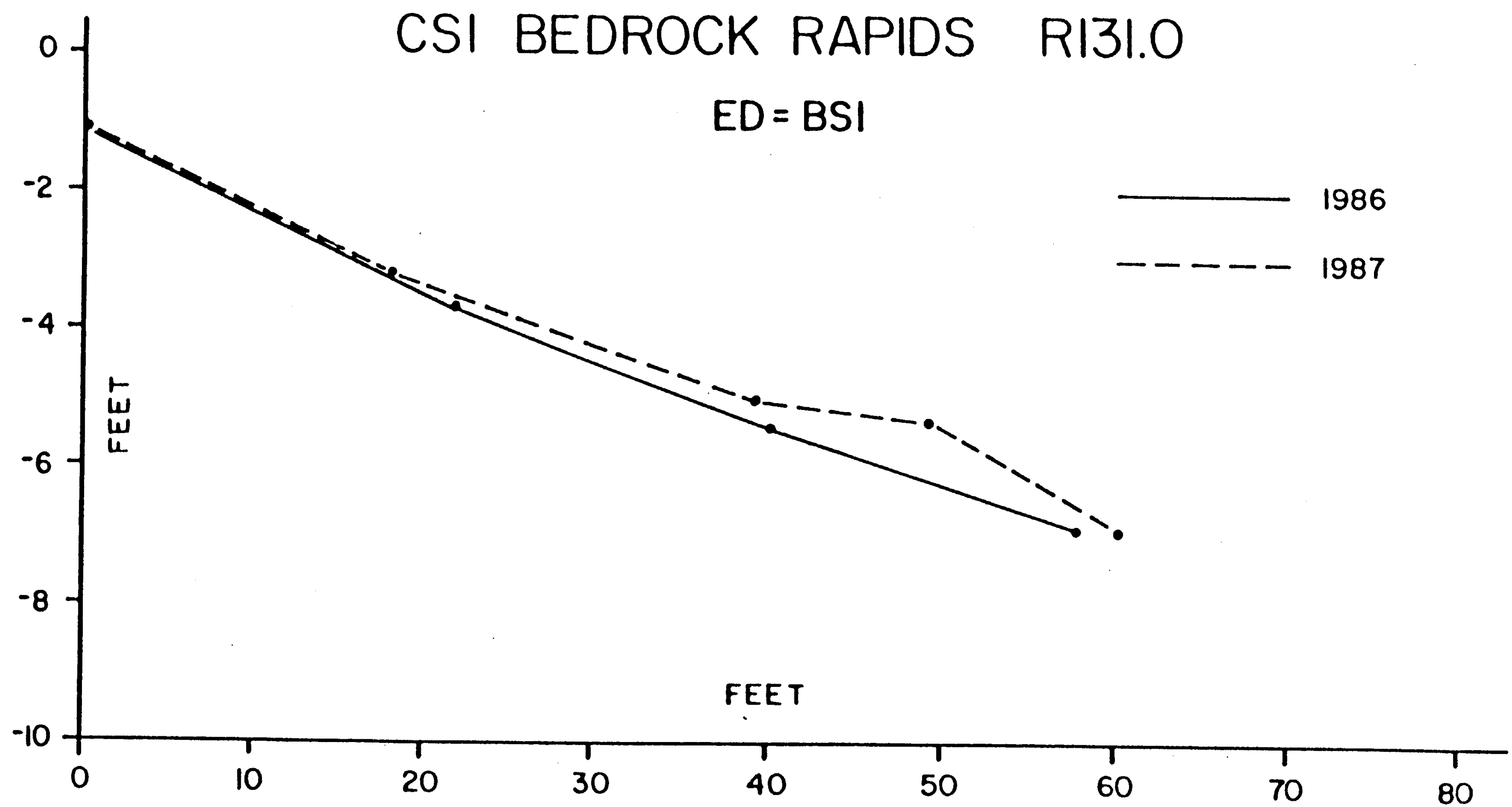


Figure 11. Cross-section 1 at Bedrock beach, mile 131

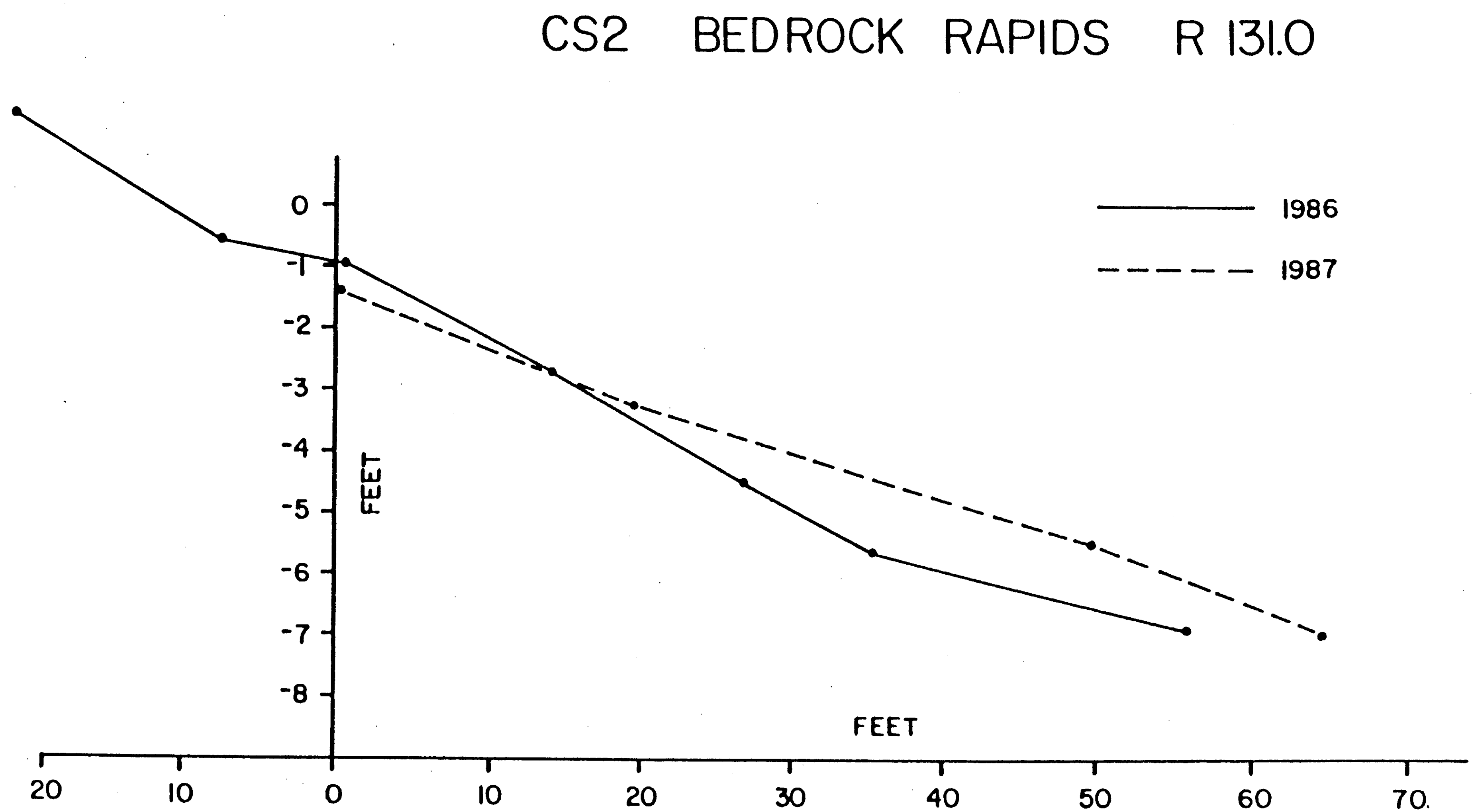


Figure 12. Cross-section 2 at Bedrock beach, mile 131

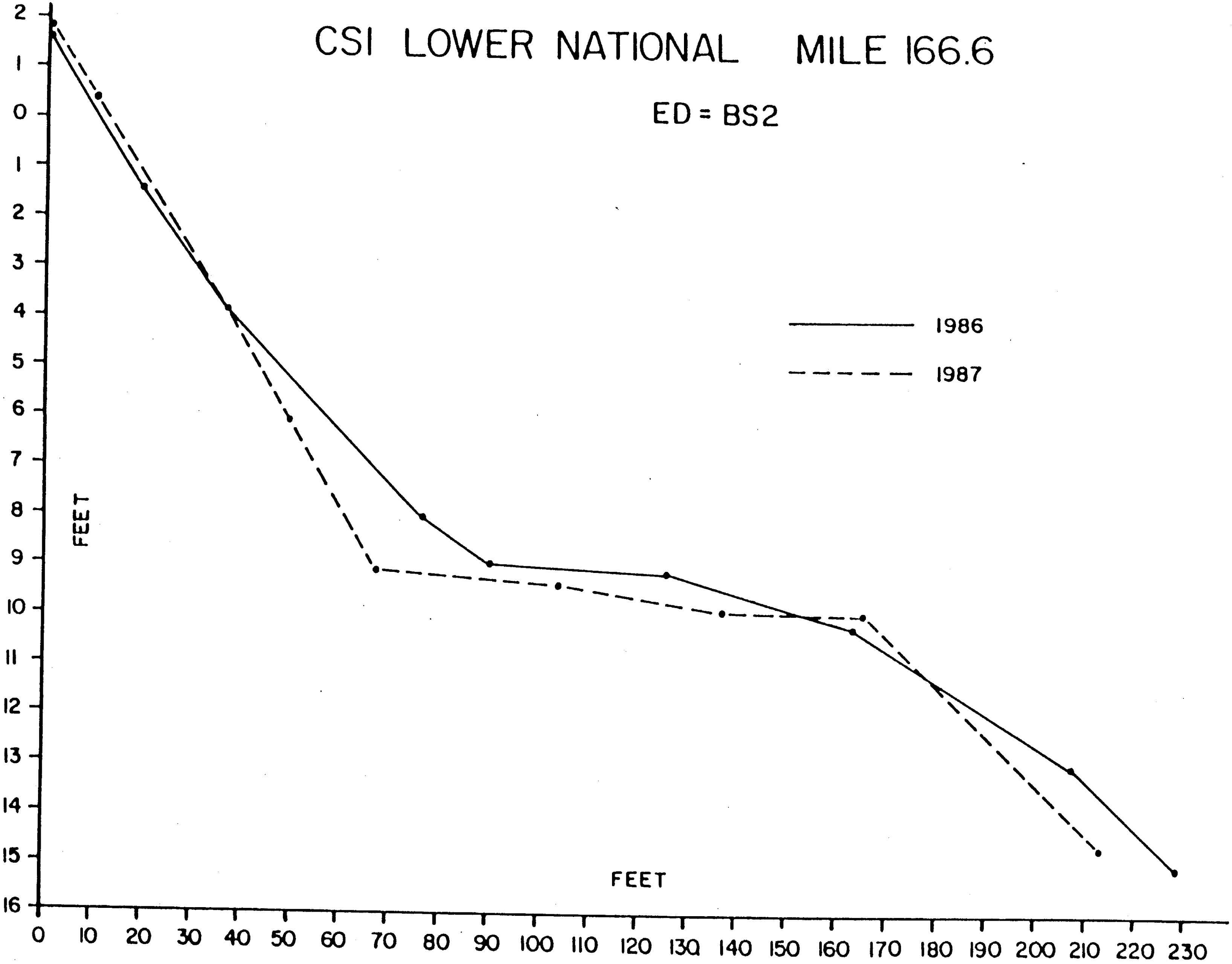


Figure 13. Cross-section 1 at Lower National beach, mile 166

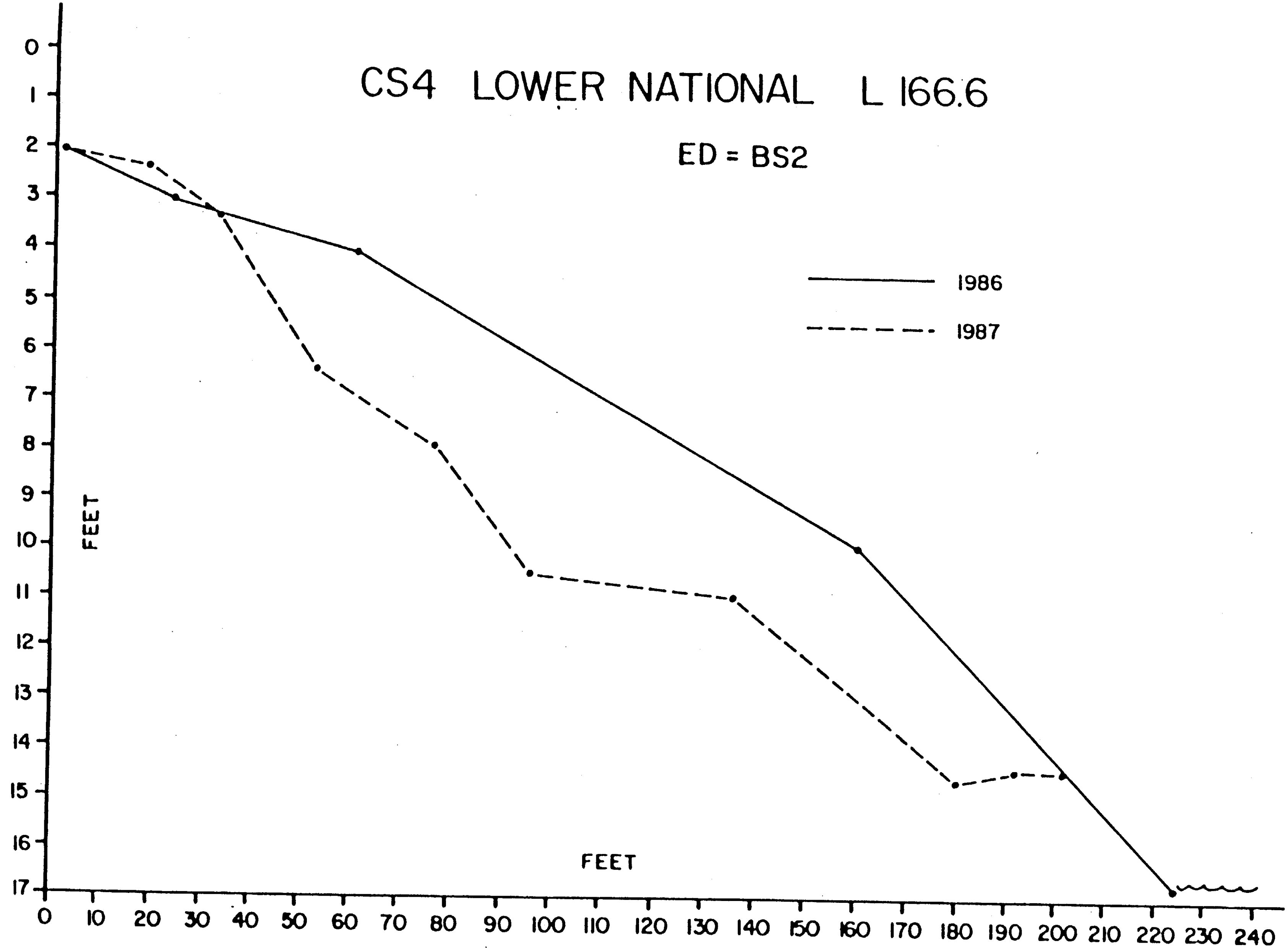


Figure 14. Cross-section 4 at Lower National beach, mile 166

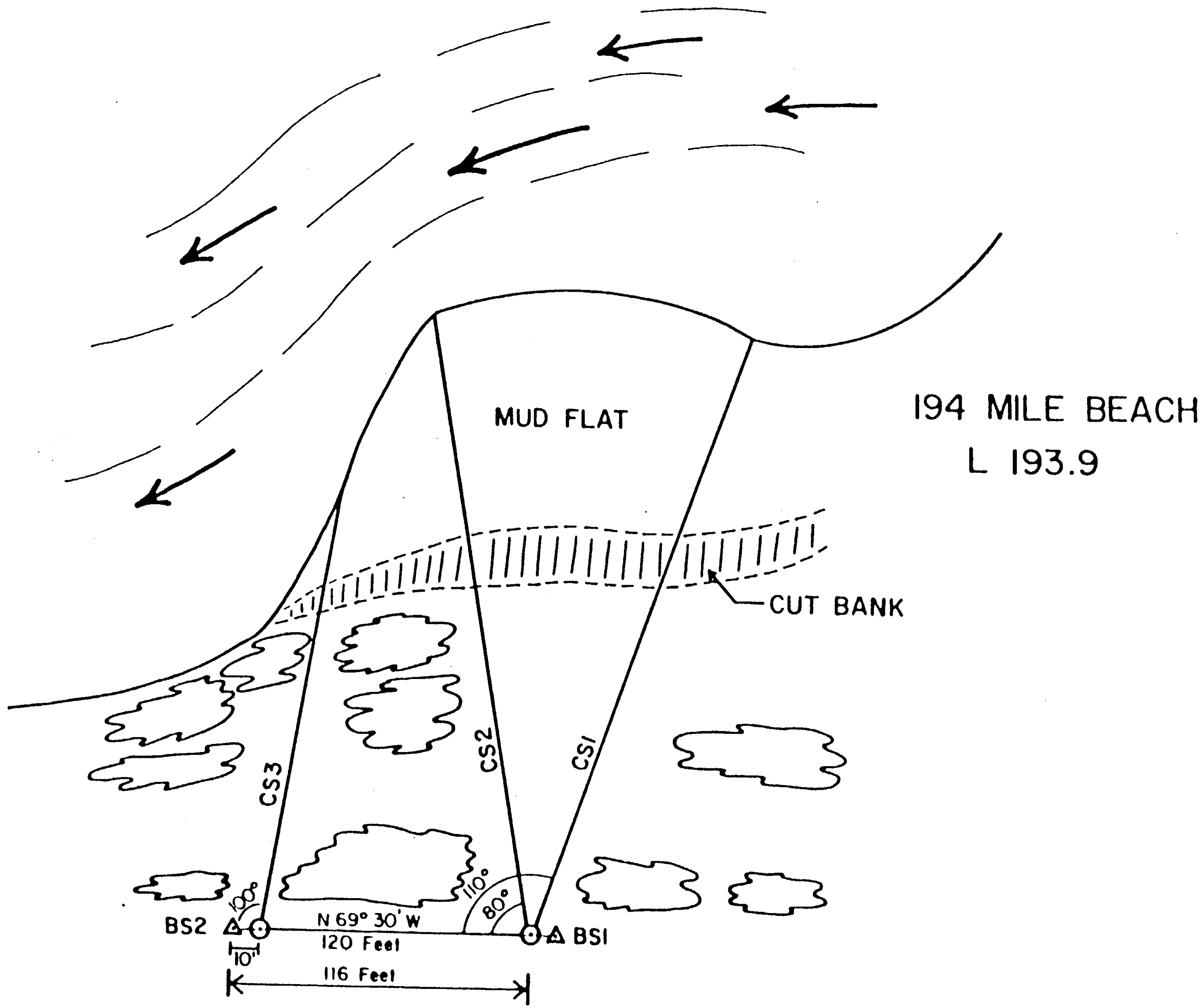


Figure 15. Location of beach profiles at 194-mile beach

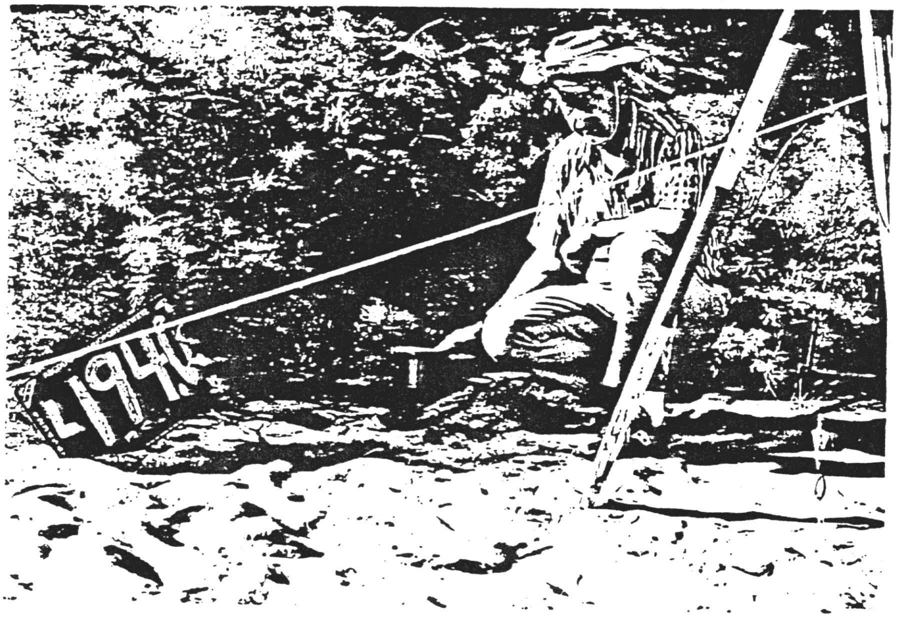


Figure 16. Location of base station 1 at 194-mile beach

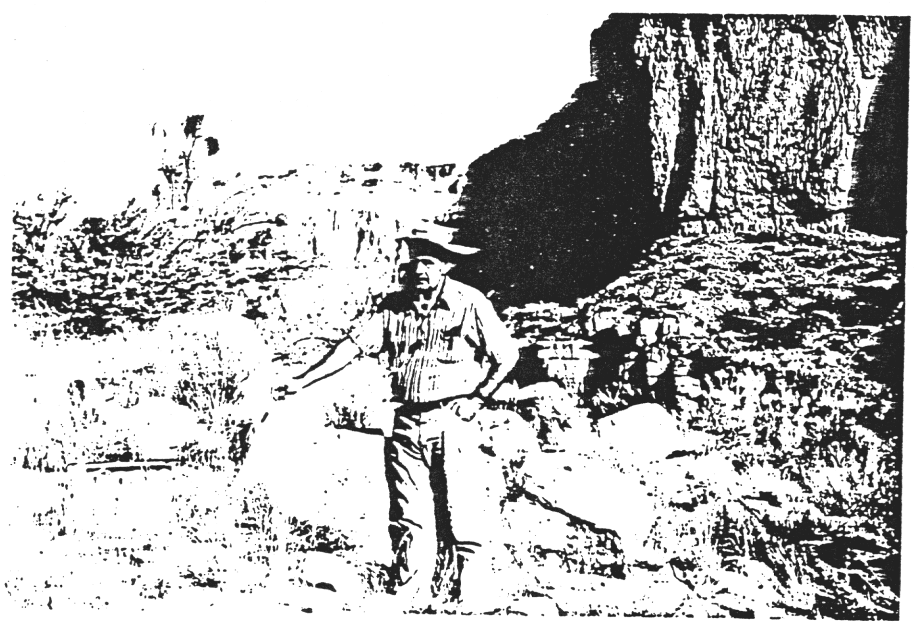


Figure 17. Location of base station 2 at 194-mile beach

BEACH PROFILE LOCATION SHEET

Site 194 Mile Beach Mile Post 193.9

Date established 2 4 ? 97

Base station #1 120 ft from BS2 Photo ✓
Perm. mark pipe

Base station #2 120 ft from BS1 Photo ✓
Perm. mark Cross chiseled on ANGULAR Blue gray limestone rock

Base Station #3 ______ Photo ______
Perm. mark ______

Elevation datum BS2 Photo # ✓

Length of base line #1 120 ft from BS2
Base line orientation S71E from BS2 → BS1

Length of ~~base~~ line # 2 116 ft from CS1 → BS2
Base line orientation N120 30' W from CS1 → BS2

Length of base line #3 ______ from ______
Base line orientation ______ from ______

Cross section #1: 116 from CS1 Toward BS2
at an angle of 112° (~~counter~~) clockwise from direction of BS2

Cross section #2: 116 from BS2
at an angle of 90° (~~counter~~) clockwise from direction of BS1

Cross section #3: ______ from CS3 to BS2
at an angle of 100° (~~counter~~) clockwise from direction ~~of~~ to BS2

Comments

✓

CROSS-SECTION DATA SHEET

MILE: L 193.9 CAMPGROUND NAME: 194 mile Beach

CROSS-SECTION NO. CS1 SURVEY DATE: AUG 7 97

ORIGINAL SURVEY? YES RESURVEY NO. ——

FROM	TO	ROD READING (feet)	SLOPE DISTANCE (ft/in)	VERTICAL ANGLE (deg)	HORIZONTAL DISTANCE	COMMENTS
CS1	BS2	0.25			116	8:00 AM
CS1	CS1(HI)	5.11				110° High Sand Terrace
	1	5.93			8.5	
	2	9.17			25.1	
	3	14.1			52.3	Edge of Depression
	4	13.78			63.7	opposite Edge) "
	5	11.35			78.6	
	6	11.04			107.0	
	7	11.14			137.0'	Slope Break
	8	11.19			157.0	Hi WATER MARK
	9	17.17			192.6	
	10	18		-8 min	255	WATER'S EDGE
						& Large mud flat
CS1	BS1	5.2			5.21	S 71° E CS1->BS

COMMENTS: ED = BS2 = 0.25

CROSS-SECTION DATA SHEET

ILE: L 193.9 Mile

ROSS-SECTION NO. CS2

RIGINAL SURVEY? YES

CAMPGROUND NAME: 194 MILE BEACH

SURVEY DATE: AUG 7, 87

RESURVEY NO.

ROM	TO	ROD READING (feet)	SLOPE DISTANCE (ft/in)	VERTICAL ANGLE (deg)	HORIZONTAL DISTANCE	COMMENTS
CS2	BS2	0.25			116	N 69°30' W ;
CS2	CS2 (HI)	5.08				80°
	1	6.03			13.4	Top of Sandy depression
	2	7.90			21.4	
	3	13.21			36.4	Bottom of Depression
	4	13.06			51.1	opposite side D "
	5	11.42			58.5	Top of Depression
	6	11.05			96.9	
	7	11.13			126.7	Edge of Beach Terrace
	8	16.54			150.8	Hi water line, Bottom of Terrace
	9	17.1			180.9	
	10	18.81			235	Water's Edge
CS2	BS1	5.2			5.21	

COMMENTS: ED = BS2 = 0.25

J. BS2

CROSS-SECTION DATA SHEET

MILE: L 53.9 CAMPGROUND NAME: 24 Mile [illegible]

CROSS-SECTION NO. CS3 SURVEY DATE: 3-7-1990 [illegible]

ORIGINAL SURVEY? Yes RESURVEY NO.

FROM	TO	ROD READING (feet)	SLOPE DISTANCE (ft/in)	VERTICAL ANGLE (deg)	HORIZONTAL DISTANCE	COMMENTS
CS3	BS2	2.20		—	10'	
CS3	CS3 (HI)	5.22				—
	1	7.39			11.8	
	2	14.82			35.0	Bottom of Depression
	3	13.38			59.6	
	4	13.52			121.9	Edge of Beach terrace
	5	18		-35 MIN	131.4	Bottom of Terrace
	6	18		-50 MIN	165.6	WATer's Edge
CS3	BS1	7.07				S69°30'E

COMMENTS: El BS2 = 2.20

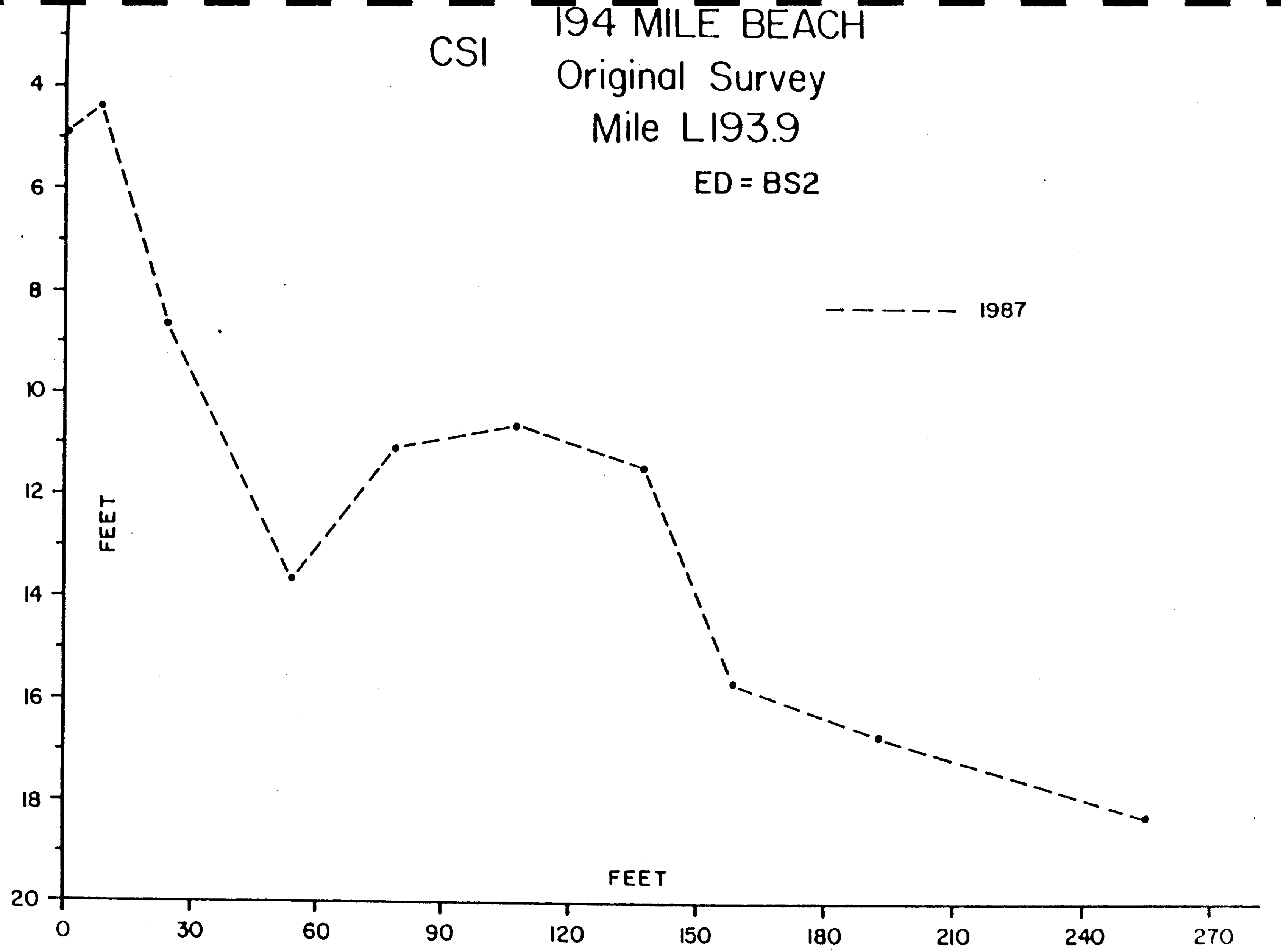


Figure 18. Cross-section 1 at 194-mile beach

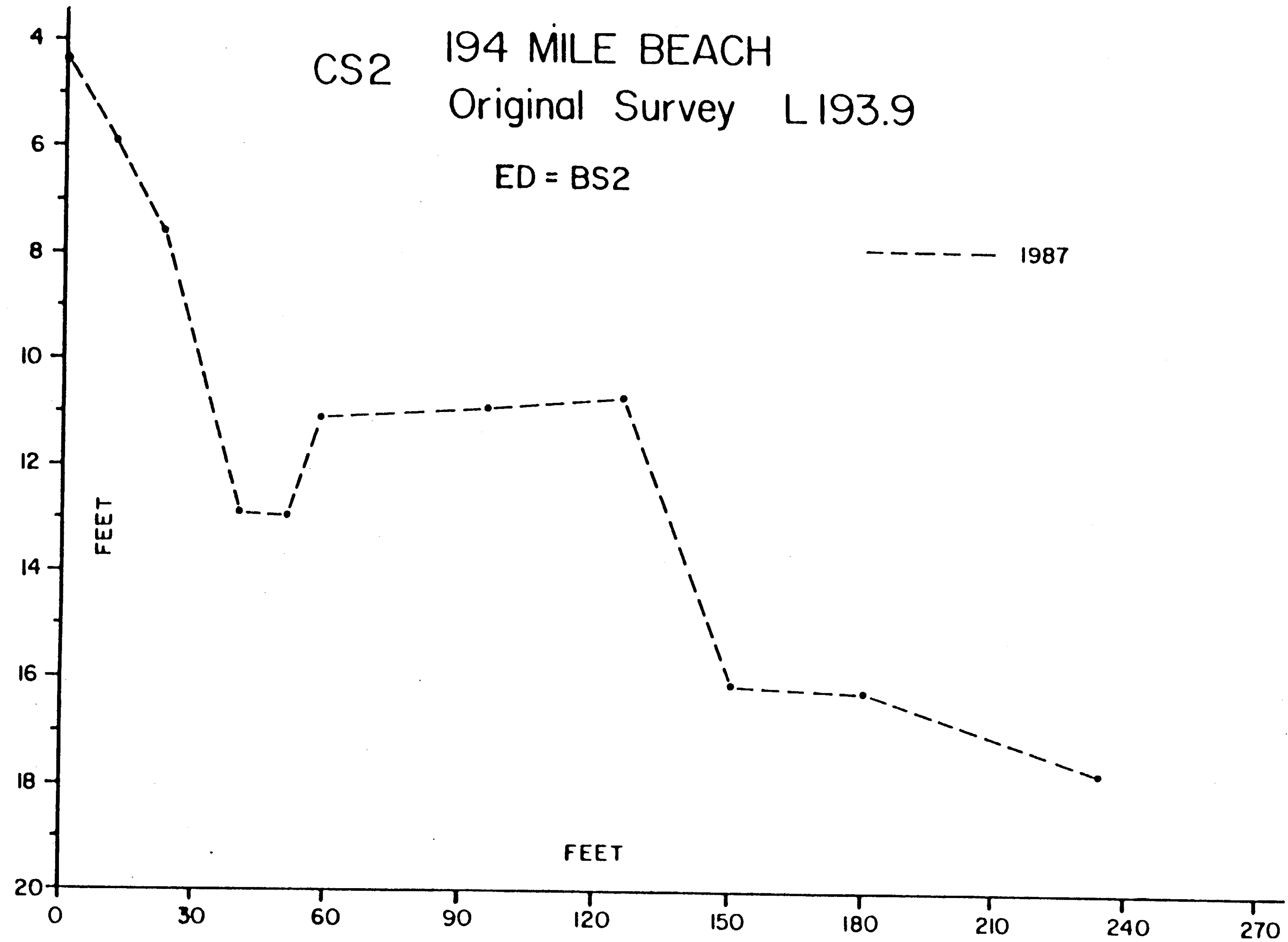


Figure 19. Cross-section 2 at 194-mile beach

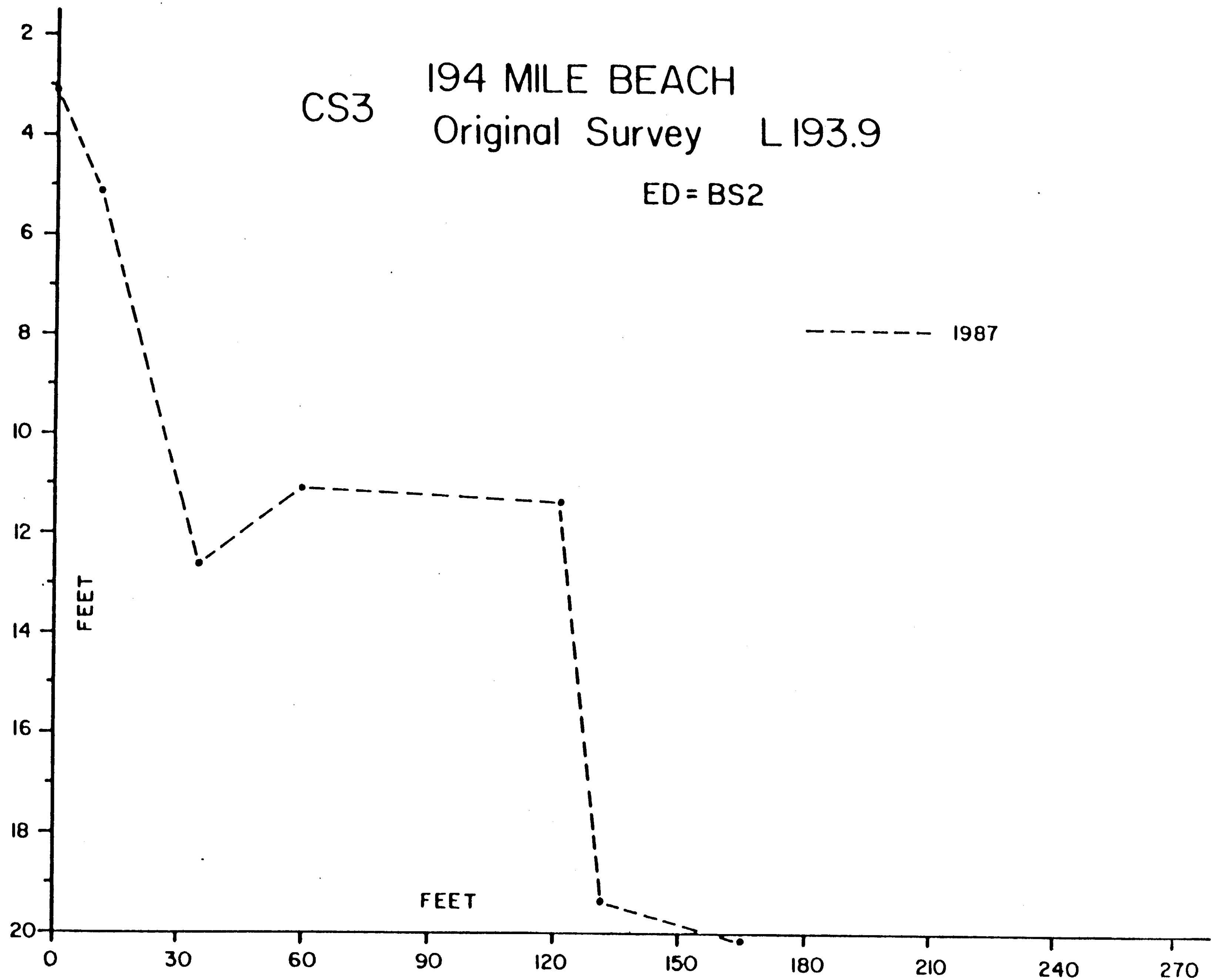


Figure 20. Cross-section 3 at 194-mile beach

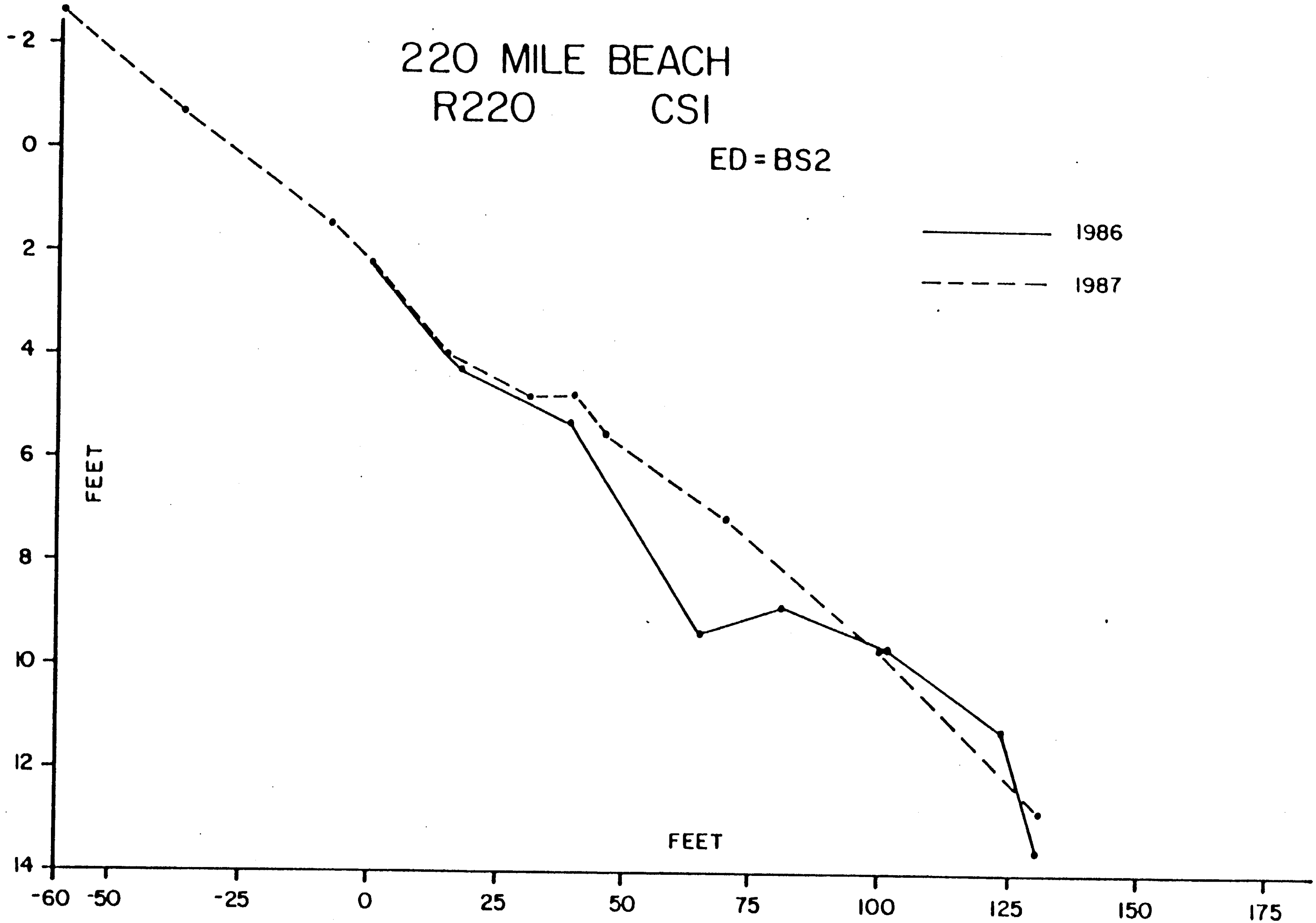


Figure 21. Cross-section 1 at 220-mile beach

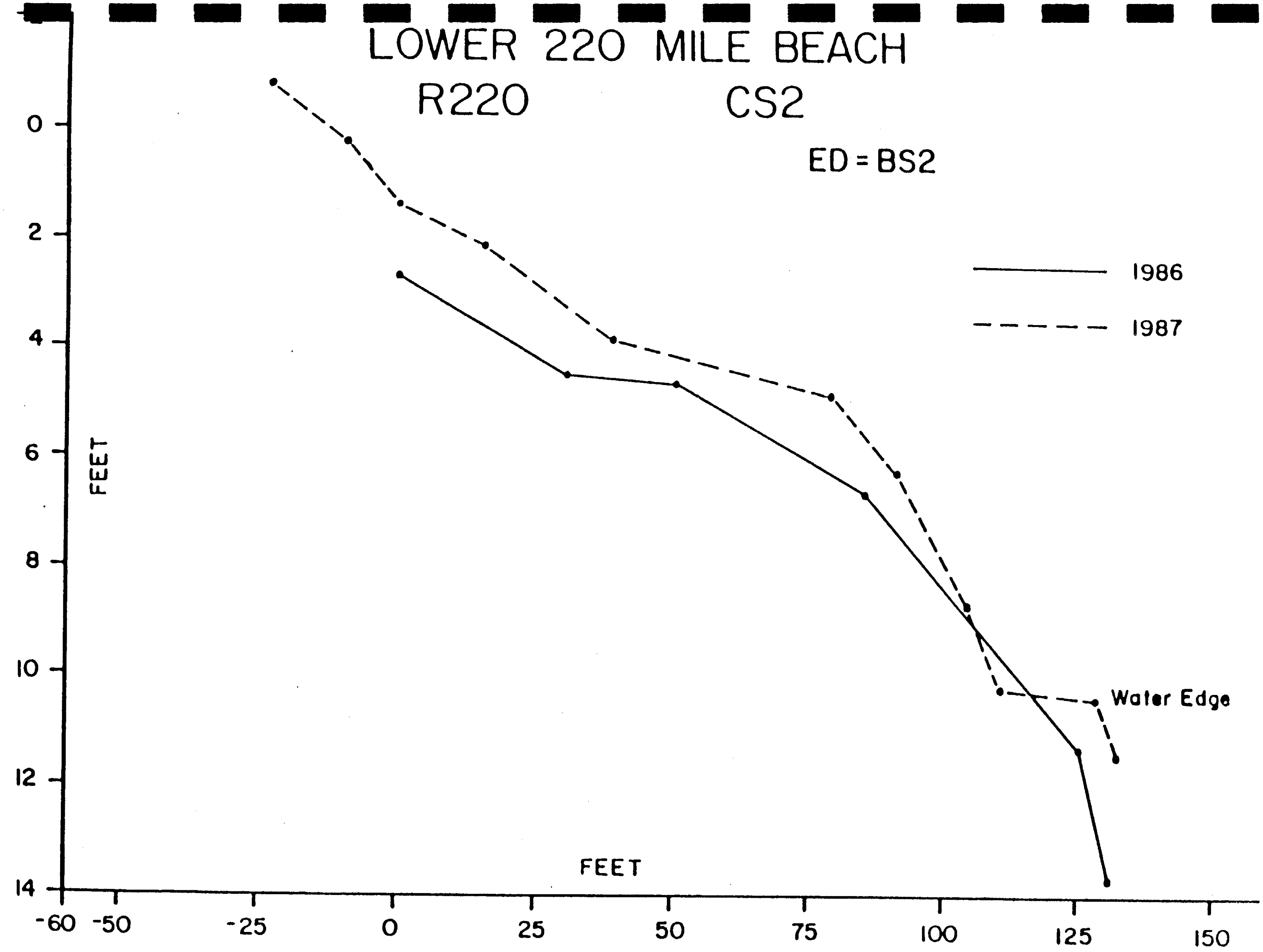


Figure 22. Cross-section 2 at 220-mile beach

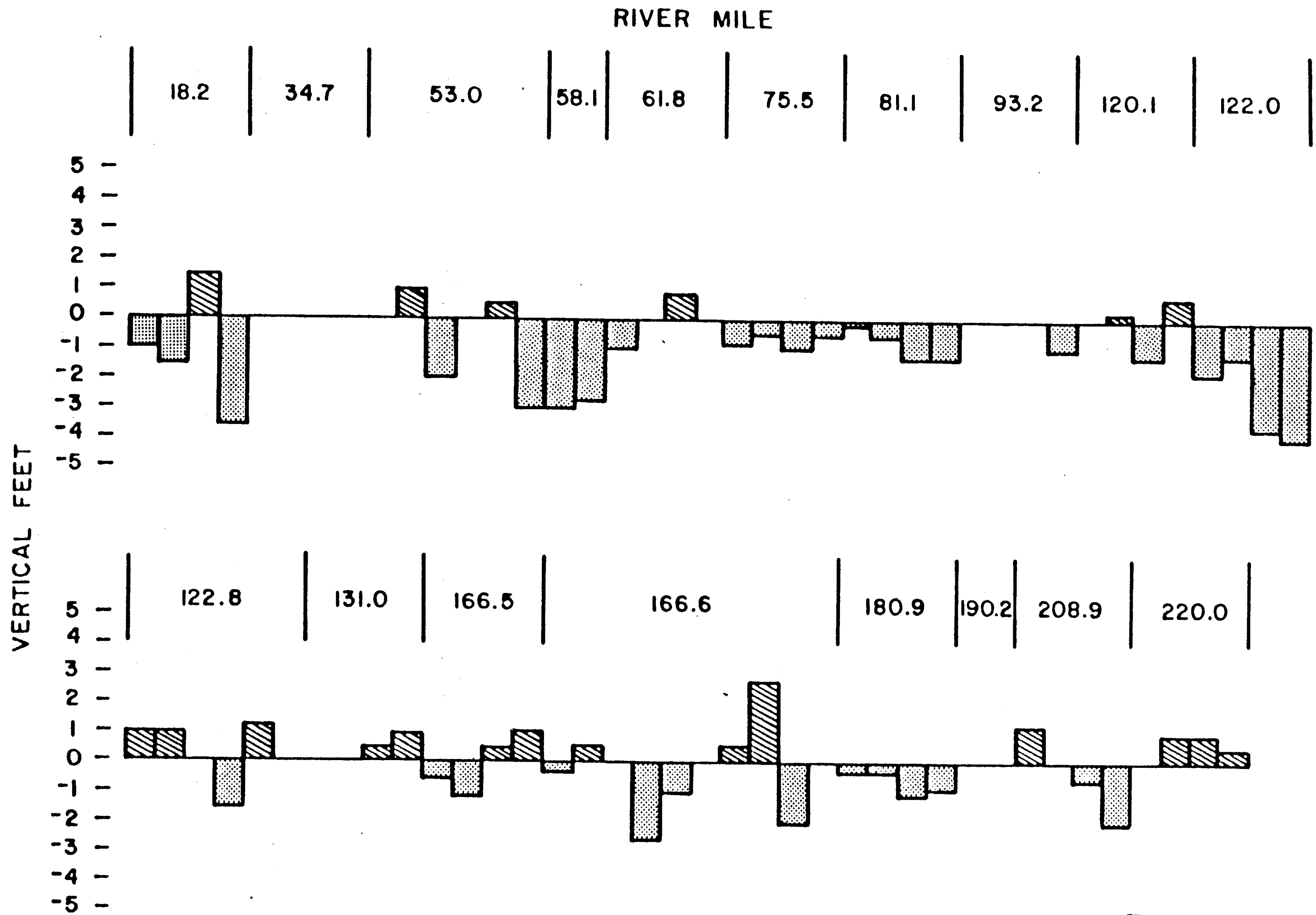


Figure 23. Graph showing vertical gain or loss of sand between 1986 and 1987 on selected beaches. Two bars for each beach indicate values for both inner (shoreward) and outer (riverward) parts of each beach.

the water. However, sixteen profiles on ten beaches showed a net loss of 0.1 to 3 feet on the inner beach and eighteen profiles on twelve beaches showed a net loss of 0.5 to 4.0 feet on the outer beach area. Twelve profiles on nine beaches showed little or no change from 1986 on the inner beaches and six profiles on four beaches showed little or no change on the outer beaches. The gain of sand on the upper beaches may have been due to redistribution of sand on the beaches. The loss of sand on the outer beaches is most likely due to erosion by the forces of the river.

The two beaches showing the most substantial changes are R58.1 and R122, losing sand on both the inner and outer beaches. R58.1 has lost 4.25 feet on the inner beach and 4.5 feet on the outer beach since 1985. R122 showed a 9.75 foot gain of sand on the outer beach in the 1986 survey but showed a loss in the 1987 survey of 1.75 feet on the inner beach and four feet on the outer beach.

CONCLUSION

Glen Canyon Dam closed in 1964 and sediment, originally deposited during annual floods on Grand Canyon beaches, was trapped behind the dam. Since that time the beach sands have shown loss due to erosion.

Most of the over 200 beaches in the Grand Canyon gained sand in 1983 after an unexpected high-water spill. Since 1983 these same beaches are again gradually eroding.

Although some of the beaches show little change, or a slight increase in sediment deposition, the 1987 findings clearly indicate the majority of the beaches surveyed are experiencing a net loss in sediment. Consideration must be given to the future of the beaches, as they have an important function in the recreational value of the canyon.

CHAPTER V

SECCHI DISC READING OF THE COLORADO RIVER IN THE GRAND CANYON

Beverly Posson

INTRODUCTION

Much of the area of the four states that drain into the Colorado River is arid land with little vegetation cover to hold back sediment. With heavy rains this suspended sediment in pre-Glen Canyon days caused the river to appear red in color. The sediment average was 140 million tons per year. Since the building of Glen Canyon Dam upstream, sediment has been trapped in Lake Powell. Therefore, the water entering the Grand Canyon is clear with little turbidity. Now any resulting sediment must be added from tributaries and side canyons below the dam, generally from melting snow or heavy summer rains.

The turbidity of the Colorado River along its course through the national park is important to know for an understanding of the resulting biological community. If the water is clear, a resulting euphotic zone is present where light can penetrate and plants such as <u>Cladophera</u> can photosynthesize. The algae in turn provide food for amphipods and ciatoms, which then are eaten by trout. The clarity of the water is necessary for the growth, reproduction and survival of these and other aquatic species of plants and animals.

OBJECTIVES

With the use of Secchi Disc readings, the turbidity of the Colorado River can be determined at various locations between Lees Ferry and Diamond Creek. These data will record any changes in turbidity resulting from tributaries and side canyons within the National Park.

METHODS

A round, 8' diameter, black and white disc was lowered into the river at designated locations, which generally bracketed major tributaries and side canyons. The disc was lowered into the water until it disappeared from sight while observing above the water at one meter. The depth of the descent was measured by the rope marked in decimeters.

RESULTS

The greatest clarity occurred at the beginning of the trip at Lees Ferry with a reading of 3.7 meters. The readings for the next 50 miles were about half that number (1.5 meters). At the 61 mile point (Little Colorado) the numbers dropped to .3 meters. At the time of our visit, the Little Colorado River was imputing muddy water into the mainstream river. Little improvement (.5 meters) was noted at Lava Canyon (RM 65.5) the next day. During the next night at Cremation Beach (RM 85.5) the turbidity reached its highest and remained there through the rest of the trip reading at .05 meters.

CONCLUSION

The readings show a marked decrease of clarity below the Little Colorado River. The next sharp drop was at Cremation Beach. This is believed to still have been the influence of the Little Colorado River which flows heavy at times from the summer storms on the White Mountains. Tapeats, Deer and Havasu Creek's discharge was clear but minimal so no net effect was recorded on the Colorado River.

DATA

Reading Site	Miles	Depth Reading Meters
Lees Ferry	0.0	3.70
	18.2	1.60
	19.3	1.65
	20.0	1.50
Nautiloid	34.7	1.20
Nankoweap	53.0	1.40
Little Colorado	61.0	.30
Lava Canyon	65.0	.50
Grapevine	81.1	.05
Bedrock	131.0	.05
Dubendorff	132.0	.05
Tapeats Creek	133.0	.05
Deer Creek Falls	136.0	.05
Matkatambia	146.0	.05
Havasu Creek Falls	156.9	.05
Upper National	166.5	.05
	190.2	.05
	220.0	.05
Diamond Creek	225.0	.05

CHAPTER VI

CONTINUED STUDIES ON THE RED HARVESTER ANT DENSITY AND FORAGING ACTIVITIES ON HUMAN IMPACTED, COLORADO RIVER BEACHES IN GRAND CANYON NATIONAL PARK, 1987

Stephen L. Ward
and
Robert Lachat

INTRODUCTION

Red harvester ants can be found on every beach along the Colorado River between Lees Ferry and Diamond Creek (RM 225). This medium large, concolorous, light ferrugineous red ant, averaging 7 mm in length, is a health/safety concern to the National Park Service since fifteen thousand river rafters, plus a greater number of hikers, frequent many of the Colorado River Beaches annually.

"The sting of these ants is remarkably severe, and the fiery numbing pain may last for hours. I grew faint and almost unable to stand. The pain appears to extend along the limbs for some distance and to settle in the lymphatics of the groin and axillae. It is commonly supposed that the poison responsible for the pain inflicted by these and other ants is a formic acid, but chemical analysis failed to reveal any traces of this substance (W. M. Wheeler, 1910 1st ed; 1960 3rd ed; p. 292)."

OBJECTIVE

This current study was designed to continue an examination of the long term distribution and density patterns of the red harvester ants (*Pogonomyrmex californicus*) within four vegetation zones on selected beaches (low to high human use) along the Colorado River in Grand Canyon National Park.

The hypothesis tested during this investigation is that ant population densities have been increasing, since the 1983 flood, as a function of human impact on the Colorado River beaches.

Three control beaches were selected for comparison based on their low occupancy by the river rafting companies, private raft groups, and backpackers. It must be noted that, "there is probably no campsite in which the impact of man is zero. In effect there is no control campsite where visitation is not permitted (Hayden, Dolan, Carothers, 1977)." We decided to use the following beaches for our 1987 control sites based on the objective and subjective professional inferences of Dr. Steven W. Carothers and Frank B. Lojko: Buck Farm (RM 40.5), Lower Little Colorado River (L61.8), and 124 mile beach (L124.4).

The study was also designed to continue establishing trends in ant densities that could, over time, return to the exceptionally high density levels of 2.40 ant hives per 100m on some of the beaches studied by Hayden, Dolan, Carothers, (1977).

The over-all canyon density average for the 1982 study was .72 $H/100^2 m$, as compared to the 1987 figure of .34 $H/100^2 m$ (Figure VI-1).

METHOD

It is important that future ant studies maintain a basic consistency in the collection of data. These methods have evolved over several year's of study and have been extensively revised over the past two years. Next year's 1988 report should have only minor revisions to the data collecting procedures. Some beaches were deleted from this year's study and some beaches were added, based on physical changes of beaches which either make them more or less desirable for human usage. There were 30 study beaches for the 1987 ant study (see Table VI-1).

It requires at least two diligent people to work on this research team; three people would be an ideal number. The team members must be willing and physically fit enough to hike in the torrid desert vegetation zone which is often not a pleasurable experience. The sun can be physically draining when ambient temperatures exceed 100°F and soil surface temperatures approach 120°F.

During the foraging surveys one of the research observers must have very good near vision in order to quickly discern what the ants are carrying in their mandibles. One of the researchers must observe and vocalize what the ants are carrying while the other records the information on a data sheet (see example Data Sheet VI-1). Researchers must be very respectful of the ants being observed. One must always be aware of the ants main forage routes, and the stray soldiers, and periodically check where feet are positioned. These ants will usually not bite or sting unless they are put into a defensive position by either stepping on them, causing excessive ground vibrations, blocking forage routes, or getting in a position "50 cm or closer to the hive" (Hayden, Dolan, Carothers, 1977).

A typical post-dam beach will generally have four, more or less, distinct vegetation zones with indicator plant species (Carothers, 1976, see Figure VI-1). These zones are not always ideal because of varying physical factors like rock outcrops; sun exposures, beach slopes and dry wash locations. Actual zone boundaries and dimensions are somewhat subjective measures by the observers.

Hive counts per each zone are done first by the observer walking in a zig-zag pattern through the zone. An estimate of the area of the zone in multiples of 10 meters is also recorded on the data sheet for the beach, along with field notes and other relevant data (see example Data Sheet VI-1). Sweeping through the zones with two observers dividing up the work will usually require 20 minutes after experience is gained. Often, zone 1 will extend a greater distance that can be paced, realistically. A sample dimension width of 10 to 20 meters and the length of the beach area will provide reliable data. The other zones must be surveyed in their entirety whenever possible. During the hive count in the zones it is smart practice to look for active hives in zones 1-2 and zones 3-4 in order to do foraging counts. Each count will require 10 minutes. At the forage study hives it is good practice to record surface and 6" soil temperatures,

Figure VI-1.

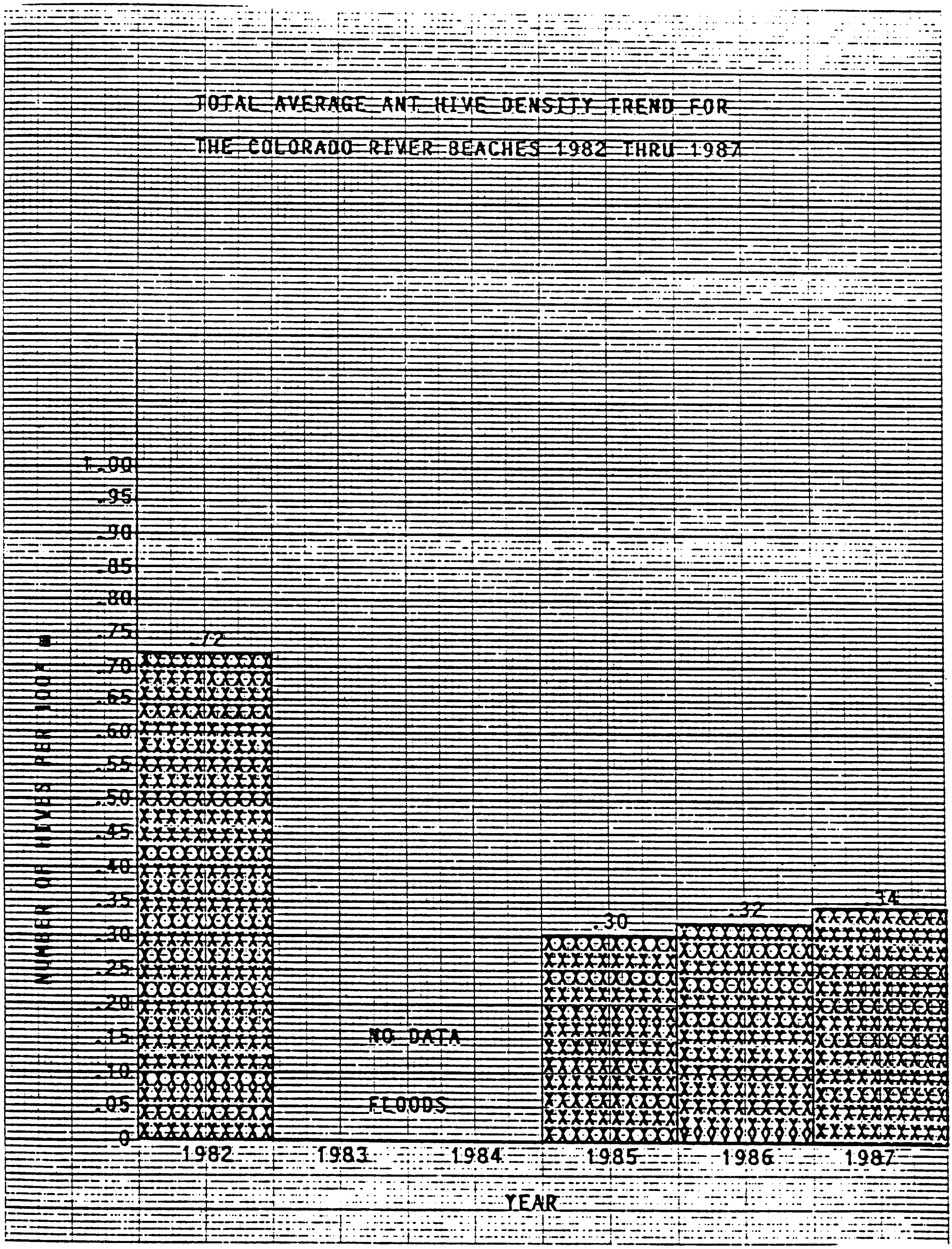

TOTAL AVERAGE ANT HIVE DENSITY TREND FOR
THE COLORADO RIVER BEACHES 1982 THRU 1987
NUMBER OF HIVES PER 100 m²
1.00
.95
.90
.85
.80
.75
.70
.65
.60
.55
.50
.45
.40
.35
.30
.25
.20
.15
.10
.05
0
.72
.30
.32
.34
NO DATA
FLOODS
1982
1983
1984
1985
1986
1987
YEAR

Table VI-1. Sample beaches July-August 1987.

Beach Name	Mile	Date	Time	Air Temp.	For. Act.	Sand Temp.	6' Soil Temp.	% Rel. Humid.
Badger	7.8	7/29	3:00 PM	95°	Yes	100	78	36
19.3 mile beach	19.3	7/29	6:60 PM	---	No	---	--	--
20 mile beach	20.0	7/30	7:40 AM	76°	No	---	--	--
Shinumo Wash	29.0	7/30	10:20 AM	82°	Yes	86	76	68
Nautiloid Canyon	34.7	7/30	2:20 PM	80°	Yes	80/82	77/72	56
Buck Farm (control)	40.5	7/30	4:50 PM	80°	Yes	80	79	53
Lower Nankoweap	53.0	7/31	11:00 AM	86°	Yes	110	78	53
Lower LCR (control)	61.8	7/31	4:25 PM	93°	Yes	102/102	100/97	27
Carbon Creek	63.5	8/01	10:45 AM	100°	Yes	105	80	20
Nevills Rapid	75.5	8/01	1:40 PM	102°	No	116	--	--
Hance Rapid	76.5	8/01	2:28 PM	105°	No	120+	--	--
Grapevine	81.1	8/01	3:53 PM	95°	No	---	--	--
Granite Rapids	93.2	8/02	10:31 AM	87°	Yes	96	79	42
Lower Bass	108.5	8/02	11:20 AM	98°	Yes	98	89	23
Blacktail	120.1	8/03	11:20 AM	94°	Yes	90/90	84/81	46
122 Mile Creek	122.0	8/03	11:10 AM	104°	No	---	--	--
Forster	122.8	8/03	11:50 AM	96°	Yes	110	84	33
124 Mile Beach (control)	124.0	8/03	1:20 PM	105°	No	120	--	--
Bedrock	131.0	8/03	3:10 PM	98°	No	---	--	--
Deer Creek Falls (left)	136.0	8/03	4:00 PM	102°	No	---	--	--
Poncho's Kitchen	137.0	8/04	8:40 AM	82°	Yes	80	74	45
Lower National	166.6	8/05	9:10 AM	86°	Yes	93	83	36
Fern Glen	168.0	8/06	10:35 AM	85°	Yes	110/102	90/85	41
Lower Lava	180.9	8/06	1:15 PM	92°	No	---	--	--
186 Mile Beach	186.0	8/06	3:40 PM	100°	No	---	--	--
190 Mile Beach	190.2	8/06	5:11 PM	98°	No	---	--	--
194 Mile Beach	194.0	8/07	8:30 AM	92°	No	---	--	--
Parashont	198.5	8/07	9:50 AM	98°	Yes	120+	86	34
Granite Park	208.8	8/07	1:15 AM	104°	No	---	--	--
Lower 200 Mile Beach	200.0	8/07	5:15 PM	94°	Yes	98	98	21

Note: Temperatures are in degrees Fahrenheit.

1987 RED HARVESTER ANT DENSITY AND FORAGING DATA

Project Leader: Stephen L. Ward
Assistant: Robert La Chat
Assistant:____________________

Beach & L/R r.m.____________________________
Date:__________Time begin________end_________
Human usage (ask boatmen): N L M H

Ambient Temp:________ % Rel Humidity________wet bulb________dry bulb___________
Barometric pressure_____________ Elevation ___________________________________

I. RIPARIAN ZONES DENSITY (tick mark count)	# of hives	Area Size L X W = M^2	Density/100 m^2
1-________________________	____________	____________	______________________
2-________________________	____________	____________	______________________
3-________________________	____________	____________	______________________
4-________________________	____________	____________	______________________
TOTALS.	____________	____________	______________________

Zone Key: 1 - desert; 2 - OHWL; 3 - camp; 4 - HHWL

II. FORAGED ITEMS DELIVERED TO HIVE

Zone: 3-4 observation (mark on map)
Sand surface temp. in sun ___________
6" soil temp. at hive ______________
Distance to common kitchen __________
T1 ______ T2 ______ Time ____________
(+/- 10 min.)

	% TOTALS
Plant parts _______________	
______________________________	________
Seeds ______________________	
______________________________	________
Black flies ________________	
______________________________	________
Insects (other) ____________	
______________________________	________
Food scraps ________________	
______________________________	________
Grease sand ________________	
______________________________	________
Wet sand ___________________	
______________________________	________
Total Items_________________	

Zone: 1-2 observation (mark on map)
Sand surface temp. in sun ______________
6" soil temp. at hive _________________
Distance to common kitchen _____________
T1 ______ T2 ______ Time ______________
(+/- 10 min.)

	% TOTALS
Plant parts_________________	
______________________________	________
Seeds ______________________	
______________________________	________
Black flies ________________	
______________________________	________
Insects (other) ____________	
______________________________	________
Food scraps ________________	
______________________________	________
Grease sand ________________	
______________________________	________
Wet sand ___________________	
______________________________	________
Total Items_________________	

Comments:

relative humidity and time of day. Taylor brand lab thermometers and a Taylor sling psychrometer were used for measurements. It is very important to always use distilled water with the psychrometer because river water sediment will distort the readings and ruin the the wet bulb thermometer wick. Relative humidity tables can be used, however we found it very helpful to use a Weksler psychometric slide rule. Sand surface temperatures must be taken where the sun has been directly hitting the sand, during this measurement, however, the thermometer needs to be shaded by a clip board or the observers body to avoid damage to the thermometer.

RESULTS AND DISCUSSION

It appears that all the beaches between Lees Ferry (River Mile 0) and Diamond Creek (RM 225) are sustaining healthy populations of *Pogonomyrmex californicus*, (Table VI-2). The table shows a crash in ant population to near 0.00 hives/100^2m for 1983-84 because of the exceptionally high water releases from Glen Canyon Dam. Flows during June of 1983 reached nearly 100,000 cubic feet per second (cfs). Inundation of vegetation in zones 2, 3, and 4 (Figure VI-1) was responsible for scouring zones 3 and 4 clean throughout the Grand Canyon and giving zone 2,the old high water line (OHWL), a long awaited drink after 20 years of controlled flows. The ants were apparently eliminated in zones 3 and 4 and drastically reduced in zone 2. The typical desert vegetation (zone 1) would have been basically uninfluenced by these high waters. As expected, the ant density in zones 1 and 2 increased because of high flow rates in the river. Zones 1 and 2 were the areas from which reproductive migrations back into the beach riparian habitat probably occurred. The extent of re-populating these areas and expected normal densities is a question that is difficult to ascertain because there is no pre-dam reference data available.

Buck Farm, LCR, and 124 mile beach currently have a low amount of human usage (Table VI-1). These were the control sites for both density and forage data gathered. The average ant density for these control sites is .12 H/100^2m. The food forages by the ants on these control sites is 39.6% blackflies, 37.8% plant parts and seeds, 9.0% other insects, 0% human impacted items (Figure VI-2).

With the influence of the river and human impact removed, harvester ants feed primarily on plant parts, seeds, and to a lesser extent, on insects. This fact can be demonstrated graphically with the 1987 data (Figure VI-3). This figure shows that the farther a hive is from the common kitchen location on a beach, the more natural food selection by the ants increases, while amounts of food scraps and grease decrease by a similar proportion. The optimum distance for the ants to forage on human impacted food is less than 35m as demonstrated in Figure VI-3. It should be noted that forage routes to a common kitchen were traced to a distance of 100^2m; however, this was only on one isolated beach (Ward and Pike 1986). Figure VI-3 has had the blackfly forage removed for a separate discussion.

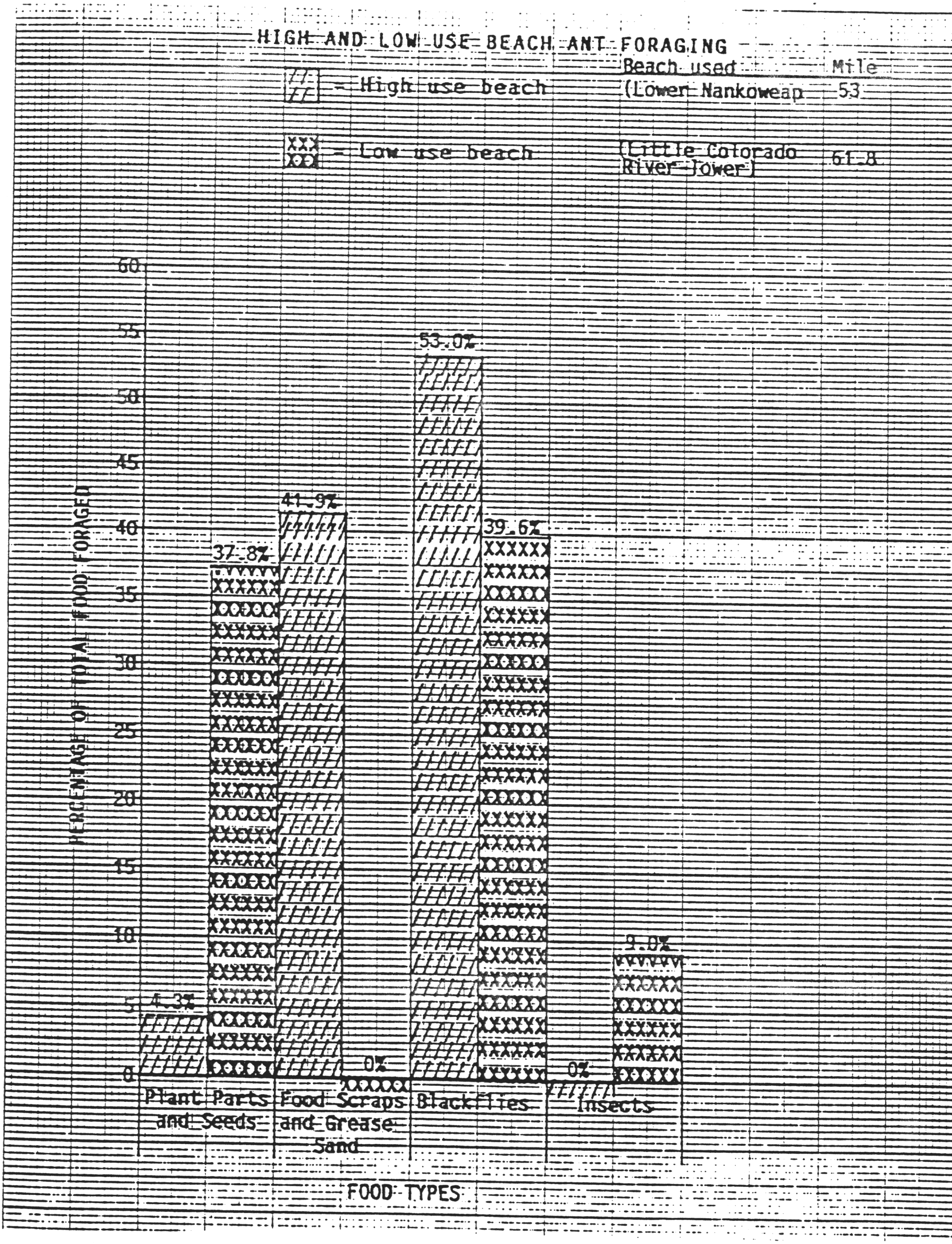
The blackflies (*Simulium* sp.) probably did not exist in the main river in any great numbers prior to the dam closure in 1963 because of their life cycle requirements for clear water (Laird

Table VI-2. List of sample site beaches showing observed Harvester Ant densities and the relative frequency of human recreational usage from 1982 thru 1987. * Used for statistical analysis.

RIVER MILE	BEACH NAME	1982	FLOOD 1983	1984	1985	1986	1987	USAGE (HIGH/LOW)
* 7.8	Jackass	-	0.00	0.00	-	.09	.27	H
* 19.3	-	-	0.00	-	-	-	.19	L
* 20.0	-	-	0.00	-	.07	.37	.19	H
23.3	-	-	0.00	-	-	.73	-	L
* 29.0	Shinumo Wash	-	0.00	-	-	.06	.13	L
* 34.7	Nautiloid	-	0.00	0.00	.13	-	.30	H
36.0	Tatahatso	-	0.00	-	-	.86	-	L
* 40.5	Buck Farn	-	0.00	-	-	-	.06	L (c)
43.5	Anasazi Bridge	0.00	0.00	0.00	.23	-	-	L
47.0	-	1.40	0.00	-	-	-	-	H
* 53.0	Lower Nankoweep	1.10	0.00	0.00	-	.09	.64	H
58.1	Awatubi	-	0.00	0.00	.26	.12	-	H
* 61.8	Lower L.C.R.	-	0.00	-	-	.04	.21	L (c)
* 63.5	Carbon Creek	-	0.00	-	-	.92	.68	H
65.5	Chuar Canyon	-	0.00	0.00	.67	-	-	H
75.5	Nevills Rapid	.56	0.00	0.00	.09	.14	-	L
* 76.5	Hance	-	0.00	-	.32	.17	.31	H
* 81.1	Grapevine	-	0.00	0.00	.29	.20	.38	H
87.0	Cremation	-	0.00	0.00	.51	-	-	H
* 93.2	Granite Rapids	.56	0.00	-	-	.29	.97	H
*108.5	Lower Bass	0.00	0.00	0.00	.55	.81	.51	H
*120.1	Blacktail	.49	0.00	0.00	.31	.21	.19	L
*122.0	122 Mile Creek	-	0.00	-	.41	.33	.29	L
*122.8	Forster	-	0.00	0.00	-	.30	.28	L
*124.0	-	-	0.00	-	-	-	.10	L (c)
*131.0	Bedrock	-	0.00	0.00	-	-	.40	L
132.0	Dubendorff	0.00	0.00	-	-	.27	-	L
*136.0	Deer Creek Fall (L)	2.50	0.00	-	-	-	.43	L
*137.0	Pancho's Kitchen	-	0.00	-	-	-	.25	H
138.5	-	-	0.00	-	-	.51	-	L
166.6	Lower National	.77	0.00	-	.04	.06	.38	H
168.0	Fern Glen	-	0.00	-	-	-	.52	H
179.0	Upper Lava	-	0.00	0.00	-	.57	-	H
*180.9	Lower Lava	-	0.00	0.00	.03	.05	.10	L
181.0	-	-	0.00	-	-	.09	-	L
*186.0	-	-	0.00	-	-	-	.25	L
*190.2	190 Mile Beach	-	0.00	-	.04	-	.33	L
192.0	-	-	0.00	-	-	.23	-	L
*194.0	194 Mile Beach	-	0.00	-	.15	-	.09	L
196.0	Creek	-	0.00	-	-	.73	-	L
198.6	Parashont	2.30	0.00	-	-	.13	.29	L
208.9	Granite Park	.67	0.00	0.00	.70	.50	.64	H
219.0	Trail Canyon	.50	0.00	.17	.18	-	-	L
220.0	Lower 200	-	0.00	0.00	.77	.51	.54	H

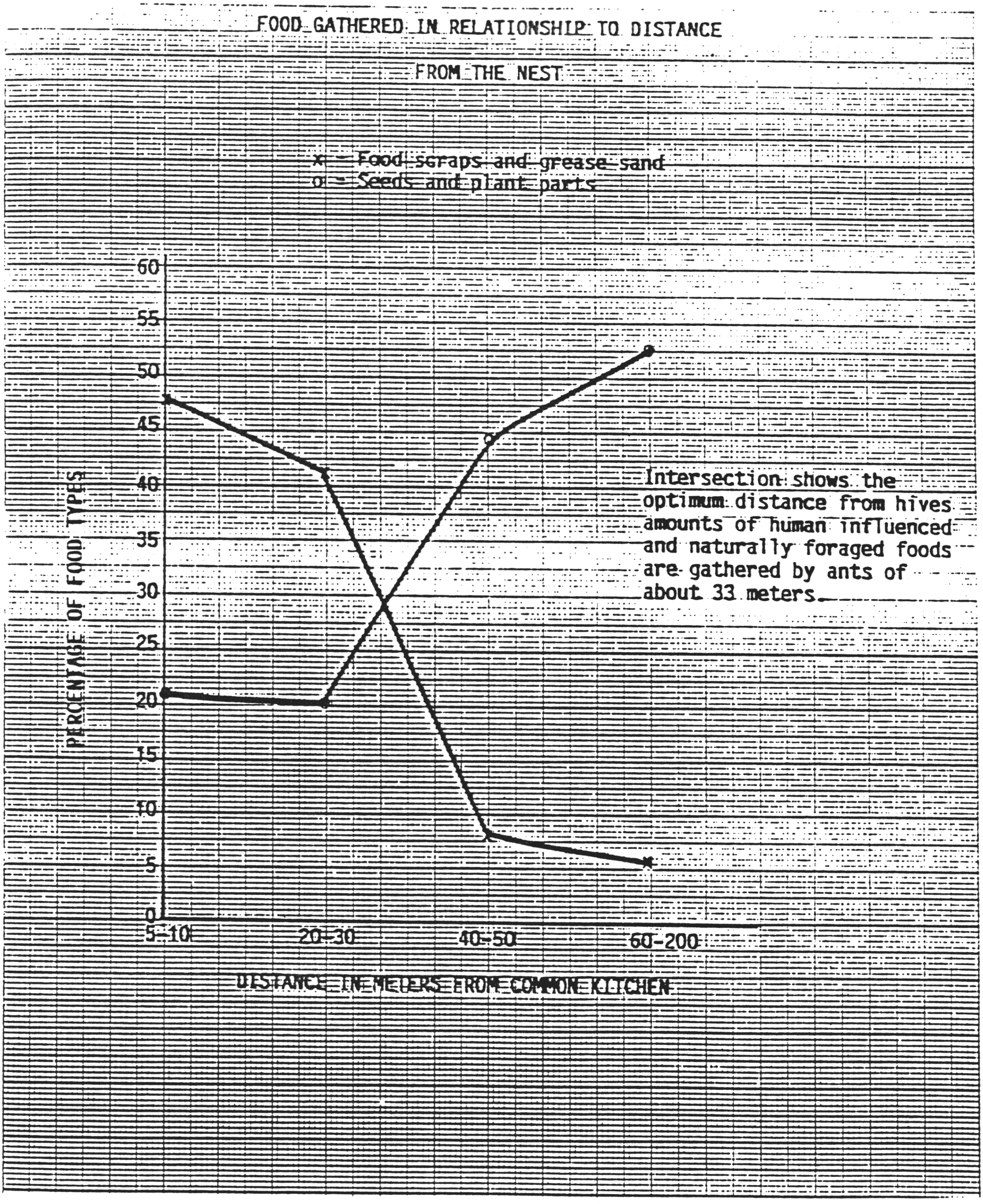
(c) - control

Figure VI-2.



HIGH AND LOW USE BEACH ANT FORAGING
Beach used
Mile
- High use beach
(Lower Nankoweap
53
- Low use beach
(Little Colorado River-lower)
61.8
PERCENTAGE OF TOTAL FOOD FORAGED
60
55
50
45
40
35
30
25
20
15
10
5
0
4.3%
37.8%
41.9%
0%
53.0%
39.6%
0%
9.0%
Plant Parts and Seeds
Food Scraps and Grease Sand
Blackflies
Insects
FOOD TYPES

Figure VI-3.


FOOD GATHERED IN RELATIONSHIP TO DISTANCE
FROM THE NEST
x = Food scraps and grease sand
o = Seeds and plant parts
PERCENTAGE OF FOOD TYPES
60
55
50
45
40
35
30
25
20
15
10
5
0
5-10
20-30
40-50
60-200
DISTANCE IN METERS FROM COMMON KITCHEN
Intersection shows the optimum distance from hives amounts of human influenced and naturally foraged foods are gathered by ants of about 33 meters.

1981). Most of the Diptera in the family Simuliidae are voracious blood feeders; however, the currently common simuliids propagating in the river are a non-biting species. These gnats are apparently prized ant forage though. Throughout the riparian environment an average of 49.5% of food items foraged on by the ants were simuliids. The flies are mainly foraged at the water's edge, but are also commonly found trapped in footprints or wind ripples in the sand (Ward and Pike 1986). There are two species of simuliids that were widely foraged by the ants on this 1987 study. They were morphologically dissimilar in the abdominal region. One has a bulbous abdominal region while the second species has a more elongated abdominal region which is more mosquito-like, or midge-like in appearance. This discovery is of significance because there were none of these second midge-like blackfly foraged by the ants in the 1986 study. Possibly the major population has a larval cycle greater than one year, and significant numbers of this species are only seen every two or three years. These two blackflies were equally foraged, where available in the 1987 study.

Since nearly half of the food foraged on by Pogonomyrmex californicus are blackflies they may be considered as separate food items in future studies.

Methods of data collection for the 1986-87 research were designed to allow for statistical analysis of the data to either refute or support the research's hypothesis: Harvester ant densities have been increasing as a function of human impact on the Colorado River beaches.

As long as the environment will support a population increase, it is a normal trend for biological organisms to increase population. The variables controlling normal population growth are food, water, shelter, physical area, predation, and disease. The variable of human impact tends to increase the food supplies available for the ants to forage. The beach areas are the most heavily impacted by people. Common kitchens are usually set up immediately above where recreational boats can find a good landing (zone 4). During meals people eat in a radius of 10-30 meters of the kitchen.

In addition to eating on the beach area it is also the area where people usually sleep. Even though most of the river recreationists and professional boat people have adapted clean kitchen techniques and eating practices there are still small crumbs and sweet liquid spills which go unnoticed on the beaches. These small food portions are highly selected by the ants because of their high caloric content per foraging energy expended. During one simple test a variety of food bits from the kitchen were placed 10 meters from active hives along with equal portions of natural ant forage. For the three trials at different hives the human food was always cleaned up first. If the ants did not utilize the bits of food dropped by people it would accumulate over time in the arid climate. Ants do help to keep the beach sands clean of this detritus.

Having an additional food source may directly increase the ants density. This is easily seen when low use beaches are compared to high use beaches (see Figures VI-4 thru 7). In 1986 there was 24% greater ant density on high use beaches as compared to low use beaches. This correlates positively to the 1987 data

Figure VI-4.

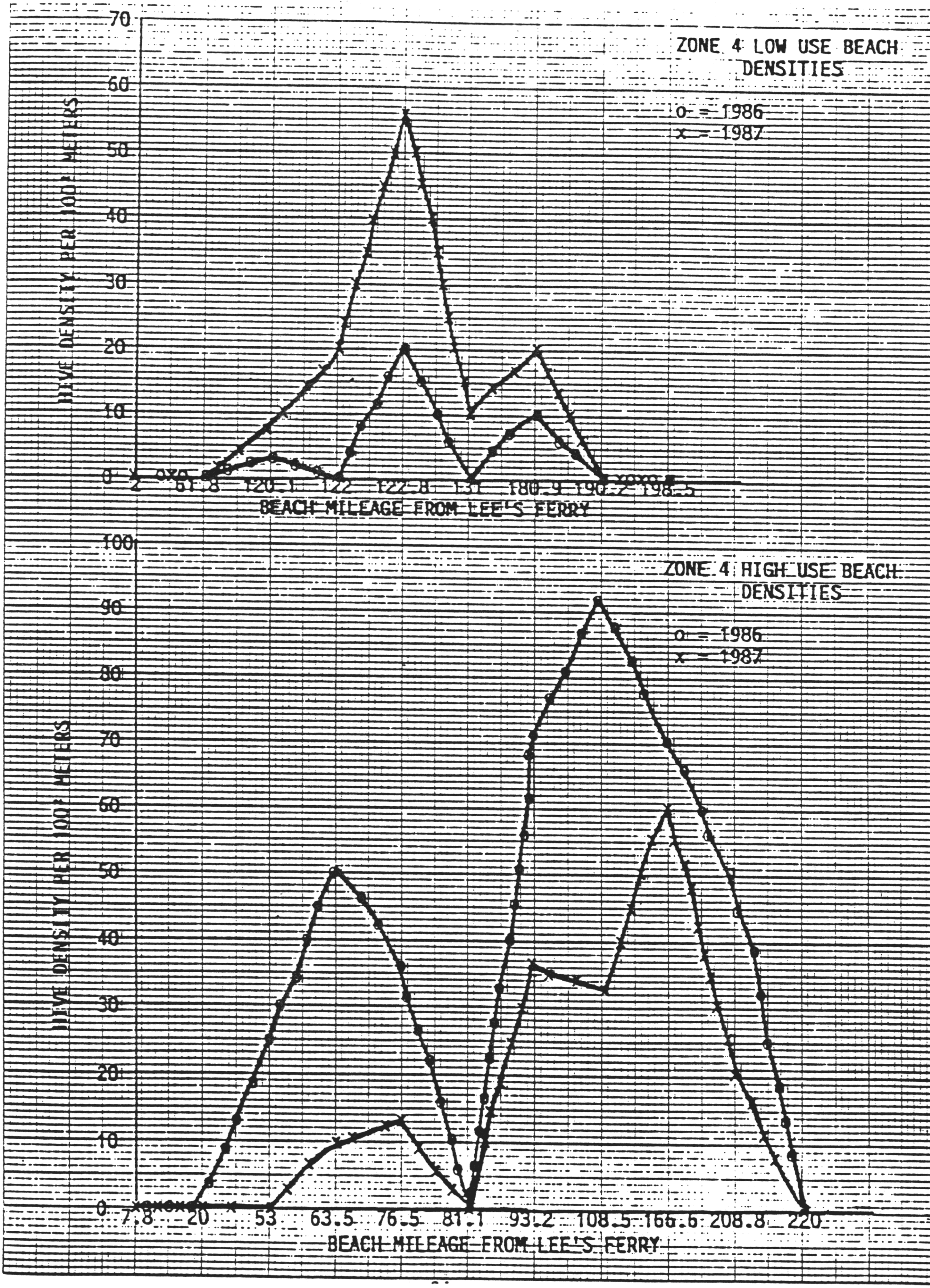
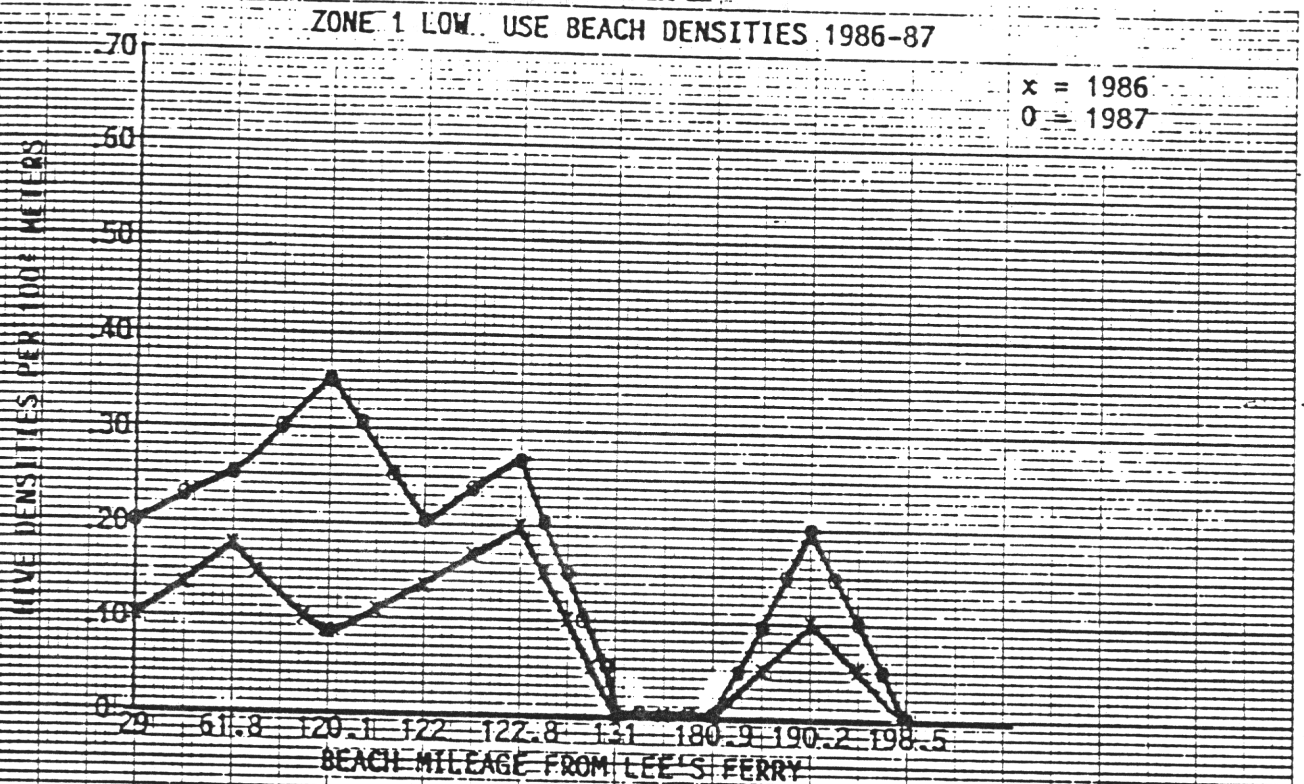

ZONE 4 LOW USE BEACH DENSITIES
o = 1986
x = 1987
HIVE DENSITY PER 100' METERS
0
10
20
30
40
50
60
70
2
61.8
120.1
122
122.8
131
180.9
190.2
198.5
BEACH MILEAGE FROM LEE'S FERRY
ZONE 4 HIGH USE BEACH DENSITIES
o = 1986
x = 1987
HIVE DENSITY PER 100' METERS
0
10
20
30
40
50
60
70
80
90
100
7.8
20
53
63.5
76.5
81.1
93.2
108.5
166.6
208.8
220
BEACH MILEAGE FROM LEE'S FERRY

Figure VI-5.



*Zero readings indicate no data collected because of inacessability or time constraints.

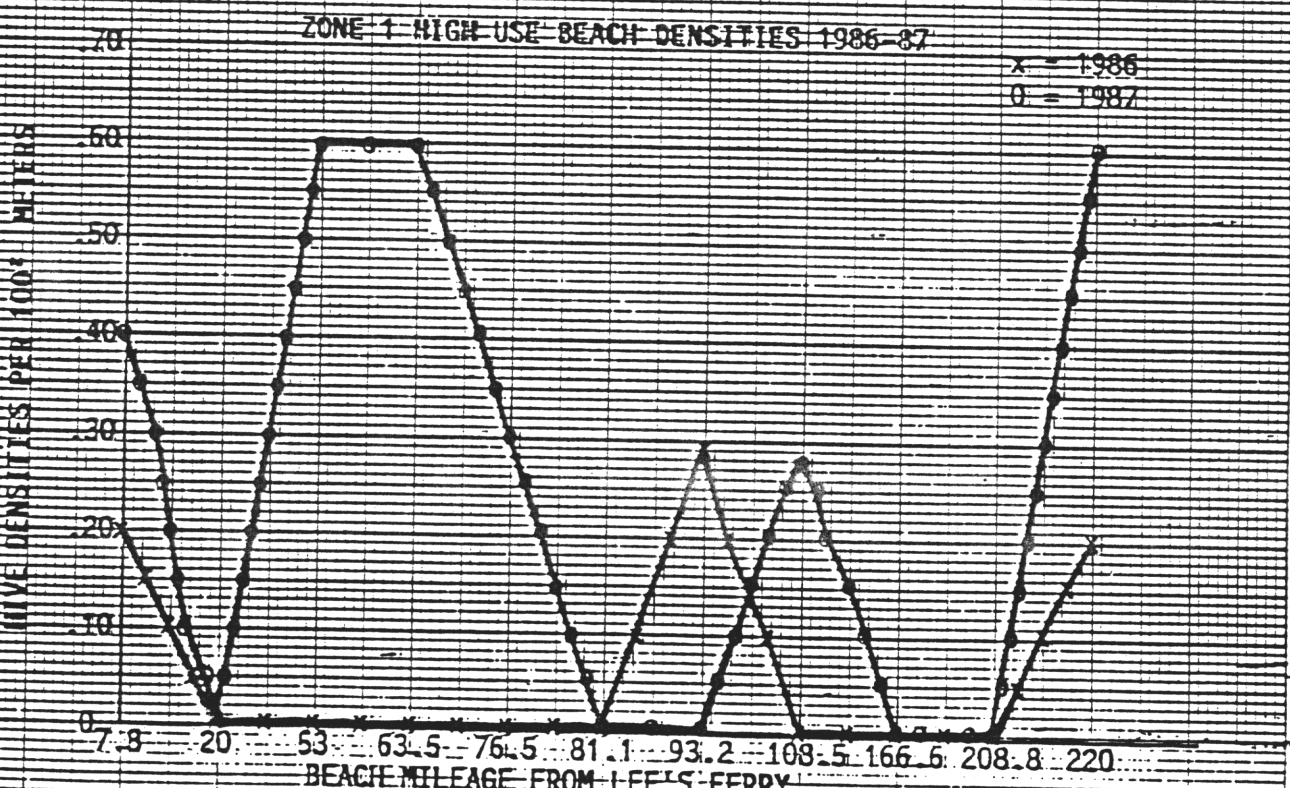
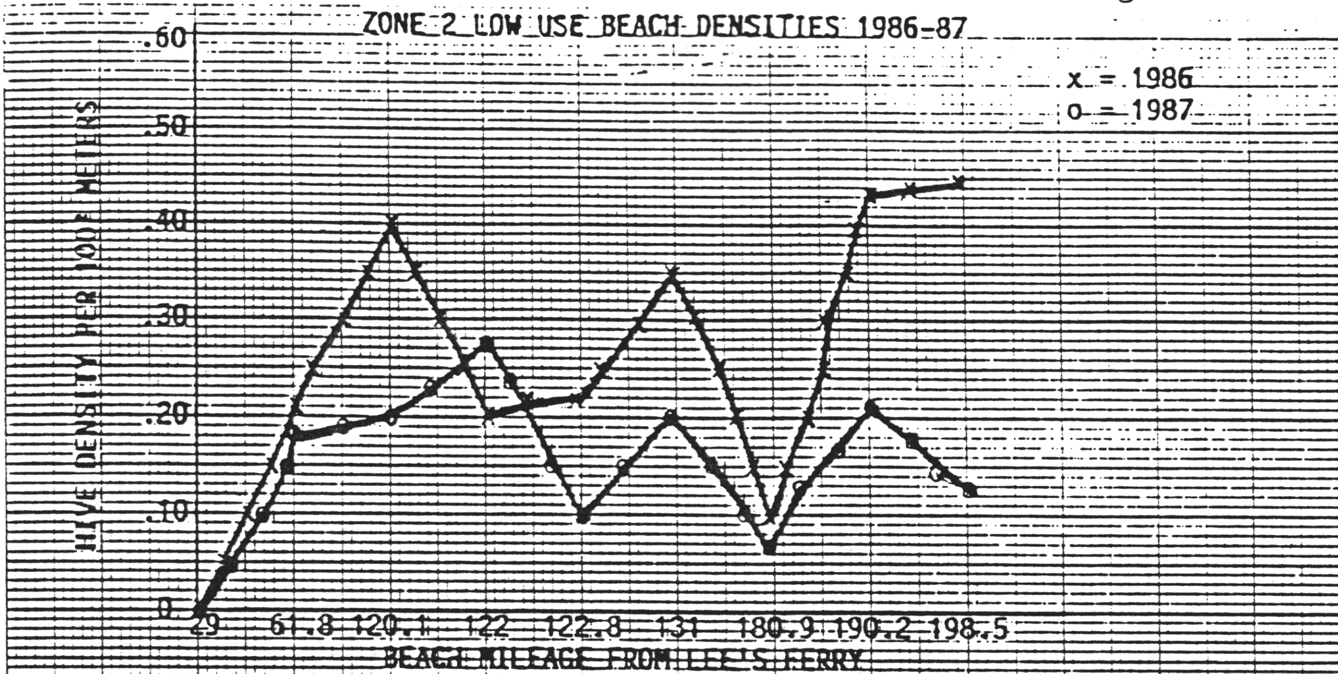


Figure VI-6.


ZONE 2 LOW USE BEACH DENSITIES 1986-87
x = 1986
o = 1987
HIVE DENSITY PER 100² METERS
.60
.50
.40
.30
.20
.10
0
29
61.8
120.1
122
122.8
131
180.9
190.2
198.5
BEACH MILEAGE FROM LEE'S FERRY

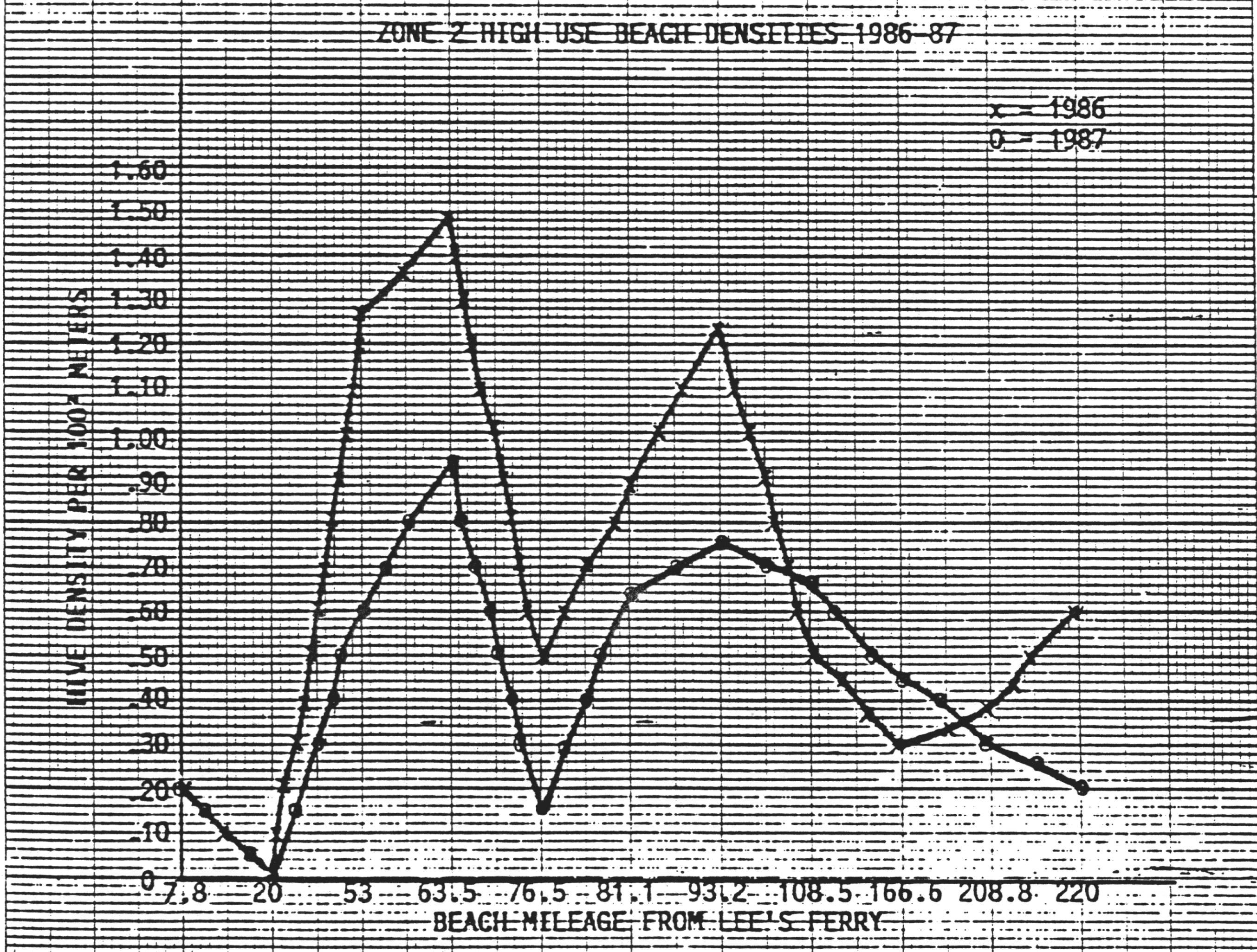
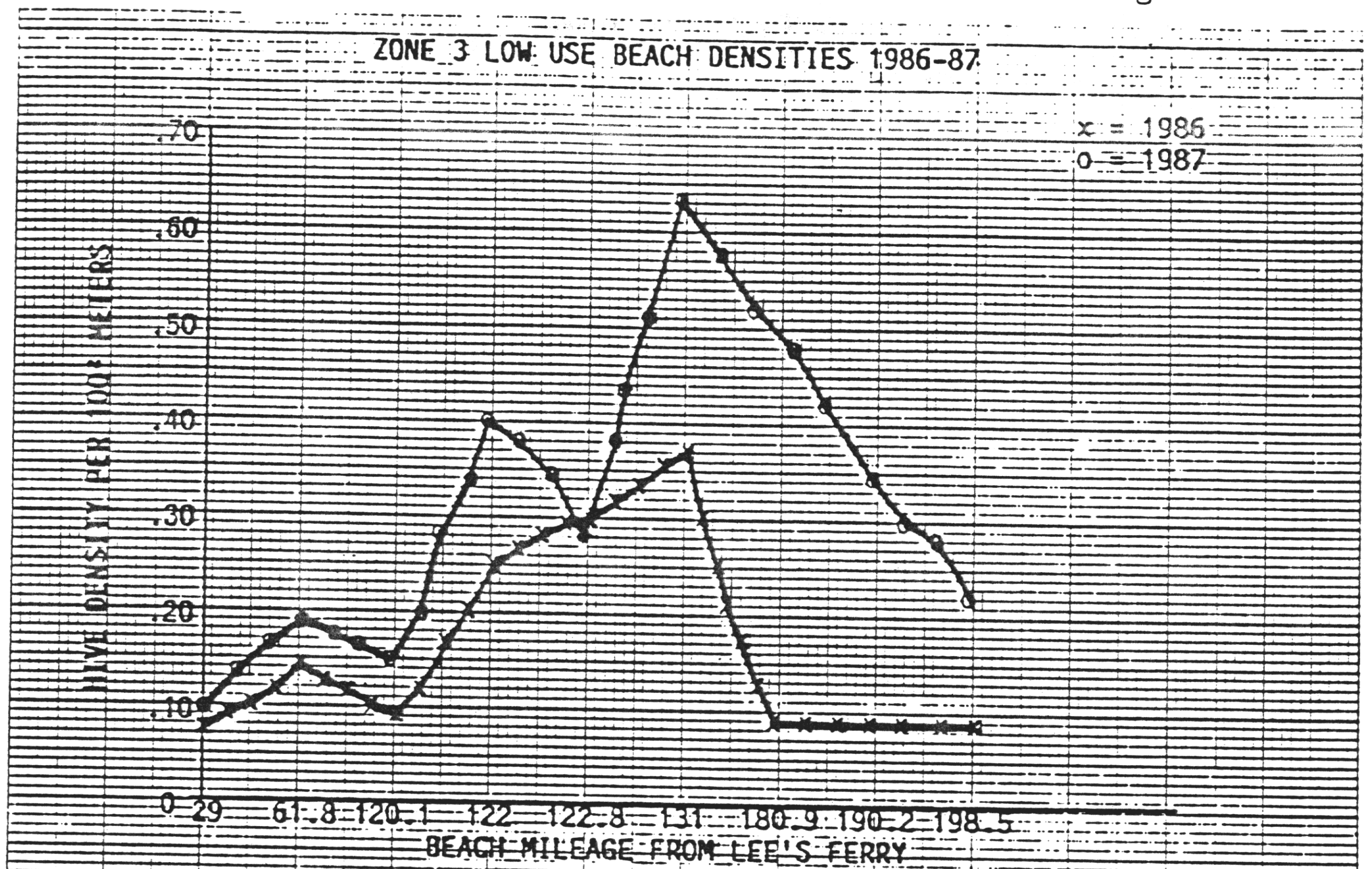
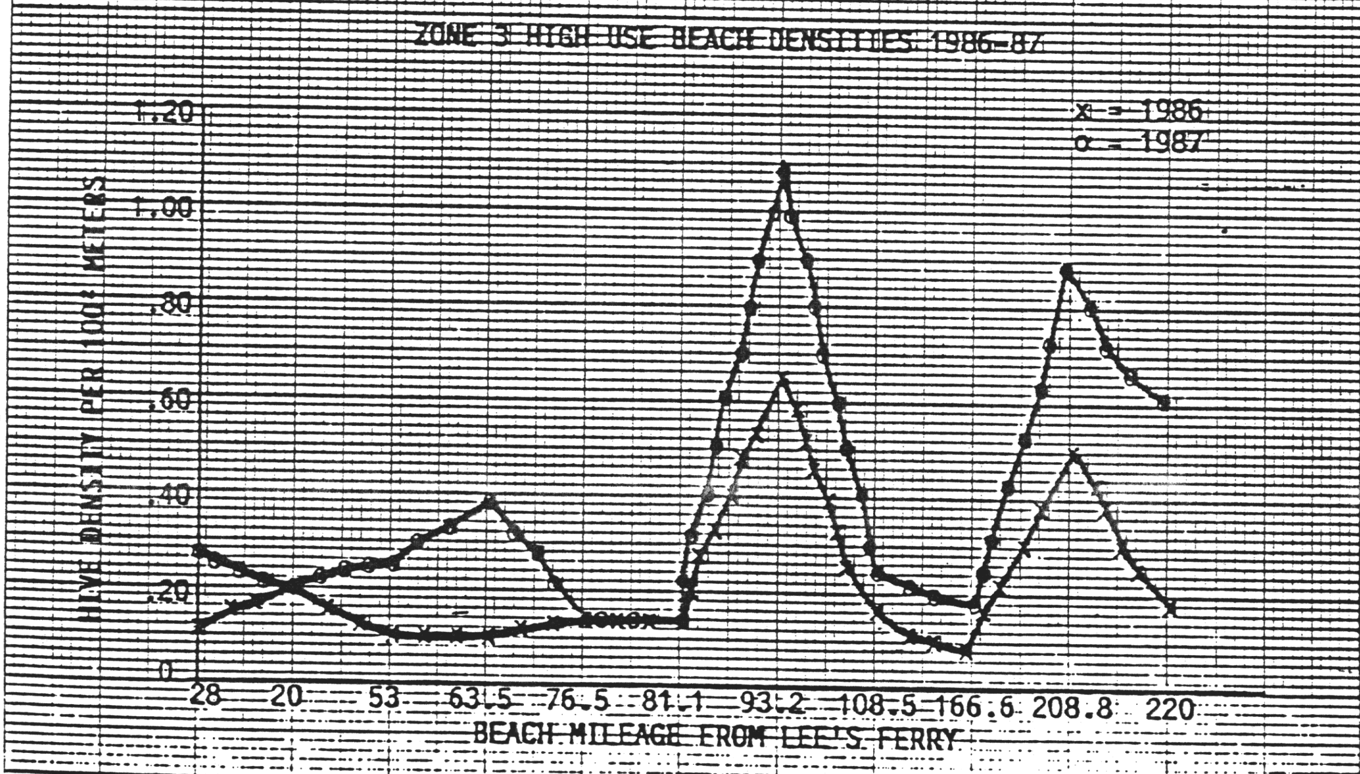

ZONE 2 HIGH USE BEACH DENSITIES 1986-87
x = 1986
0 = 1987
HIVE DENSITY PER 100² METERS
1.60
1.50
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
7.8
20
53
63.5
76.5
81.1
93.2
108.5
166.6
208.8
220
BEACH MILEAGE FROM LEE'S FERRY

Figure VI-7.


ZONE 3 LOW USE BEACH DENSITIES 1986-87
x = 1986
o = 1987
HIVE DENSITY PER 100: METERS
.70
.60
.50
.40
.30
.20
.10
0
29
61.8
120.1
122
122.8
131
180.9
190.2
198.5
BEACH MILEAGE FROM LEE'S FERRY


ZONE 3 HIGH USE BEACH DENSITIES 1986-87
x = 1986
o = 1987
HIVE DENSITY PER 100: METERS
1.20
1.00
.80
.60
.40
.20
0
28
20
53
63.5
76.5
81.1
93.2
108.5
166.6
208.8
220
BEACH MILEAGE FROM LEE'S FERRY

which show a 31% greater density of ants on high use compared to low use beaches for zone 3 (Table VI-4). The "t" test for non-independent samples was applied to the 1986-87 data. This statistic was used for each of the four vegetation zones. Ant densities for all four zones have significantly changed from 1986 to 1987. The results of the "t" test are as follows: formula t = zone 1 p = .05, df = 7, t = 3.783 is greater then the distribution of t value 2.365; zone 2 p = .05, df = 7, t = 3.630 > d.o.t. = 2.110; zone 3 p = .05, df = 19, t = 4.864 > d.o.t. = 2.093; zone 4 = .05, df = 19, t = 3.849 > d.o.t. = 2.093.

To further substantiate the difference between the heavily used beaches and lowest used beaches we applied the Pearson "r" as a descriptive statistic for my 1987 high/low use data. Formula r = the derived correlation coefficient of r = -.0932 is not greater than or equal to .5324 supports our hypothesis that there is a significant correlation between the extent of human impact and quantitative ant hive densities.

Table VI-4. A comparison of data on selected high and low used beach areas (within zone 3) to support the general pattern of denisty increase on all beaches.

River Mile	High Use Beaches 1986/1987	Versus	River Mile	Low Use Beaches 1986/1987
7.8	.11/.27		29.0	.07/.10
20.0	.19/.19		61.8	.13/.19
53.0	.09/.25		120.1	.08/.19
63.5	.10/.38		122.0	.25/.40
76.5	.13/.13		122.8	.30/.28
81.1	.13/.13		131.0	.35/.63
93.2	.67/1.06		180.9	.08/.11
108.5	.14/.25		190.2	.08/.33
166.6	.08/.18		198.5	.08/.22
208.8	.50/.88			
229,9	.17/.53			
Avg. .21/.39 = 46% increase from 1986 to 1987 for the high use beaches.			Avg. .16/.27 = 41% increase from 1986 to 1987 for the low use beaches.	

Comparing the high and low data for 1986 indicates 24% more ants on the beaches used most by people. The 1987 figures indicate an increase of 31% more ants on the more highly used beaches. The variable of human usage has increased the total number of ants by 7% in only one year!

CONCLUSION

Application of the "t" test for non-independent samples, inferential statistics was used to compare the 1986-87 ant hive densities in the four zones. It was found that this statistic supports the hypothesis that ant hive densities have been increasing since 1983 based on the last two years of data collection. It has also been statistically supported through use of a descriptive statistic, Pearson "r" correlation coefficient, that the more heavily used beaches support a significantly greater density of ants. Using these statistic for future studies will help to establish a reliable growth curve for hive densities within the vegetation zones. We can also establish comparison data for the high and low recreationist usage of the beaches.

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Ward, Stephen L. and Chris Pike. 1986. Further Investigations on Pogonomtyrex sp. Ants on Colorado River Beaches in Grand Canyon National Park. IN Colorado River Investigations V, edited by Gayle C. Weiss, SWCA, Inc., Environmental Consultants. Northern Arizona University Manuscript Report. Submitted to Richard W. Marks, Superintendent Grand Canyon National Park, pp. 138-174.

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CHAPTER VII

LIZARD DENSITY STUDIES ALONG THE COLORADO RIVER IN THE GRAND CANYON NATIONAL PARK

Larry G. Langstaff and Bernard Wides

INTRODUCTION

The data gathered in this project, attempt to quantify the preferred reptile habitat and density in the Colorado River's riparian zones. In the Grand Canyon, four distinct environmental zones may be observed (Figures VII-1a and 1b). Zone I is the environmental desert zone farthest from the river and essentially uninfluenced by it. Zone II marks the old high water flood line (OHWL). It is a stable community of woody vegetation such as acacia and mesquite. During the high water releases from Glen Cayon Dam into the Colorado River in 1983, the water level reached this OHWL. This was the first time the water had reached that high level since 1963, when the dam first started backing up water. Zone III, below Zone II, is an unstable vegetative zone due to human impact. This beach area is primarily used for camping. Zone IV, the new riparian zone, consists mainly of the exotic tamarisk (Tamarix chinensis), and the native plant species arrowweed (Tessaria sericea) and coyote willow (Salix exiqua). The proliferation of this type of vegetation is a direct result of controlled river flows from Glen Canyon Dam. It was thought that the tamarisk in the new high water line (NHWL) is of little or no value to most native wildlife. However, findings by students in this course in recent years, and in the study by Warren and Schwalbe in 1979 and 1983, indicate this NHWL zone to be not only richly inhabited by reptiles, but possibly the preferred habitat.

OBJECTIVES

The objectives of this project are as follows:

1. To compare the densities of reptiles in all four zones with particular emphasis between zone II, the OHWL zone, and zone IV, the NHWL zone.

2. To determine the types of vegetation most inhabited by reptiles, particularly in zone II and zone IV.

3. To determine a correlation between ambient temperature and density.

The initial hypothesis is that of all the species of vegetation in the riparian zones of the Colorado River corridor, the tamarisk is utilized to a far greater extent than any other tree and shrub species. In addition, the vegetative zone most closely associated with the river, zone IV, has the greatest

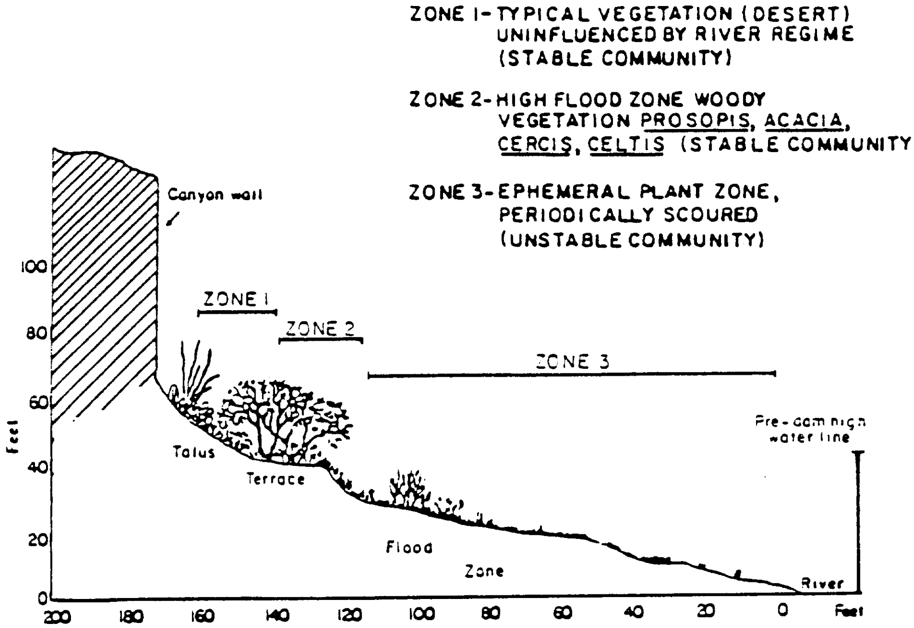

Figure VII-1a. A Profile of the vegetative zones of the Colorado River floodplain in the Grand Canyon prior to the construction of Glen Canyon Dam (from Carothers, et. al., 1979).

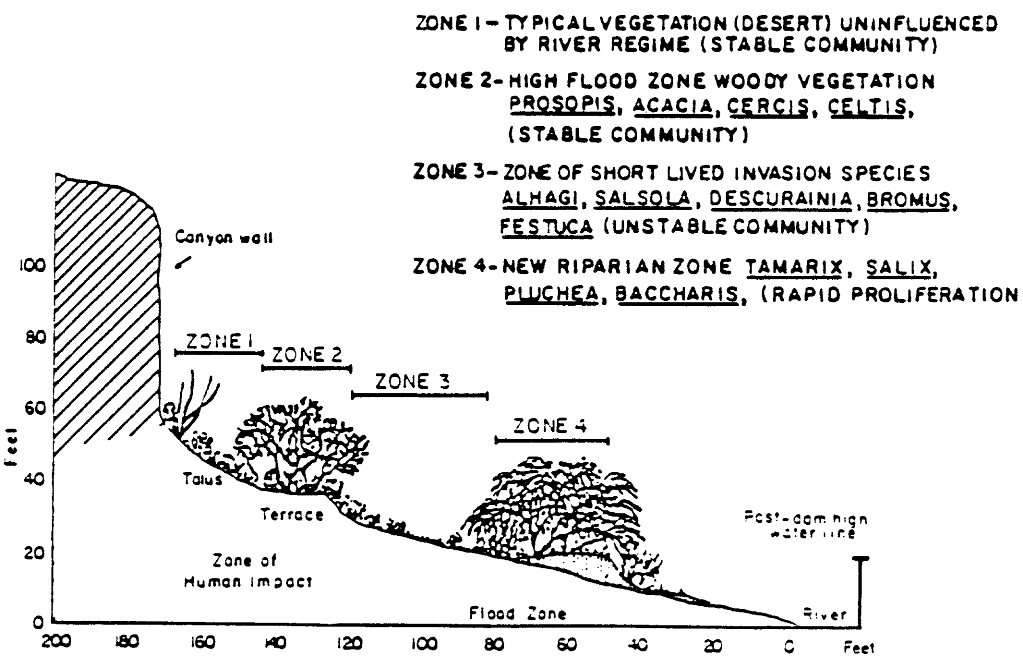

Figure VII-1b. A profile of the vegetative zones of the Colorado River floodplain in the Grand Canyon 13 years after the impoundment of Colorado River waters by Glen Canyon dam (from Carothers, et. al., 1979).

density of reptiles.

METHODS

This project attempts to sample all four zones at as many beaches as possible. The most critical factors are as follows:

1. For this study two observers are consistently used in each zone.

2. Keep accurate records of the species observed.

3. Keep accurate records on the duration of observation. The data are computed on the number of lizards seen per minute.

4. Keep an accurate record of the vegetation associated with each reptile observation.

5. Sample the habitats in a consistent manner throughout the river trip.
6. Record an accurate ambient temperature in each observed zone.

Data sheets are provided to facilitate the gathering of information (Figure VII-2).

Materials used:
1. clipboards for observers
2. data sheets
3. watch(es)
4. pencils - no ink
5. 2 air thermometers (unbreakable)
6. reference books - Field Guide to Western Reptiles and Amphibians by Stebbins, and Amphibians and Reptiles of the Grand Canyon by Donald M. Miller and others.

Observers are familiar with the species of lizards and plants listed on the data sheets. If a reptile is not identified, it is marked "unknown" in the space provided on the data sheet.

Plant species associated with the sightings are indicated. The consistancy with which the observer moves through a specific vegetative zone is very important in comparing the study team's data sheets. Each observation is a minimum of 10 minutes and not more than 20 minutes. Although the four zones are not always present at each beach, attempts are made to sample as many habitats as possible, when available.

RESULTS

Table VII-1 and Figures VII-3, 4 and 5 represent the results of reptile usage in the various species of vegetation, and those found on rocks and sand. Of all the individuals observed, 10% were found in tamarisks as compared with .5% and .5% of all individuals found in acacia (<u>Acacia greggii</u>) and mesquite (<u>Prosopis landulosa</u>), respectively. It is significant to note

REPTILE PROJECT DATA SHEET - AUGUST 1987

OBSERVER________________ BEACH NAME (RIVER MILE)______________

DATE___________ TIME START________TIME STOP______

AMBIENT TEMPERATURE___________ LAPSED TIME_________

VEGETATION ZONE 1	2	3	4

SPECIES REPTILE 1	2	3	4	5	6	7		SPECIES VEGETATION 1	2	3	4	5	6	7	8

Total Number

Percent

TOTAL INDIVIDUALS PER MINUTE _________

KEY TO ZONES
1 - desert vegetation
2 - Old High Water Line
3 - Zone of Human Impact
4 - New High Water Line

KEY TO REPTILES
1 - side blotched lizard
2 - desert spiny lizard
3 - western whiptail
4 - tree lizard
5 - desert collared lizard
6 - chuckwalla
7 - __________

KEY TO VEGETATION
1. tamarisk
2. seep willow
3. coyote willow
4. arrowweed
5. mesquite
6. acacia
7. desert scrub
8. rock
9. sand

NOTES

Figure VII-2. Example of reptile project data sheet.

Table VII-1 Reptiles Found in Various Environments

Vegetation	Zone 1 Number Observed	%	Zone II Number Observed	%	Zone III Number Observed	%	Zone IV Number Observed	%	All Zones Number Observed	%
Tamarisk	0	0	0	0	0	0	22	16	22	10
Seep Willow	0	0	0	0	0	0	5	4	5	2
Coyote Willow	0	0	0	0	0	0	23	17	23	11
Arrowweed	0	0	0	0	0	0	8	6	8	4
Acacia	0	0	1	2	0	0	0	0	1	.5
Mesquite	0	0	1	2	0	0	0	0	1	.5
Desert Scrub	6	55	0	0	0	0	0	0	6	3
Rock	5	45	48	92	11	85	41	30	105	50
Sand	0	0	2	4	2	15	36	27	40	19
Total	11	100	52	100	13	100	135	100	211	100

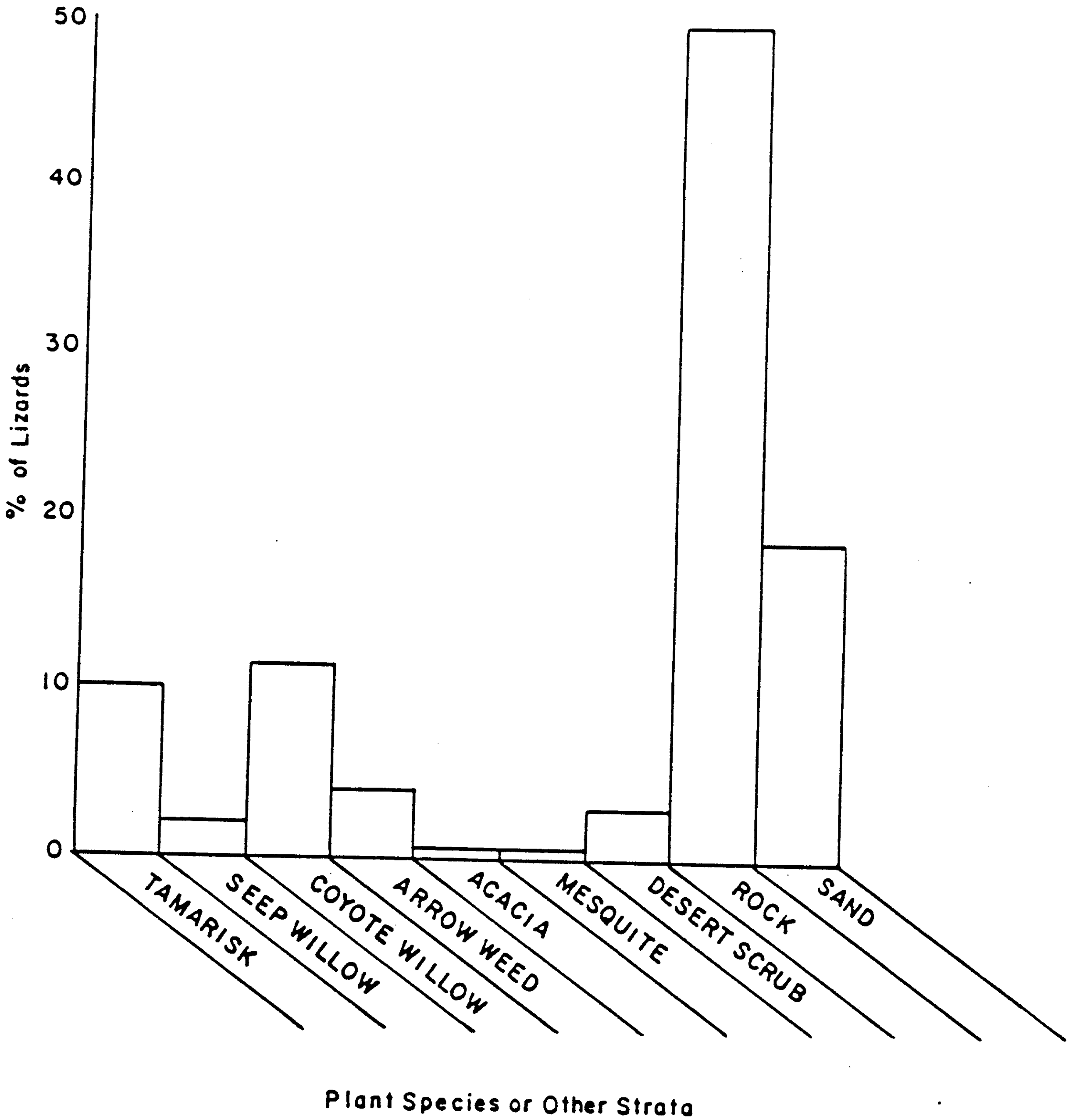

Figure VII-3. Percent of lizards observed on each plant species, rock, or sand (all zones).

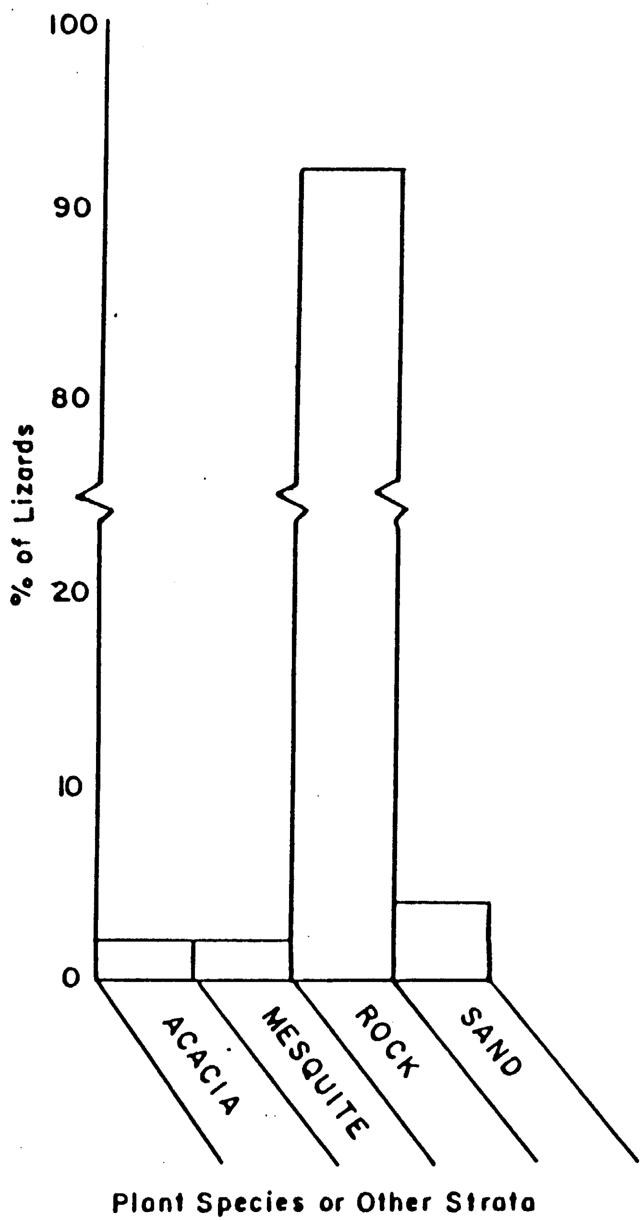

Figure VII-4. Percent of lizards observed on each plant species, rock, or sand (zone 2).

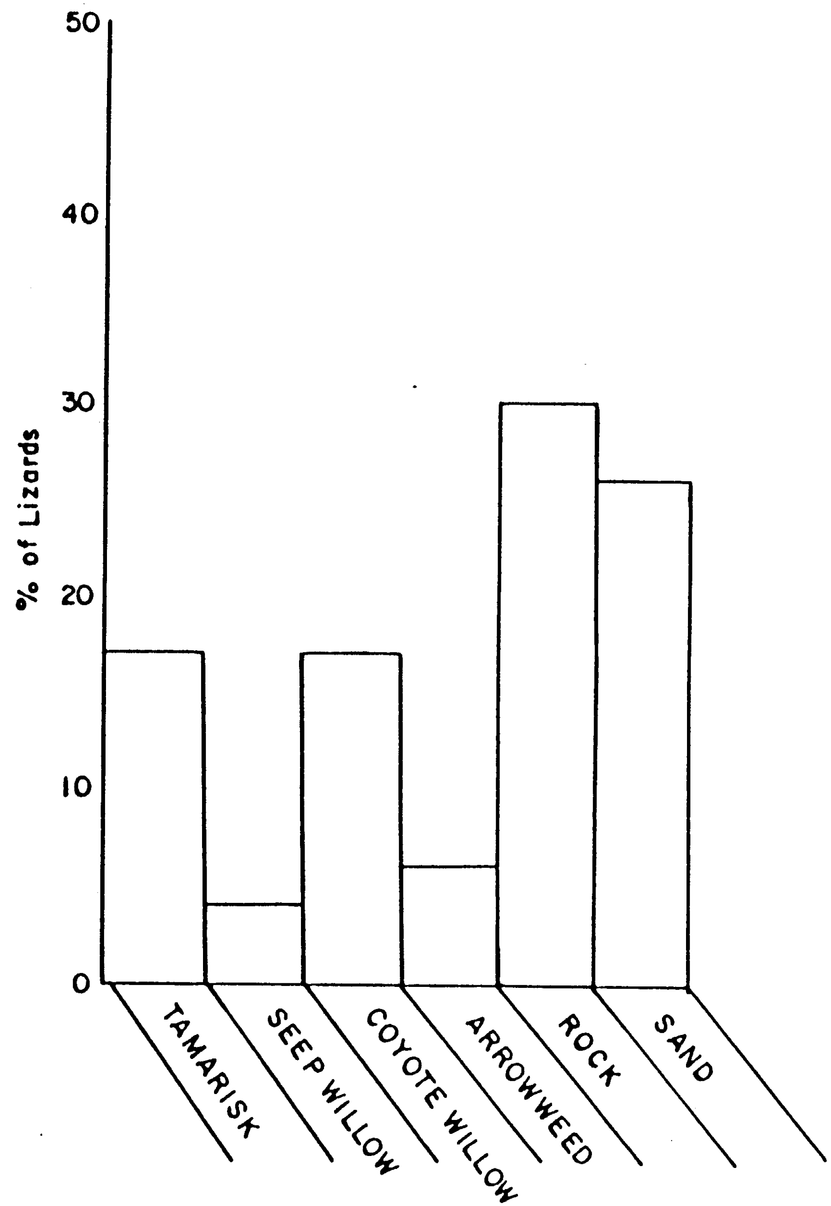

Figure VII-5. Percent of lizards observed on each plant species, rock, or sand (zone 4).

that 50% of the total individuals observed were found on rocks.

Figures VII-6 and VII-7, and Table VII-2, represent the results of the reptile densities. Total number of reptiles seen in all four zones are 211 individuals in 456 minutes. In zone I, 80 minutes were spent observing 12 individuals for an individual total of .15 per minute. In zone II, 145 minutes were spent observing 52 individuals for an individual total of .36 per minute. In zone III, 20 minutes were spent observing 13 individuals, for an individual total of .65 per minute. In zone IV, 211 minutes were spent observing 88 individuals, for an individual total of .64 per minute.

Figure VII-8 shows the effect of temperature on numbers of reptiles sighted per minute. It is observed that as the temperature increased in zone IV, a greater number of reptiles were sighted per minute. It appears that there is a temperature range in zone II that is most favorable for lizard activity. Above and below that range lizard activity was seldom observed.

Snakes, treefrogs, and toads were also seen during the course of the river trip. Three Grand Canyon rattlesnakes (*Crotalus viridis viridis*) were seen. After dark at Carbon Creek beach, one was caught under tamarisk trees (zone IV). The snake rattled very little, struck at nothing, had about eight buttons on its tail, and was about one meter long. The snake was released when the group left the campsite. The second rattlesnake was found on a hike while scrambling up through the Tapeats Sandstone (zone 1) about a third of a mile north of the camp at Blacktail Canyon. Air temperature was about 30°C. The snake was about .5 meters long. The third rattlesnake was found in zone II at Poncho's Kitchen (L137) while counting lizards. It was coiled up, sleeping on a ledge. It was a big, tan colored snake, about 120 cm long. It had eight buttons on its rattle.

Two desert striped whipsnakes (*Masticophis taeniatus taeniatus*) were seen. The one at Upper Granite Beach (L93.2) was caught among tamarisk trees, and photographed. Ambient temperature in zone IV at that beach was 32°C. After many photographs, the snake was released. The second whipsnake was seen while counting lizards in zone IV at mile L186. It was probably hunting whiptail lizards among the tamarisk roots exposed along the eroded sandy shoreline. It disappeared under thick arrowweed stocks that were lying on the sandy beach. Ambient temperature was 35°C at that beach.

Amphibian species seen during the trip were identified as three species: red-spotted toad (*Bufo punctatus*), Woodhouse's toad (*Bufo woodhousei woodhousei*), and canyon treefrog (*Hyla arenicolor*). Locations by river mile (RM) for sighting the amphibians are listed in the following table:

B. punctatus	RM	*B. woodhousei*	RM	*H. arenicolor*	RM
Badger Beach	8.0L	North Canyon	20L	Nautiloid	34.7L
Soap Creek	11.1R	Nankoweap	53L	Chuar Creek	65.3R
Buckfarm	41.0R			National Canyon	166.5L
Nankoweap lwr	53.0R				
Chuar Creek	65.3R				
Monument	93.2L				
National Canyon	166.5L				

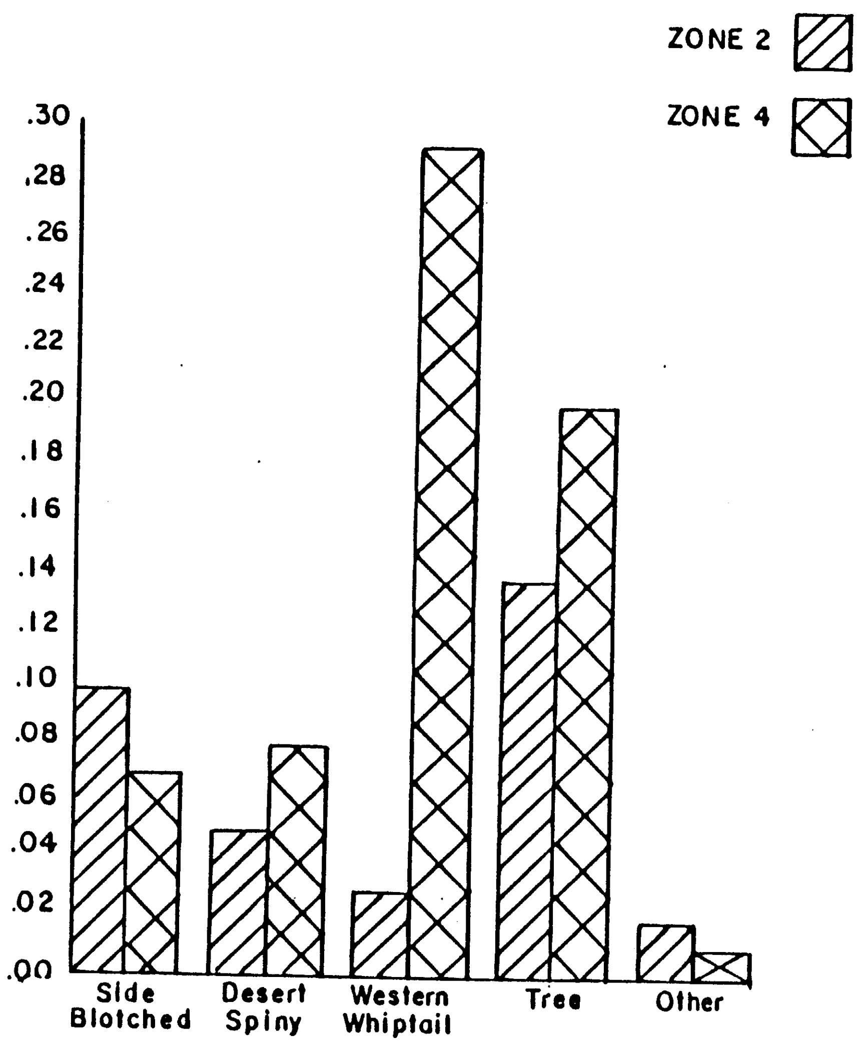

Figure VII-6. Relative density of reptiles (individuals per minute) in two zones.

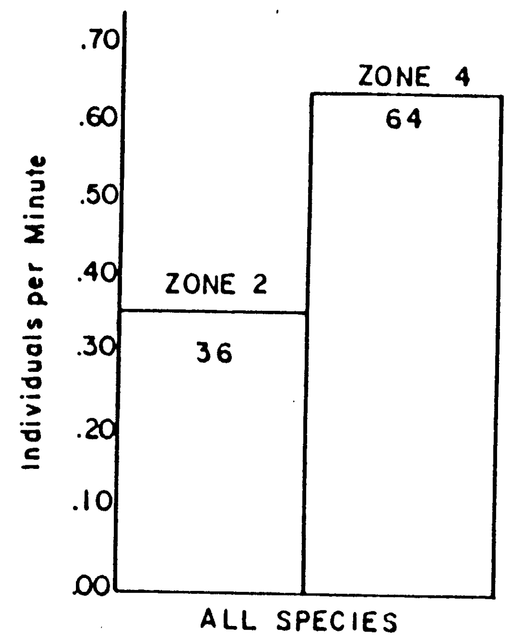

Figure VII-7. Relative density of reptiles (individuals per minute) in zones 2 and 4.

Table VII-2 Number of Lizards Observed

	Zone I		Zone II		Zone III		Zone IV	
	Number	/minute	Number	/minute	Number	/minute	Number	/minute
Side Blotched	3	.04	15	.10	1	.05	14	.07
Desert Spiny	0	.00	7	.05	0	.00	16	.08
Western Whiptail	3	.04	5	.03	0	.00	61	.29
Tree	6	.08	21	.14	12	.60	42	.20
Others	0	.00	4	.02	0	.00	2	.01
Totals	12	.15	52	.36	13	.65	88	.64
Observation Time /Zone (minutes)		80		145		20		211

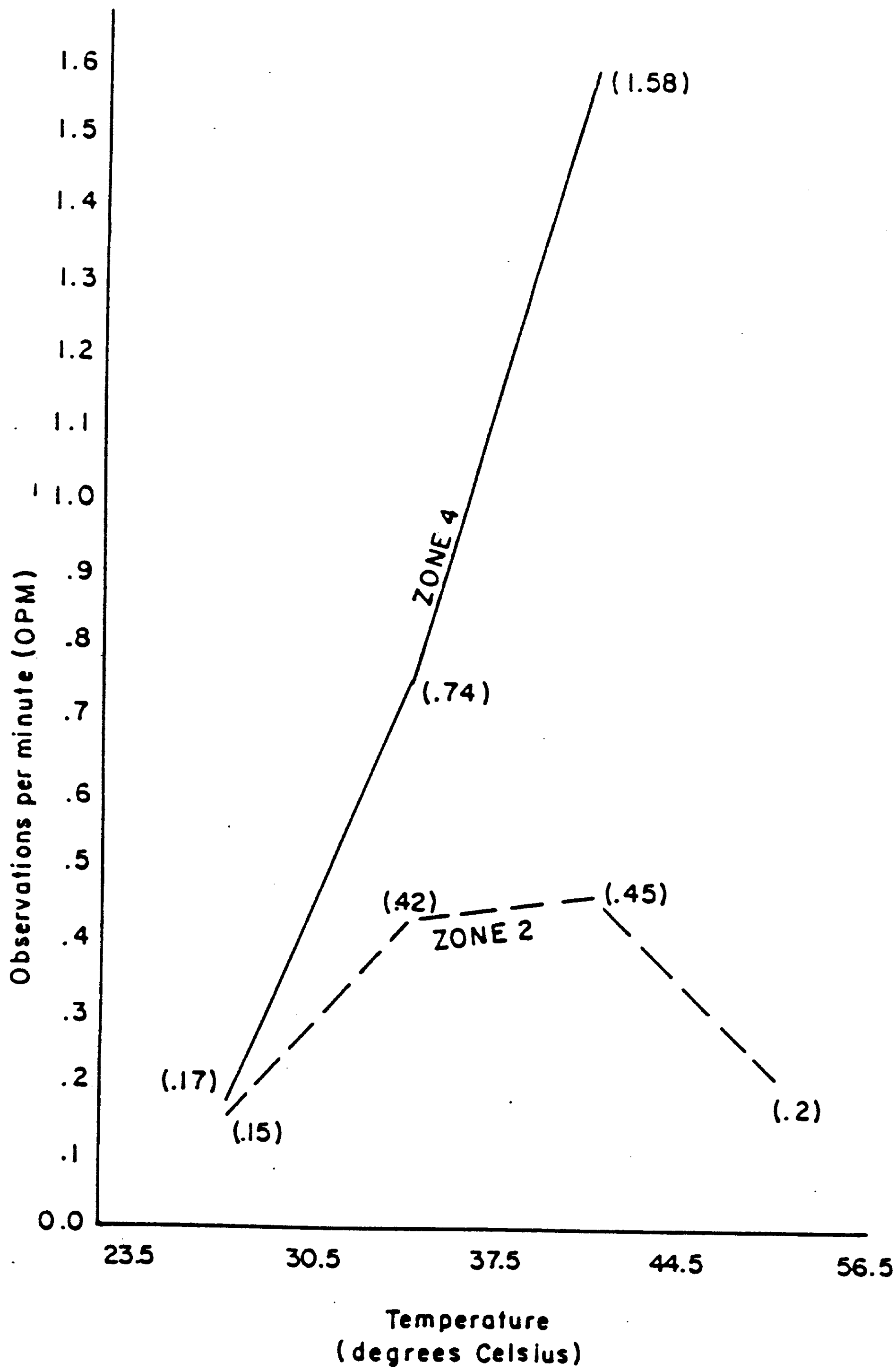

Figure VII-8. Observations per minute in zones 2 and 4 as a function of temperature.

Many hundreds of tadpoles were seen in creeks and pools. Tadpoles in the Nautaloid Canyon pools were possibly treefrogs, as adults were seen on the rocks adjacent to the pools. Tadpoles there were about 5 cm long from nose to tail. Dozens of them had bent tails as if they had been injured somehow. A picture was taken of them in the pools. Most of the tadpoles were light-colored, but some were dark-colored. Positive identification might be hard because the tadpoles seemed larger than Bufo or Hyla species usually are (Stebbins, 1985).

Hundreds of immature red-spotted toads were seen while hiking down Chuar Creek. They evidently had just metamorphosed from tadpoles. They were about 1.6 to 2.1 cm long. A picture of one was taken with a pencil as a reference object.

At Nankoweap's lower beach, hundreds of both species of adult toads were observed along the trails through the dense stands of arrowweed. Walking along the wet, sandy shoreline after dark was hazardous to the toads. At 9p.m., we walked 100 steps along the water's edge, and counted 20 red-spotted toads and 32 woodhouse's toads.

A surprising find of a desert-banded gecko (Coleonyx variegatus variegatus) was made at Poncho's Kitchen (L137). After squishing a pop can, a yellow and black striped tail was discovered sticking out of the opening at the top of the can. The gecko's tail was still twitching, although it had been cut off when the can was squished. The tail of another desert-banded gecko was observed sticking out of a crack in a rock at National Canyon (L166.6).

Western chuckwallas (Sauromalus obesus obesus) were seen at three locations on the river trip. The locations are listed below.

Mile L18.2 - in a vertical crack at the base of the Supai Formation.
Mile R122.0 - in a crack in a tilled boulder.
Mile R207.0 - in a vertical east facing crack.

CONCLUSION

Zone IV represents the Colorado River's new high water mark. zone II represents the old high water mark. It is obvious that the new riparian zone accounts for a higher number of reptiles than zone II. We can safely say that zone IV, a zone created by the effects of Glen Canyon Dam, is providing habitat for a considerable number of native reptile species.

A pattern emerged which shows a relationship between reptiles observed per minute and temperature. The number of reptiles per minute was generally greater with increasing temperatures in zone IV. This was not the case in zone II. Zone II showed a favorable temperature range (31°C to 42°C) for lizard activity, above and below which activity dropped off.

It appears to us that reptiles in zone IV could remain active during higher temperatures because of the dense shade created by the tamarisk trees. We also observed lizards feeding voraciously on Diptera flies under the tamarisks. So, not only do tamarisks in zone IV provide shade, they also support a large supply of food for the lizards. Food supply is a limiting factor that must affect lizard density.

A note about the comparison of zone II and zone IV's individuals observed per minute must be made. This study's results were affected by two locations where high numbers of tree lizards were active on a cliff face or on boulders. Both of these locations were included in zone II's data. The inclusion of that data into zone II's results caused a shift in the individuals observed per minute (1PM) from .261PM to .361PM. Our results show, in zone IV, almost twice as many lizards observed per minute than in zone II. If the previously mentioned counts were taken out of the zone II study, the results would show almost three times as many lizards observed per minute in zone IV than in zone II.

RECOMMENDATIONS

We think density studies have established that zone IV is where a high proportion of lizards are found. We think future lizard studies could investigate where the lizards feeding during the day in zone IV, live at night. By observing lizards in the evening, a careful observer could see where they go to spend their nighttime hours. We think they are living in burrows or cracks in zone III or II, because the diurnal river flow keeps zone IV sand too moist. Moist sand would prevent eggs from hatching and might cause some sort of fungus or respiratory problems for the lizards.

Two more suggestions could be made. 1. Observers might follow the research design that Warren and Schwalbe used in their study. Their delineation of ten zones could be used in this same study. A more accurate indication of preferred sites would result. 2. A study might be initiated to determine the distribution of the desert collared lizard and the black collared lizard. Both species occur in the Grand Canyon and need to be differentiated in further lizard studies.

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CHAPTER VIII

DISTRIBUTION OF BEAVER ALONG THE COLORADO RIVER IN GRAND CANYON NATIONAL PARK: POSSIBLE RESULTS FROM THE HIGH WATER FLOWS OF 1983

Larry George Langstaff

INTRODUCTION

Most people would think there are very few beavers in the Grand Canyon. They do not seem to fit there. The Grand Canyon is a very hot place for many months of the year. Most people picture beavers as living in a pond with a lodge and a dam, high in a cool mountain valley. This study was done to compare a 1987 study with a similar study of canyon beaver density done by George Ruffner in February, 1983 and one done by George Spears in August, 1983. Ruffner's study was completed before the high water flows of spring/summer, 1983. Spears' study was completed in late July and early August of 1983, after the high water had dropped. This study was undertaken knowing that the 1983 high water scoured the river bed, removing 40% of the riparian vegetation volume. Undoubtedly, coyote willow (*Salix exigua*) was lost then in some volume approaching 40%.

OBJECTIVE

The goal of this project was to try and determine whether beavers along the Colorado River were affected, to any degree, by the high water of 1983. The two studies completed before the high water, provide some indication of past beaver numbers.

METHODS

This study was conducted by a single individual watching the riverbank for beaver slides and/or burrows. Beavers slide down into the water after feeding on the bank on willow stem bark. Beavers that live along rivers, without lodges or dams, burrow into the bank to make their den. They are primarily nocturnal, so counting actual beavers is impossible. When the water was low enough, burrows could be observed and their river mile location was noted. Any time willow cuttings were observed on shore they were also noted.

One observer riding on a raft cannot inspect both shores at all times, so the data reflects mainly just the left side of the river. Close inspection of most slides and burrows is too time-consuming on a raft trip like the Northern Arizona University research trip. Observations are usually made from mid-stream.

The study Spears worked on was probably the result of observations made by several people on his boat that could spend more time inspecting the shoreline. That difference should be noted. Spears' study was probably the most complete of the three.

PROCEDURE

An observation sheet that left space for recording the date, river mile, and whether burrows, slides, or gnawings were observed, was designed for this project. Room was left for descriptive notes and whether the observation was made from the raft or from shore. Reference was made to the Guidebook to the Colorado River by Hamblin and Rigby (1968) for river mileage. The beaver study was conducted to RM220, which is past the point of Ruffner's study, but the same distance as Spears'.

RESULTS

Eighteen beaver slides were recorded and eight burrows were observed (Tabel VIII-1). One beaver was observed at early morning in Blacktail Canyon. That adds up to a total of 26 burrows or slides observed, less than 50% of the number Spears recorded (Table VIII-2).

In comparing just the distance to Phantom Ranch (Table VIII-3), the sightings were about 33% as often as Ruffner's February, 1983 study. That seems to be significant.

Almost all the coyote willow plants along the river had been gnawed at one time or another, by a beaver. The resulting growth usually came back in the form of two stems where originally there had been one.

This study was often conducted when water levels were high and burrow openings were hidden beneath the water level. This had some effect on the data.

CONCLUSION

Beaver slides and burrows along the Colorado River were found to be 50 and 67% fewer in number than those found by Spears in August, 1983 and by Ruffner in February, 1983, respectively. This large change indicates the scouring effect of the high water in 1983, reducing riparian vegetation volume by 40%. Coyote willow volume reduction was probably somewhere near the same 40%. Some beavers may not have been able to find enough food to stay alive along the Colorado River since the scouring. They may have died or tried to find food up the tributary creeks. The willows will regenerate by cuttings from stems and roots, but probably not much of that occurred. There would be at least a several year lag time before willow saplings regained their hold on the beaches and returned to their original volume.

Table VIII-1. Beaver Location Project Sheet.

Date	River Mile	Burrows	Slides	Gnawings	Observed From: Raft	Shore
		Observations				
7-29	7.8L		X		X	
7-29	11.2R		X	X		X
Note: Beaver tracks and tail print in wet sand, many chewed willow stems.						
7-29	16.3R		X		X	
7-30	24.5L	X			X	
Note: Burrow .5 meter below base of willows.						
7-30	40.5R		X		X	
Note: Lots of willows in the next mile have been cut by beavers.						
7-30	41.0		X		X	
7-30	41.4		X		X	
7-30	46.0L		X		X	
7-30	47.0R		2X		X	
7-30	49.2		6X		X	
Note: 6 slides and much chewed willow in the next mile.						
7-30	52.0R		X		X	
7-31	52.8R	X			X	
7-31	54.5L	X			X	
Note: Willows cut just below Grey Castle.						
8-1	74.0	X			X	
8-1	120.0L	2X		X		X
Note: 1 adult beaver swimming, 6:50a.m., feeding on willows on shore. 1 adult, 8:00a.m., possibly the same as the one seen earlier, near the right shore, close to willows. Dove when approached to within 10 meters. Not observed surfacing after dive.						
8-6	168.0R		X	X	X	
8-6	168.5L	X		X	X	
8-6	193.0L	X			X	
8-6	194.0R	X			X	
Note: First cholla on trip observed on right shore, 20 meters above a stand of willows with a burrow under them.						

Table VIII-2. Comparison of observations.

Area	Number of Observations 1983	Number of Observations 1987
RM1.8-10.0	16	1
RM11.0-51.5	11	15
RM52.5-69.0	13	3
RM70.0-165	0	3
RM165.7-172.7	1	2
RM172.7-212.7	15	2
RM212.7-214.1	2	0
TOTAL	58	26

Table VIII-3. Comparison of beaver burrows.

Area (River Miles)	Spring 1983 Sightings	Summer 1983 Sightings	Summer 1987 Sightings
0 - 19.0	0	16	3
19.0 - 37.6	3	1	1
37.6 - 47.3	11	1	6
47.3 - 58.3	14	13	5
58.3 - 65.6	9	9	0
71.9 - 76.5	9	1	0
TOTAL	46	41	15

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CHAPTER IX

SMALL MAMMAL POPULATIONS WITHIN THE COLORADO RIVER CORRIDOR

G. Rotstein, C. Burfield, L. Langstaff, S. Brinkhuis

INTRODUCTION

This study was designed to determine small mammal use of four distinct habitats along the Colorado River corridor from Lees Ferry to 220 Mile Beach. Mammal populations in the corridor have been described since the completion of the Glen Canyon Dam (Hoffmeister, 1971; Ruffner, 1975, 1976, 1978). The four habitats were described as zones by Carothers (1976), and limited trapping of small mammals was done before and just after the flood of 1983 (Trimble, 1982; Spears, 1983).

The habitat zones (Figure IX-1) are: 1) Talus - desert vegetation, 2) Terrace - old high flood zone vegetation, 3) new beach/boulders - short lived invasion species, 4) New riparian - _tamarix_, _salix_, _pluchea_.

METHODS

During the 11 day river trip, mammals were trapped on nine beaches (National Canyon was trapped on two days) using Sherman live traps baited with oatmeal. Traps were set in the evening and distributed in proportion to the amount of habitat zone present. At dawn, mammals were measured, sexed, identified by species, and released unharmed (See Field Notes for measurements).

RESULTS

Table IX-1 shows a wide range in numbers of animals captured on each beach. It ranges from 28 over two days at National Canyon to 2 at Blacktail. Table IX-2 (and Field Notes) show the Cactus Mouse (_Peromyscus eremicus_), to be found in greatest numbers on every beach and in every zone. Cactus mice comprise 67% of all mammals captured. The totals of animals captured by zone, from Tables IX-1 and IX-2, are drawn on Figure IX-1, and show more animals in zone 2 (43%) than any other.

Eighty-two individual mammals were captured in 649 trap nights for a success rate of 13%.

CONCLUSION

Figures IX-1, IX-2, and IX-3 show changes in mammal capture patterns, before, just after, and four years after the 1983 flood. In 1982, the new riparian zone 1 yielded the most small mammals (63%), after 20 years of uninterrupted plant habitat growth. The small mammals were on high ground zone 1 (47%) in 1983, after the new riparian zone 4 vegetation had been swept away. In 1987,

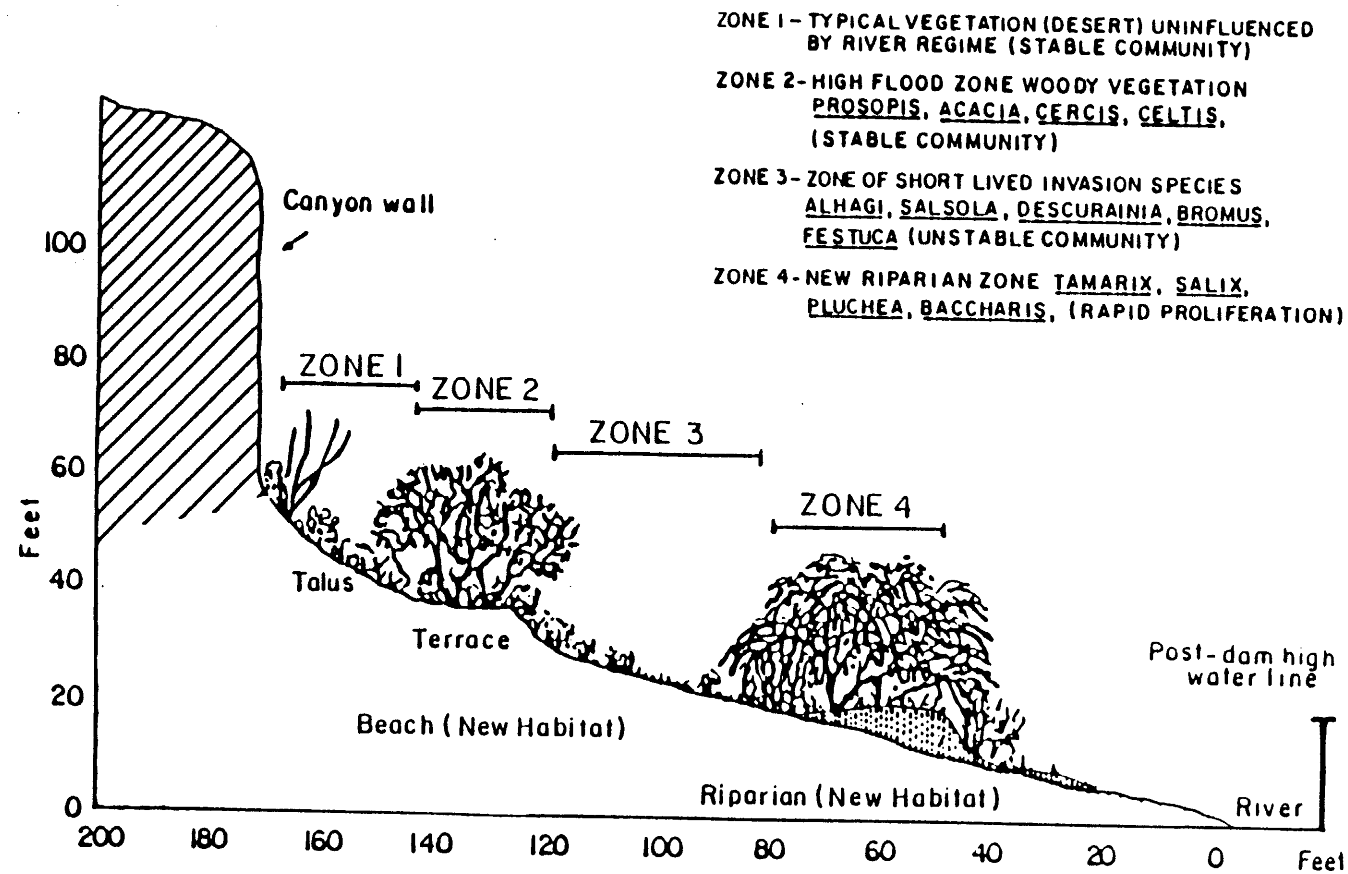

Figure IX-1. Diagrammatic cross-section of vegetation zones in the Inner Gorge of the Colorado River in Grand Canyon after the construction of Glen Canyon Dam (from Carothers, et. al., 1979).

Table IX-1. Mammals captured by beach and habitat zone.

Date		Beach	Traps	Zone 1	Zone 2	Zone 3	Zone 4	Total
7-30	L	20 Mile	60		3		1	4
7-31	R	Nankoweap 52.5	69		10		6	16
8-1	R	Carbon Crk. 63.5	69		4		2	6
8-2	L	Cremation 85.4	69	1	1		1	3
8-3	R	Blacktail 120.1	68		1		1	2
8-4	L	Poncho's 137	33		2			2
8-5	L	National 166.6	68	2	7	2	4	15
8-6	L	National 166.6	68	3	2	3	5	13
8-7	L	Mile 194	68	6	4		5	15
8-8	R	Mile 220	67	2	1		3	6
			649	14 (17%)	35 (43%)	5 (6%)	28 (34%)	82 (100%)

Table IX-2. Mammals captured by species and habitat zone.

Species	Zone 1	Zone 2	Zone 3	Zone 4	Total
Peromyscus maniculatis				3	3
Peromyscus eremicus	8	25	5	17	55
Peromyscus crinitus	5	2		7	14
Peromyscus boylii		2		1	3
Perognathus formosus		1			1
Perognathus intermedius		3			3
Neotoma albigula	1				1
Neotoma lepida				2	
	14 (17%)	35 (43%)	5 (6%)	28 (34%)	82 (100%)

despite the recovery of the new riparian zone 4 plant community, the small mammals were trapped in greater number in zone 2 (43%).

Why are the mammals found in greater numbers away from the river while reptiles and birds are found in 1987 in markedly higher numbers in riparian zone 4 (personal communication, S.W. Carothers)?

Zone 4 plant community has not reached the same abundance as in 1982. The increase in cover in zone 4 has resulted in plentiful nesting sites and insect food sources for birds and reptiles, respectively. However, small mammals are basically seed eaters and occasionally insectivorous (Hoffmeister, 1971). Seed food sources for small mammals may still be more plentiful in zone 2.

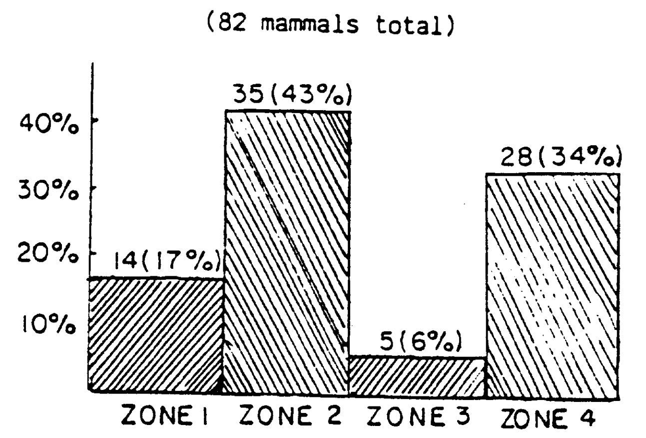

Figure IX-2. Percentage of mammals captured by zone in 1987.

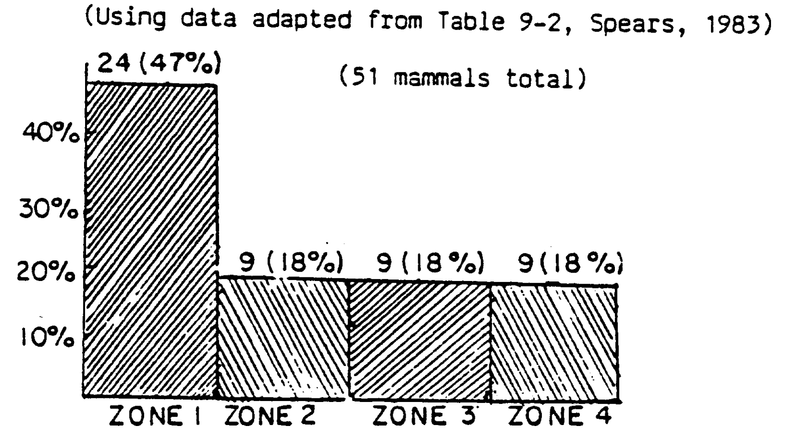

Figure IX-3. Percentage of mammals captured by zone in 1983.

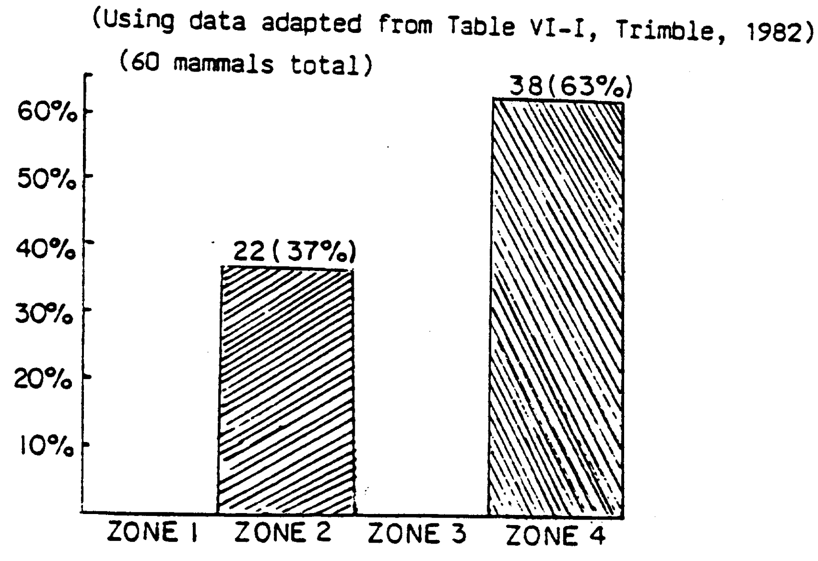

Figure IX-4. Percentage of mammals captured by zone in 1982.

The overwhelming numerical dominance of <u>Peromyscus</u> <u>eremicus</u> (67%) continues a historical pattern first commented upon by C. Hart Merriam (1890). The percentages captured of the other seven species approximate reports given by previous observers, both by beach and zone.

The variation in capture success rate in 1982, 1983, and 1987 may be related to two principle variables: choice of beaches for trapping, and weather. After extremely hot nights (Cremation), very few mammals were found in the traps, while after a rainstorm (National Canyon) trapping was exceptionally successful. Different beaches were trapped in each year.

Beaches with high numbers of ants (RM 220) yielded traps with many ants, and few mammals.

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FIELD NOTES

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CHAPTER X

ABUNDANCE AND DISTRIBUTION OF THE EXOTIC CAMELTHORN (ALHAGI camelorum) ON THE COLORADO RIVER FROM LEES FERRY TO DIAMOND CREEK

Rosemary Bernstein

Sandy Kyle

INTRODUCTION

It was the purpose of this investigation to survey the abundance and distribution of the exotic Camelthorn (ALHAGI camelorum) on the Colorado River from Lees Ferry to Diamond Creek.

Sandy beaches along the Colorado River in the Grand Canyon are used as campsites and lunch stops for 15,000 river recreationists each year. Most of the residential use is concentrated on approximately 100 beaches out of more than 200 available beaches along the river corridor from Lees Ferry to Diamond Creek.

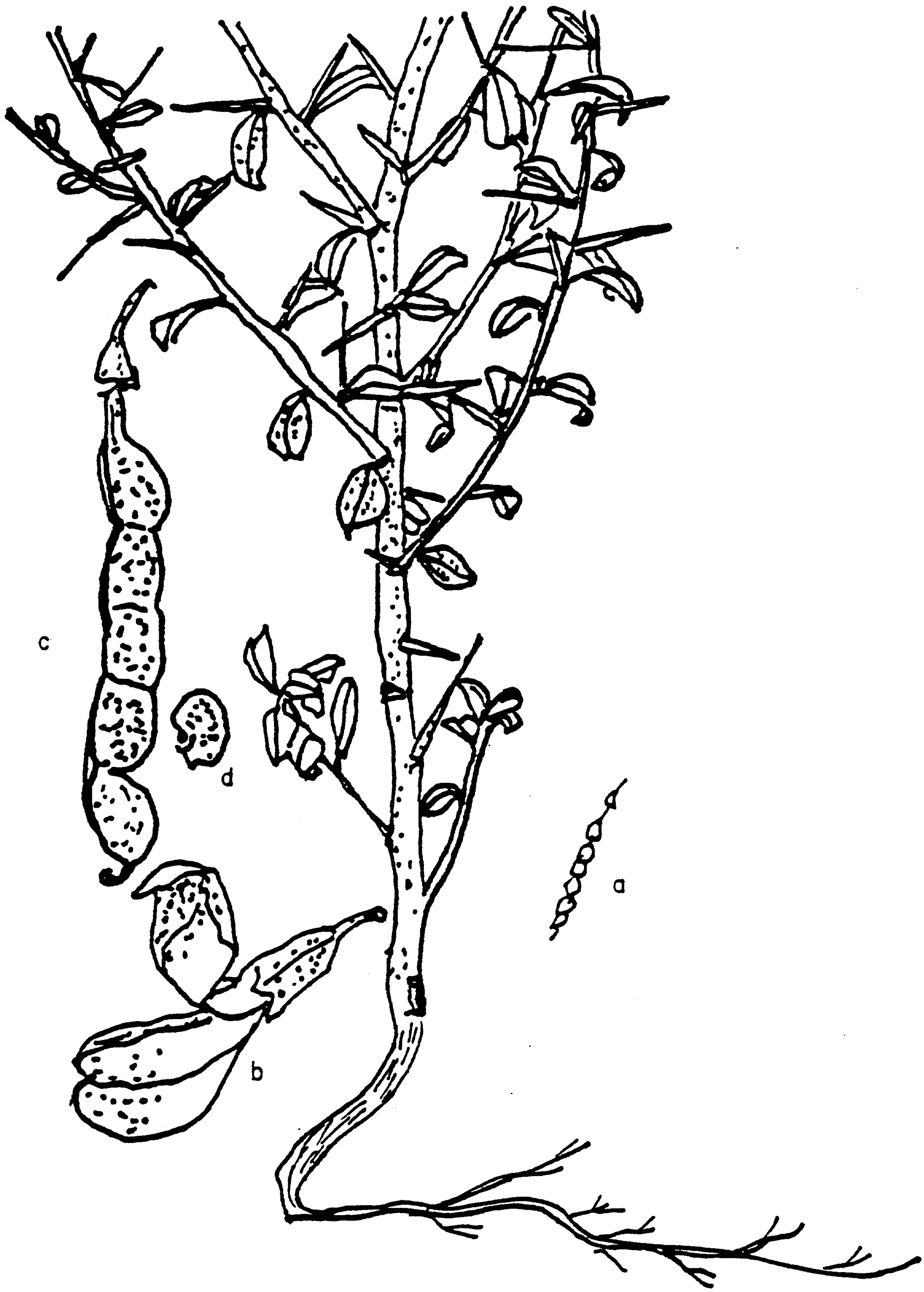
Since 1963, the river has changed dramatically. Glen Canyon dam discharge rates are carefully controlled by the Bureau of Reclamation at the dam in response to hydroelectric power needs. Under the present direct controlled flow on the river, the higher terrace levels never receive new sediment from the river. The lower terrace levels are, in places, eroding more than they are aggrading even though, in part, they are flooded almost daily by the river. There is concern that what the Colorado River and other agents now erode from these alluvial terraces may never be put back. Laursen and Silverton (1976) have predicted that the beaches in the Grand Canyon will be gone in 200 years.

In the spring and summer of 1983 unexpected high run-off filled Lake Powell above design level forcing "major spills" which changed the water levels greatly and flooded campsite beaches for periods of several days to several weeks. This was the most major departure from the normal alluvial deposits between 1963-1984.

Camelthorn, is a spiny, intricately branched, completely hairless shrub 1 1/2' to 4' high, reproducing principally from deep vertical roots and extensive rhizomes and also seeds (Figure X-1). The greenish stems bear slender vicious spines, green with yellow tips, 1/4" to 1 3/4" long. The alternate wedge-shaped leaves, yellowish above, bluish green beneath, are 1/4" to 1 1/4" long, 1/8" to 1/2" broad, and have very short stalks.

The small pea-like flowers, about 3/8" long, are pinkish purple to maroon. These occur on short slender spine-tipped branches which arise uniformly and in large numbers along the upper part of the stems. When the pods mature and fall off, these branches become persistent spines.

The reddish-brown jointed seedpods are curved upward, and



a. Pod, natural size b. Enlarged flower c. Enlarged pod d. Seed

Figure X-1. Plant and plant parts, Alhagi camelorum.

commonly have 1 to 4 seeds, or up to 9. The pod is deeply indented, and each seed is clearly outlined like a bead on a string. The kidney-shaped seed is grayish brown, about 1/8" long, and 1/12" broad.

Camelthorn, introduced from Asia, grows principally in deep moist soil, but also in dry rocky soil. It is abundant in colonies along the banks, bottomlands, and drainage of the Little Colorado and Salt rivers, along canals, irrigation ditches, and sometimes spreading to adjacent cultivated fields. It is present in Navajo, Coconino, Gila, Maricopa, and Yuma counties at 100 to 5,000 feet in elevation. Flowering season is May to July and the seedpods persist until October or November.

The underground roots and rhizomes branch extensively, but usually after they are 2' to 4' deep. Once established, a colony increases in size each year. In less than 20 years, the infestation along the canals near Gillespie Dam (Maricopa County) has become continuous for more than 15 miles (Parker, 1972).

Distribution in the Grand Canyon indicates that the plant probably invaded the Canyon downstream from the lower Colorado River.

METHOD

Twenty-nine beaches, beginning at RM 7.8 and ending at RM 225, were surveyed for the invasion of camelthorn. The two researchers walked along the length of each beach parallel to the river to the end of the beach, then climbed the slope to the terrace above. They walked back along the terrace, parallel to the river to the far end of the terrace, then descended to the beach at river level and walked back to the point of origin, completing a loop that traversed both beach and terrace environments. The researchers easily observed camelthorn by their noxious, thorny stands. When single individuals could be counted they were tallied (see data sheet), but on a few beaches stands were so dense that an estimate was recorded.

RESULTS AND DISCUSSION

In 1986 a study of the abundance and distribution of native and domestic plants on the Colorado River from Lees Ferry to Diamond Creek (Wilke, 1986) alerted these researchers that the exotic camelthorn, a noxious weed, was encroaching on seven frequently used recreational campsites in the Canyon (see Table X-1).

The hypothesis is, that more beaches or campsites are becoming unusable due to camelthorn invasion.

We noted more widespread distribution of camelthorn on both sides of the river than previously reported. In a few instances, beaches that were campable in 1986 are now unusable due to dense growth on beaches and terraces by this noxious weed (Figure X-2). Camelthorn is apparently distributed by wind and water movements. At bends in the river seeds are being pushed into back eddies where growth begins at the water's edge. Later, seeds are dropped and moved up the beach to the terrace by wind action.

CAMELTHORN DISTRIBUTION DATA SHEET

RIVER MILE ________ DATE ________________

NAME OF BEACH ______________________________

NAME OF OBSERVER _______________________ ZONE ___1 ___2 ___3 ___4

KEY TO ZONES:
1 - DESERT VEGETATION
2 - OLD HIGH WATER LINE
3 - ZONE OF HUMAN IMPACT
4 - NEW HIGH WATER LINE

SURVEY OF CAMELTHORN DISTRIBUTION BY OBSERVABLE SWEEPS

SKETCH OF BEACH

COUNT OF PLANTS PER ZONE

ZONE 1

ZONE 2

ZONE 3

ZONE 4

NOTES AND COMMENTS:

TABLE X-1. 1986 Camelthorn Count.

River Mile	Bank	Number Counted
65.5	L	60
98.2	R	50
120.1	L	20
190.2	R	7
194.0	R	6
198.5	R	1
208.8	L	200

CONCLUSION

Camelthorn appears to be invading beaches at an observable rate that will need to be dealt with in the near future to maintain recreational campsites in sufficient number to handle the 15,000 visitors who run the Colorado River each year.

The plants seen at water's edge at mile R58.1 appear to be new invaders. Those at mile R207.0 and mile L208.8 were well entrenched creating unusable beaches for a campsite, since camelthorn covers banks, beach, and terrace.

Camelthorn is such a noxious plant, that during this investigation, Bernstein was deeply punctured in the thumb by a stem thorn and bled for two hours before clotting. This experience is evidence of the danger campers could experience on beaches where camelthorn has invaded.

In 1987 there are now ten campsites endangered by camelthorn which is a significant increase in one year of all campsites surveyed since 1986.

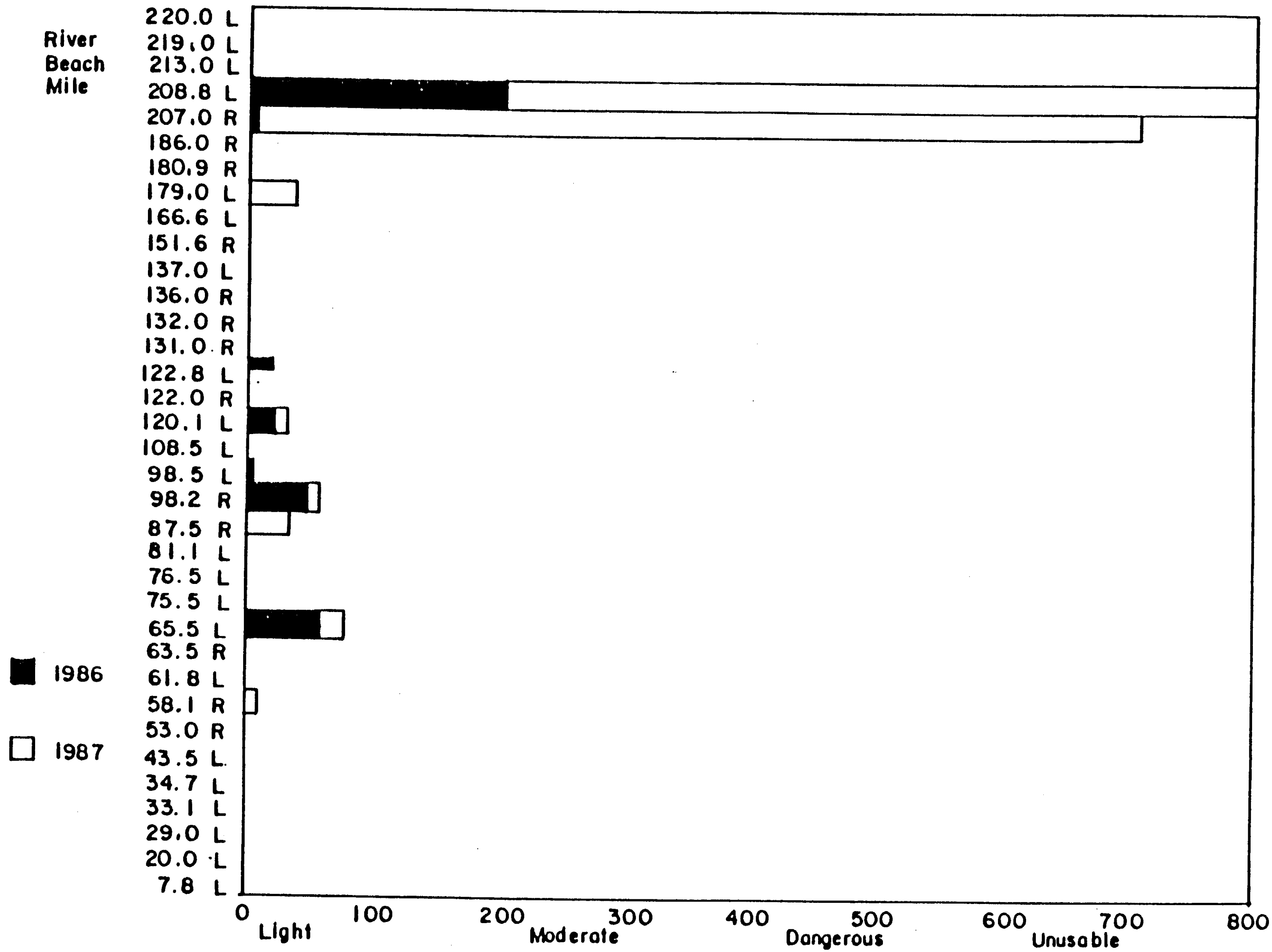


Figure X-2. Numbers of _Alhagi camelorum_ infesting Colorado River campsites in 1987.

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CHAPTER XI

RECREATIONAL IMPACTS ON RIVERINE HABITATS IN GLEN CANYON NATIONAL RECREATIONAL AREA, ARIZONA

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Anne Kalinowski

INTRODUCTION

Glen Canyon National Recreation Area is known for its 180 mile long, nine trillion gallon reservoir, Lake Powell. The excellent recreational opportunities afforded by the lake and its 1800 mile shoreline attract hundreds of thousands of annual visitors, all either in pursuit of water-based recreation or curious about one of the largest man-made reservoirs in the world. Another significant recreational attraction and unique geographic feature of this National Park Service administrative unit is a 15 mile (24.5 Km) segment of the Colorado River. The River flows from the Glen Canyon Dam tailwaters downstream to Lees Ferry, the present easternmost boundary of Grand Canyon National Park.

The geographical and geological uniqueness of this area results from the the fact that the only remaining portion of the now almost completely inundated Glen Canyon, with its massive and spectacular Navajo Sandstone cliffs, is found in this area. There is nothing similar in Grand Canyon or on the upper reaches of Lake Powell where Cataract Canyon gives way to Glen Canyon. One can only imagine what the original river channel must have been. What remains of Glen Canyon, once 180 miles (292 Km) of river-carved beauty, is now only found in the 15 miles below Glen Canyon Dam. Recreational opportunities in this area include non-consumptive tourism, on both private and commercial levels, and consumptive fishing and hunting (waterfowl). Trout (<u>Salmo</u> spp.) fishing pursuits are by far the most popular recreational aspects of the Colorado River component of the recreation area. Visitation in the area has been growing steadily in recent years. Over 30,000 fisherpersons and in excess of 5,000 commercial tourists are using portions of the 15 mile corridor each year. Many of these recreationists camp or picnic in the area and the signatures of their use are left in the form of litter, human wastes, campfire scars and trails. The present study involves identifying and quantifying recreational impacts.

Prior to the closing of the flood gates of Glen Canyon Dam in 1963, the streamside habitats (beaches and associated vegetation) of the Colorado River were subjected to wildly variable discharge levels that ranged from extremely low flows (< 1000 cubic feet/second) to spring floods commonly in excess of 90,000 cfs. (Dolan, et al. 1974). Once the flood gates were closed and the lake began to fill, the amount and periodicity of water released from the Dam became a complex function of hydro-electric energy demands in distant cities as well as requirements of the Colorado River Compact of 1922. From 1963 until 1983, low dam discharge levels rarely fell to 1000 cfs and high flows usually peaked at 30,000 cfs. In 1983 the flood caused the river flow to exceed 100,000 cfs. The beaches were scoured clean. The Dam prevents the high flow which would obliterate any sign of human recreational activities and sand scour the flood zone of its annual vegetative growth. As a result, litter and other signs of human passing accumulate.

Recreation in the Glen Canyon area prior to the Dam was minimal. It is doubtful whether prior to the mid-1960s more than 200 persons per year entered the Glen Canyon area for recreational or economic purposes (see Carothers, et al. 1976). The presence of the Dam, however, and the dramatic changes that have occurred in the nature of the river as a result, have changed the recreational attractiveness of the area. The Dam has replaced the sediment-laden, cold in winter, warm in summer pre-Colorado River with a sparkling clear, perpetually cold (45°F - 50°F; 7°C - 10°C) river. Without the Dam-related changes in the very physical nature of the River, neither the spectacular trout fishing nor the current recreationally related problems on the limited number of campable beaches would exist.

It is necessary to describe and inventory the principal components of the potentially impacted environment in order to be able to identify and analyze human related impacts to the Glen Canyon beaches. Our specific objectives are detailed below.

OBJECTIVES

1. Identify and quantify human impacts on selected campsites reflecting a variety of use levels.
2. Compare the human impacts to data collected during previous studies.
3. Analyze samples collected during a 1983, post flood survey.

METHODS

A group of Northern Arizona University students visited the study sites in August 1983. Samples were collected and stored for further analysis.

In July 1987, another group of students visited the study area and collected more samples from some of the same beaches.

All collected samples were analyzed at Northern Arizona University for sand discoloration.

1. Identification and quantification of human impact.

At each study site, a permanently marked baseline of from 15 to 40m was established. From this baseline, 10m sample points were selected. At each of these sample points, specific measurements were taken. This allowed for the determination of relative cleanliness or dirtiness of beaches or portions of beaches throughout the time frame of the project.

A relative index of human impact was primarily determined by quantification of the following environmental elements: a) accumulation of debris and charcoal ≥ 1 cm in size and b) discoloration of beach sand.

a) <u>Accumulation of debris and charcoal</u> (≥ 1 cm in size). At each sample point a collapsible wooden frame one meter square (m^2) was placed along the baseline meter tape. Within the plot frame all items considered to be human related (e.g. cigarette butts, food items, band-aids, etc.) were counted and recorded. In addition, all particles of charcoal ≥ 1 cm in size were counted and recorded. Although charcoal can be of natural occurrence, all charcoal on Glen Canyon beaches can be attributed to recreational campfires. Sand samples taken from isolated beaches (e.g. control site) where little recreational activity occurred had no significant charcoal accumulation. The litter from each m^2 was placed in appropriate containers and carried out by the Northern Arizona University group. The charcoal was returned to the site from which it was originally taken.

b) <u>Sand discoloration</u>. On each beach a dry sand sample from the surface of each study plot was collected in a whirl pack. Each sample was labeled with the beach name, river mile, and the plot number. Each sand sample was sifted through a 150 micron stainless steel mesh apparatus until the amount of sifted material covered the bottom of the collecting container. A piece of No. 7 coarse grade filter paper was placed in the lid, hatched side up, and the sifted material was shaken against the filter paper 75 times. The filter paper was removed and stored in a labeled Petri dish. When all the samples from a transect were shaken, the discoloration on the filter paper was evaluated with a Colorguard II Reflectometer and recorded on a data sheet. The Colorguard II Reflectometer is an instrument operating with an optical system, photocell amplifier, digital read-out and portable power system, and is used to make reflective measurements. Hence, with a digital read-out display reflected light can be measured from any source. The reflectometer was used to obtain reflective values from the filter paper discs which were discolored with filtrate from the sand samples. The reflectometer was standardized prior to each series of readings against a white standard and a gray standard to calibrate the instrument.

The campsite name, location, and side of river for 1981, 1983 and 1987 are presented in Table XI-1. All of the sites are located below the pre-dam highest flood terraces and none of the sites are subject to periodic inundation with current water release schedules of Glen Canyon Dam. During the late spring, early summer of 1983, however, releases from the Dam were, at times, in excess of 100,000 cfs. "Normal" dam releases are on the order of 30,000 cfs. maximum. This excessive release was primarily due to high spring run-off from throughout the Colorado River drainage area upstream. The effect of this flooding was to cleanse the beaches of human debris and charcoal, thereby creating a baseline for cleanliness from which to compare. It was noted by the 1983 survey group that there was no evidence of accumulated materials on the study areas.

Table XI-1. Campsite locations in Glen Canyon National Recreation Area.

Name of Camp	Mileage from Lees Ferry	Side of River
1981		
Water Plant	14.0	South
Ropes Trail	13.5	North
Ferry Swale	11.0	South
Faatz Camp *	10.0	North
Finger Rock	7.0	South
Three Mile Bar	3.0	North
Two Mile	2.0	North
1983		
Water Plant	14.0	South
Ropes Trail	13.5	North
Ferry Swale	11.0	South
Faatz Camp *	10.0	North
Finger Rock	7.0	South
Three Mile Bar	3.0	North
One Mile	1.0	South
1987		
Ferry Swale	11.0	South
Faatz Camp *	10.0	North
Finger Rock	7.0	South
Three Mile Bar	3.0	North
Lees Ferry (Boatman Beach)	0.0	North

* Control Beach

RESULTS

Table XI-2 presents a summary of the average values for litter accumulation, charcoal concentration and sand discoloration for the study sites during each sampling period. Faatz Camp, Number 14, Figure XI-1, serves as a common control site in each of the sampling years, as the portion of this site from which the data was taken receives no recreational use. This site is relatively inaccessible to recreationists due to a poor boat landing beach, heavy vegetation and moderately rough terrain over which individuals would have to transport their equipment. On an average, over the study period, the values for litter, charcoal, and sand discoloration at Faatz Camp indicated no litter, no charcoal and uncontaminated beach sand. When other sites are compared with Faatz Camp, it becomes apparent that human related recreational impacts are taking their toll on Glen Canyon beaches. No other beaches in the survey indicated the degree of non-use that Faatz Camp showed (Figures XI-2, XI-3, and XI-4).

Table XI-2 Identification and Quantification of Human Impact

Mile Study Site	Litter[1] 1981	Litter[1] 1983[3]	Litter[1] 1987	Charcoal[2] 1981	Charcoal[2] 1983[3]	Charcoal[2] 1987	Sand Discoloration 1981[4]	Sand Discoloration 1983[5]	Sand Discoloration 1987[5]
14.0	7.5	0.0	-	23.5	0.0	-	10.3	70.63	-
13.5	7.8	0.0	-	57.9	0.0	-	6.6	70.34	-
11.0	1.5	0.0	3.4	26.0	0.0	50.6	5.5	71.96	65.54
10.0[6]	0.1	0.0	0.0	0.1	0.0	0.0	1.2	68.82	65.88
7.0	5.3	0.0	0.0	121.8	0.0	0.8	7.6	72.53	70.04
3.0	5.3	0.0	0.2	69.0	0.0	0.2	6.7	71.86	70.86
2.0	8.0	0.0	-	89.9	0.0	-	8.2	-	-
1.0	-	0.0	-	-	0.0	-	-	72.40	-
0	-	0.0	0.2	-	0.0	10.0[7]	-	-	60.04

1 Values expressed as number of litter items per square meter.

2 Values expressed as number of charcoal particles (≥ 1cm in size) per square meter.

3 1983 litter and charcoal values are expressed as zero because beaches were cleaned by the flood.

4 Values expressed against relative scale, 1 = pure; 16 = sand completely blackened by charcoal and ash.

5 Sand discoloration values for 1981 and 1983 are based against a standard of 87.1 on the Colorguard II Reflectometer.

6 The section of Faatz Camp within which our measurements were made has been virtually unused by recreationists. Data for this site therefore serve as a control against which the other sites may be compared.

7 Charcoal is probably as a result of a non-human caused fire.

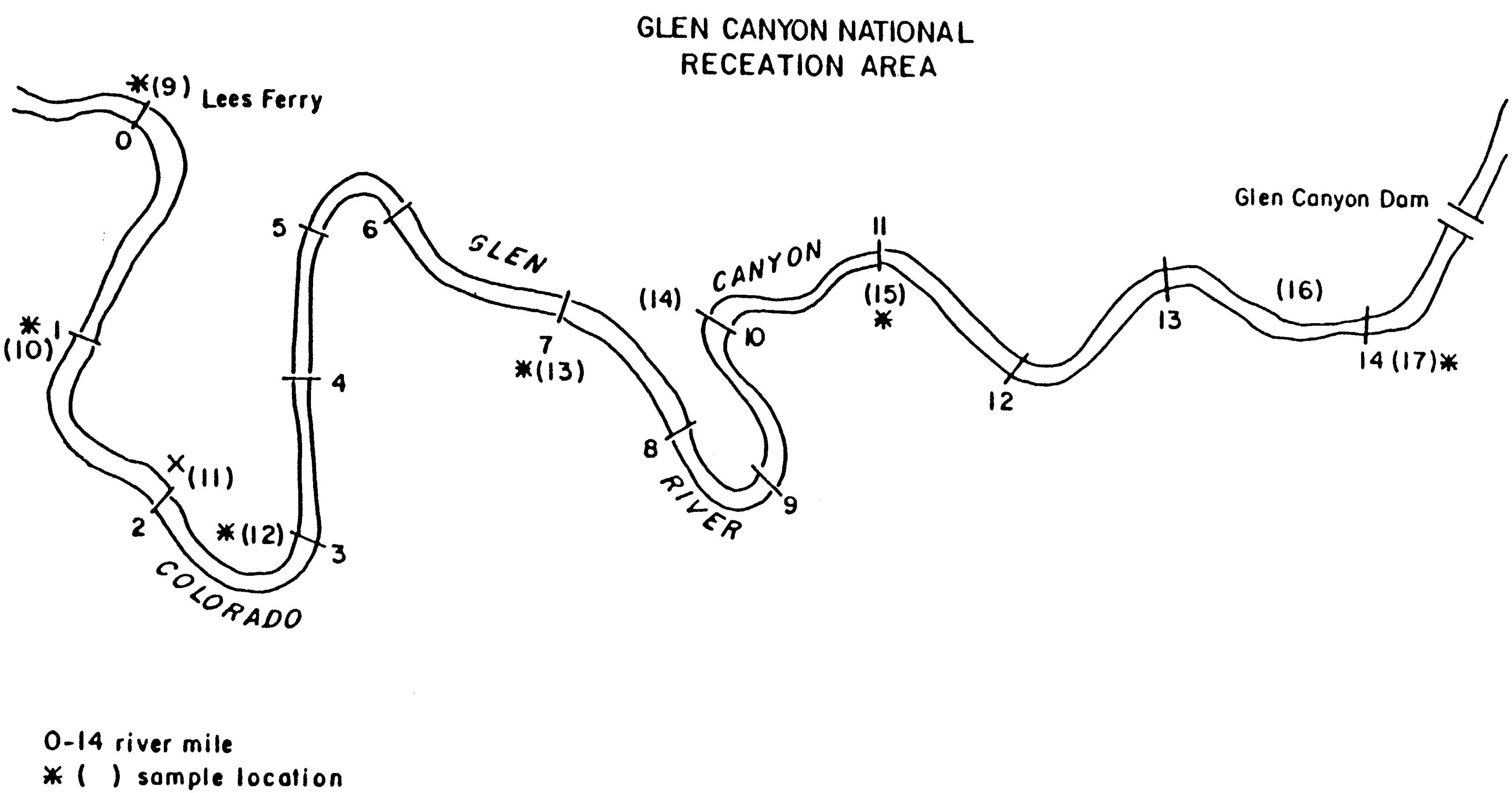
GLEN CANYON NATIONAL
RECEATION AREA
*(9) Lees Ferry
0
*1
(10)
2
X(11)
*(12)
3
4
5
6
GLEN
7
*(13)
8
RIVER
9
COLORADO
(14)
CANYON
10
11
(15)
*
12
13
(16)
14 (17)*
Glen Canyon Dam
0-14 river mile
* ( ) sample location

Figure XI-1.

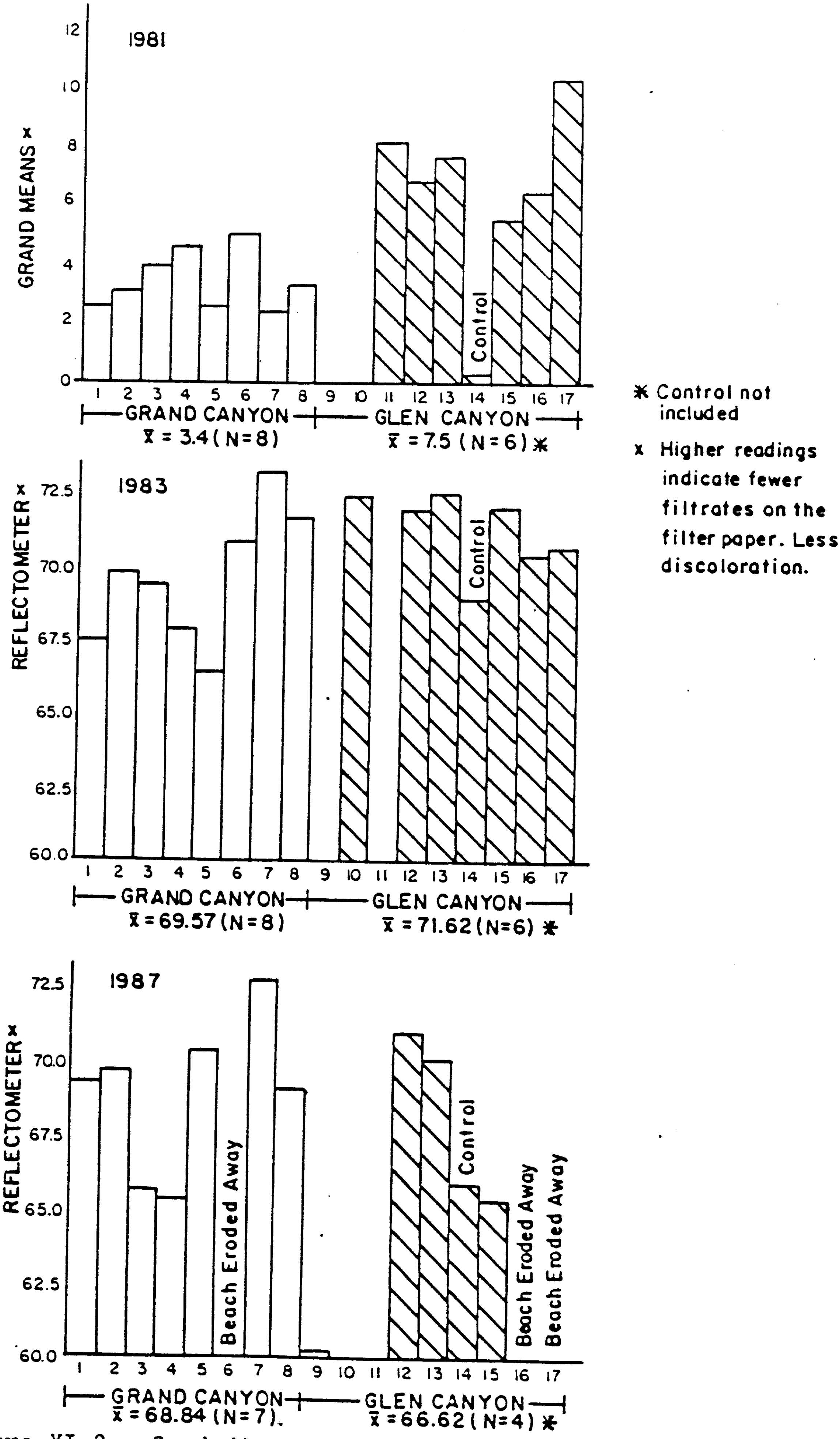

Figure XI-2. Sand discoloration, Glen Canyon and Grand Canyon beaches.

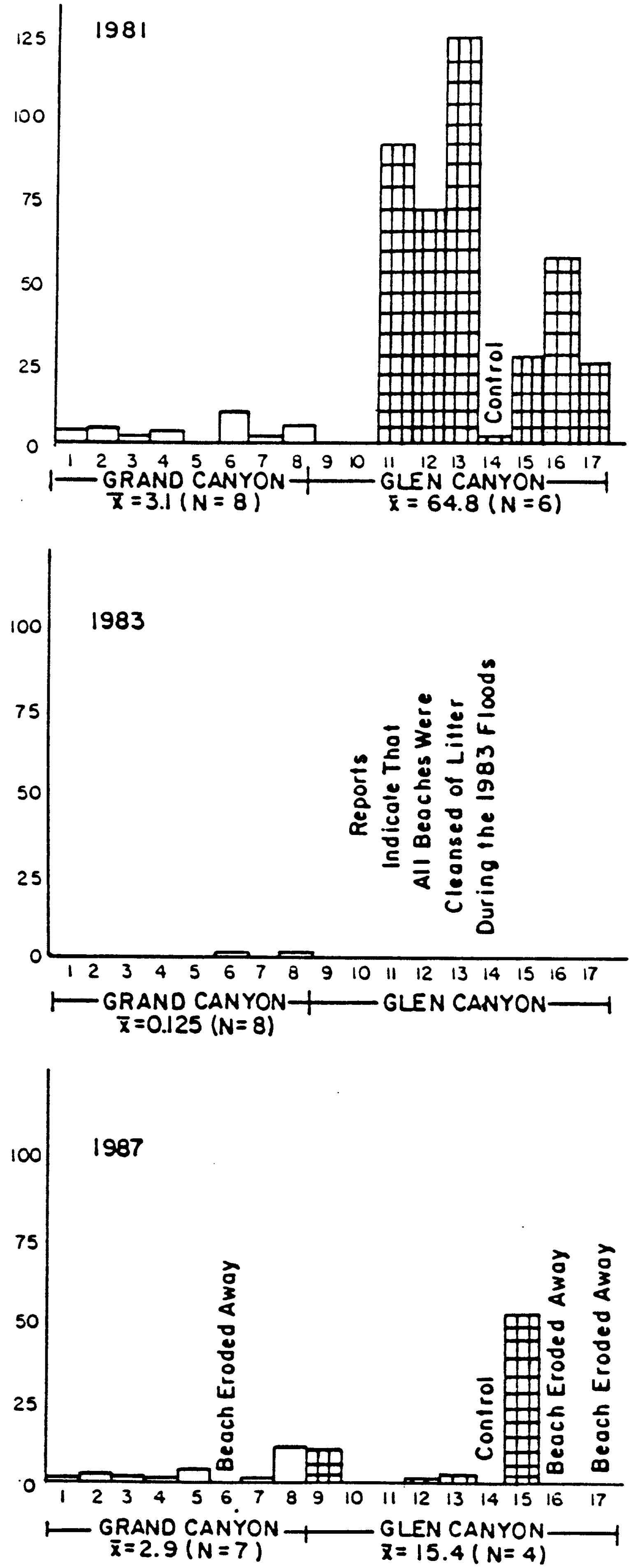

Figure XI-3. Amount of charcoal per square meter, Glen Canyon and Grand Canyon beaches.

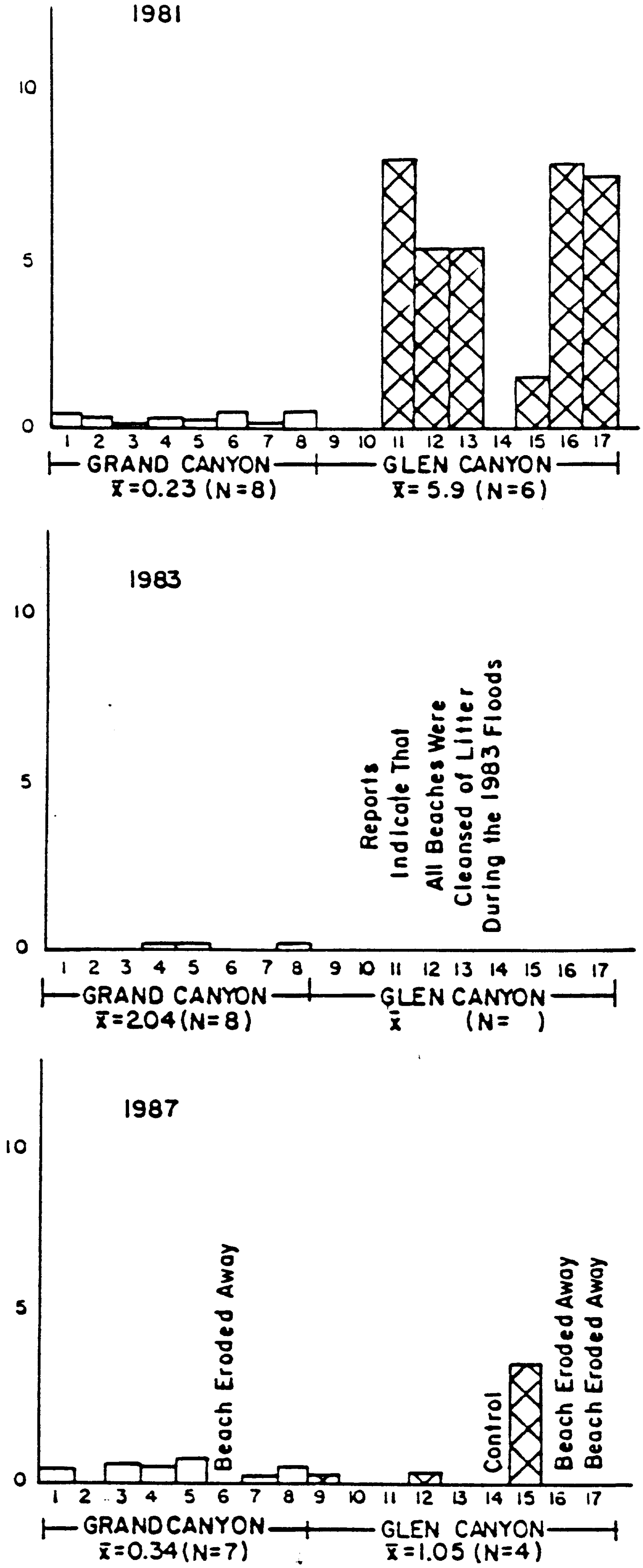

Figure XI-4. Amount of litter per square meter, Glen Canyon and Grand Canyon beaches.

An interesting aspect of the study was that the samples taken after the 1983 floods indicated no charcoal or human litter and a high degree of reflectivity. The flooding of the beaches had the effect of a cleansing action. This is further noted when the 1987 results are compared to the 1983 readings. Generally there was an increase in human litter and charcoal and a decrease in reflectivity indicating a general degradation of the beaches by human activities.

DISCUSSION

This recreational area use can be characterized by some simple observations made on two successive weekends in July 1987 by the survey team. During this time period it was noted that an average of 198 people (non-consumptive users) per day were participating in a commercial float trip from Glen Canyon Dam to Lees Ferry and that an average of 27 boat trailers per day were in the overnight parking area and 8 boat trailers per day in the use area. With an average of just over 3 people per boat, this meant that approximately 114 consumptive users could be found on the river daily. The total number of both non-consumptive and consumptive users per day equaled 313 persons. While this may not seem especially high, it represents 21 people per mile per day, hardly a wilderness experience. It should be further noted that in discussions with the National Park Service personnel at Lees Ferry, the number of boaters and float trip persons was low during this time of the year. Most boaters and a large number of float trips utilize the river and its facilities during the fall and spring.

The principal goal of our project was to analyze the Glen Canyon beaches and assess the "health" of the popular campsites as this condition is related to human recreational activities. It seems a logical extension of our study to investigate and compare the campsite conditions in the area upstream of Lees Ferry and compare the conditions with selected beaches in the downstream reach of the Colorado River below.

Comparison of the visitor use levels between the two areas is difficult to assess. Both Grand and Glen Canyons accommodate thousands of recreationists each year in the riverine habitats. The use in Grand Canyon is dispersed over an excess of 300 campsites compared with the 5 established campsites in Glen Canyon. Some "Day Use Only" beaches in Glen Canyon were also being used as campsites, as noted by the research team in 1987.

However, since fisherperson groups are generally smaller than river recreation groups in Grand Canyon, the user days per campsite is probably less in Glen Canyon. A user day is defined as one person per day per site, so that if 10 people occupied a single beach in one day, that experience would be equivalent to 10 user days. One must be cautious, however, in comparing recreational uses and resultant environmental degradation in the two National Park Service administrative units. In the first place, there are obvious and fundamental differences in the management criteria that have been established to provide guidelines for recreation uses and levels of impact tolerances between "Parks" and "Recreational Areas". Secondly, there is little question that substantial differences exist, relative to apparent environmental conscientiousness, between the average

Grand Canyon river recreationist and the average Glen Canyon river recreationist. Thirdly, agency control of river recreation use, that is private vs. commercial user allocations, are skewed far more toward commercial use in Grand Canyon than in Glen Canyon (Carothers, et al., 1976; Carothers and Johnson, 1980; Carothers et al., 1981).

The differences in conservation/preservation attitudes of the Grand Canyon vs. Glen Canyon river recreationists are probably very real and relevant to any present differences in resource quality between the two areas. The majority of the consumptive recreationists in Glen Canyon go to the area in pursuit of a "trophy", perhaps in addition to the recreational experience for its own sake. Most of these fisherpersons are not prepared or conditioned to "leave no signs of their passing" as they utilize campsites. In Grand Canyon, by comparison, the recreationists are required to be almost fanatical in their treatment of beach resources. Also, agency control of regulation implementation is virtually guaranteed in Grand Canyon, as the majority of use is commercial, and in theory, outfitter permits could be withdrawn if regulation compliance was disregarded. This was best exemplified in 1977 when the administrators of Grand Canyon found it necessary to require outfitters and private parties alike to haul out their wastes (see Carothers, 1977).

The campable beaches of Glen Canyon have, through simple overuse and unconscious misuse, reached a point of deterioration that is clearly not in step with usual National Park Service Resource Management policy. While the flood of 1983 cleansed the beaches, they are slowly but definitely approaching the dirtiness that existed prior to the 1983 inundations. Most of the beaches are dirty, and with each passing season, they will become significantly more degraded. Evidence even exists that some areas are sufficiently dirty that even the trophy-seeking fisherpersons refuse to use them, e.g. the tents in "Day Use Only" areas.

The quantitative data of the Glen Canyon beach conditions suggests a definite need for a comprehensive recreational use management plan designed to eliminate the practices causing present resource deterioration.

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CHAPTER XII

HUMAN IMPACT ON THE BEACHES OF THE COLORADO RIVER IN GRAND CANYON

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Sandra Kyle and Rosemary Bernstein

INTRODUCTION

Within the past 20 years two major and distinctly interrelated natural resource management problems have arisen along the river corridor of the Colorado River in Grand Canyon National Park. Specifically, the problems relate to: 1) the extensive environmental changes that have taken place in the hydrological characteristics of the river as a result of Glen Canyon Dam, and 2) the dramatic increase in recreational use of the systems by river runners.

Although located 15 miles upstream of the national park boundary, Glen Canyon Dam changed the very nature of the Colorado River in Grand Canyon almost as soon as construction began in the mid 1950s. Post-dam changes in water flow, temperature, and sediment discharge have all combined, often synergistically, to alter the Grand Canyon river ecosystem. On one side of Glen Canyon Dam, the wildly variable and raging Colorado River has been buried beneath the deep waters of Lake Powell; on the other side, the river we still call the Colorado is now released through turbines and gates as a predictable, computer-regulated, icy cold, sediment-free, and partially tamed river. To further complicate the matter, the "new" dam-controlled Colorado River in Grand Canyon has recently proven to be one of the most popular white-water recreation areas in the world, with a strict National Park Service permit system regulating and allocating both private and commercial use of the 225 miles of Colorado River from Lees Ferry to Diamond Creek (NPS 1981). The high waters and ensuing floods of 1983 unexpectedly disrupted the stabilizing patterns of water flow established during the past 20 years.

Given the above considerations, the present challenges to developing an adequate system for resources management along the river corridor of Grand Canyon National Park includes: a) determining the eventual ecological "steady state" of the dam-altered river in terms of sediment erosion and deposition, vegetation and animal community composition, and overall ecosystem stability; b) determining and evaluating the impacts of river recreationists on the changing aquatic and terrestrial systems; and c) mitigating such recreational impacts to the extent that natural park values are not compromised.

As mandated by "The Planning Process of the National Park Service in 1975, a Colorado River Management Plan (NPS 1981) was drafted to guide short- and long-term management of the riverine and riparian areas of Grand Canyon National Park. Subsequently, a monitoring program was initiated to analyze and quantify human impacts and to determine how changes in management policies influence present resource trends. This monitoring program was designed to gather baseline data and show the impact (adverse and otherwise) of visitor numbers and use patterns on the riparian environment.

Preliminary data from Grand Canyon (Carothers and Aitchison 1976) indicated that similar changes or impacts were taking place on the principal 100 plus campsites of the river corridor. All of these campsites are on alluvial terraces (sand and silt/sand composition) that were deposited during pre-dam flood discharges. In the 20 years prior to 1983, vegetation previously scoured from the beaches on an annual basis proliferated, while human related debris incorporated into beach sands during normal camping activities accumulated. With no natural purging of recreation related debris (organic as well as inorganic) there existed the potential for popular beaches to fill "cat box style" with any number of forms of human waste products. Additional problems of a similar vein have recently been observed in backcountry campsites where recreational use is clearly in excess of the natural purging capacity of the system.

In an effort to clean up the beaches, the Colorado River Management Plan requires that all wood and charcoal carried into the Canyon by river recreationists be burned in fire pans and the ashes be carried out. Gas stoves are now required for most cooking purposes. Regulations also require all river users to haul out solid human wastes.

The 1983 floods cleaned the beaches, resorted the sand, and gave the system a fresh start. Along with this cleansing, new beaches formed and others disappeared. The 1983 study established important baseline data for future investigations. These data are the control for this study.

Early in 1976, approximately 25 Colorado River campsites in Grand Canyon were selected for the purpose of monitoring levels of recreational impact (see Carothers 1977). In 1980-81, nine additional beaches in the 15 miles of Glen Canyon below Glen Canyon Dam were evaluated for levels of human impact (Carothers et al. 1981). Since 1976, the original Grand Canyon sites have been monitored and re-evaluated several times (Carothers and Johnson 1980). In 1982, human impact data for 35 beach sites in Glen and Grand Canyons were presented and compared with the results of previous sampling efforts.

In 1983, human impact data for 22 Grand Canyon beach sites, included 17 of the beaches evaluated in 1982 and five new beaches, were compared to the 1982 data. Eleven of the original beaches were no longer comparable in 1983 and were dropped from the study. In 1984, two previously studied beaches were not included: however, seven new beaches were added. The beaches which were deleted or added in the 1985, 1986, and 1987 studies are indicated in the tables.

OBJECTIVES

The objectives of this 1987 study are 1) to collect data on the degree of sand discoloration and the incidence of charcoal and human litter present on Colorado River beaches in the Grand Canyon, and 2) to compare those data with the findings from similar studies conducted in 1983, 1984, 1985, and 1986 to determine the human impact on the beaches in the years following the flood. It was hypothesized that human use in these years had resulted in a significant increase in sand discoloration, and in charcoal and litter on the beaches.

METHODS

1. A 40 meter transect line was run through the principal use area of the beach along the same upstream-downstream line established in previous years. If the beach had been so altered by the river as to change patterns of use, a new transect line was established and documented. If a 40 meter transect line could not be established, the longest possible line was run and the distance recorded.

2. Black and white photographs of the transect, including the metric tape and river mile marker, were taken from upstream and downstream directions. The river mile number was written on a chalkboard and positioned in the sand for inclusion in the photograph.

3. Ten $1m^2$ plots were laid out equidistant from each other in an alternating pattern along the transect line.

4. Each $1m^2$ plot was inspected by hand sifting through the surface sand, and pieces of charcoal of 1 cm or over and all pieces of human litter found in the plot were counted, recorded, and removed. A dry sand sample from the surface of each plot was collected in a whirl pack. If damp sand was unavoidable, it was collected to be dried out later. Each sample was labeled with the beach name, the river mile, and the plot number. Plots were numbered 1-10, beginning upstream.

5. Sand samples, charcoal and human litter, were also collected at the sand/water interface and from the terrace above the beach at the old high water line.

6. Each sand sample was sifted through a 150 micron stainless steel mesh apparatus until the amount of sifted material completely covered the bottom of the apparatus.

7. A piece of No. 7 course grade filter paper was place in the lid, hatched side up, and the sifted material shaken against the filter paper 75 times.

8. The filter paper was removed with tweezers, and stored in a labeled petri dish. The apparatus was then cleaned by swirling sand around inside the containers and discarding the sand.

9. When all of the samples from a transect were shaken, the discoloration on the filter paper was evaluated with a Colorguard II Reflectometer and recorded on a data sheet.

> The Colorguard II Reflectometer is an instrument operating with an optical system, photocell amplifier, digital readout and portable power system, and is used to make reflective measurements. Hence, with a digital readout display, reflected light can be measured from any source. The reflectometer was used to obtain reflective values from the filter paper discs which were discolored with filtrate from the sand samples. The reflectometer was standardized prior to each series of readings against a white standard and a grey standard to calibrate the instrument.

10. Means and standard deviations of the reflectometer readings from the ten transect samples were calculated for each beach. These were then tabulated with the 1982, 1983, 1984, 1985, and 1986 data. A small sample two-tailed t test for a 0.05 level of significance was calculated for the differences between the 1987 data and all years from 1983 to 1986.

RESULTS

Twenty-four beaches were sampled in 1987. The levels of sand discoloration as measured by reflectometer readings are presented in Table XII-1. For purpose of comparison, these data are presented with equivalent figures from 1983, 1984, 1985, and 1986. Due to available for erosion and/or change in vegetation, six beaches were deleted from the study and the transect line on one beach was changed. One additional beach was added to the study but no previous data is available for comparison. One beach was occupied and deleted from the 1987 study due to river protocol. Twenty-three beaches were compared between 1986 and 1987. The differences in sand discoloration between 1986 and 1987 are as follows (see Table XII-2): Two beaches showed a significant increase in discoloration, Twelve showed a significant decrease in discoloration, and six showed no significant difference in discoloration. Twenty-two beaches were compared between 1985 and 1987. One beach could not be compared due to a lack of data from 1985. The differences in sand discoloration between 1985 and 1987 are as follows: Three beaches showed a significant increase in sand discoloration, seven showed a significant decrease in discoloration, and eight beaches showed no significant difference. Nineteen beaches ere compared between 1984 and 1987. Four beaches could not be compared due to lack of data from 1984. The differences in sand discoloration area as follows: one beach showed a significant increase in discoloration, ten showed a significant decrease in discoloration, and eight showed no significant difference in discoloration. Nineteen beaches were compared between 1984 and 1987. Four beaches could not be compared due to lack of data from 1983. Of the nineteen beaches that were tested in both 1983 (the year the flood cleansed the beaches) and 1985, nine showed a significant increase in sand discoloration, six showed a significant decrease in discoloration, and four showed no significant difference in discoloration. A composite of the means for all beaches tested were compared for all years between 1983 and 1987 (Tables XII-2.4 and 2.5). There was a significant decrease in sand discoloration between 1983 and both 1984 and 1985. There was significant increase in sand discoloration between 1984 and 1987, and 1985 and 1987. There was no significant change in sand discoloration between the years 1983 and both 1986 and 1987, 1984 and both 1985 and 1986, 1985 and 1986, 1986 and 1987. There is a significant difference in all 1987 samples and the clean filter paper in 1987, which acted as a control (Table XII-2.6). There are no significant differences in sand discoloration between the sample beaches and terraces in 1987.

Table XII-1. Results of sand discoloration analysis of beach campsites in Grand Canyon, 1983-1987 (means only).

Site No.	Campsite Name	River Mile	Sand Discoloration (Standard Deviation) 1983 (S.D.)	1984 (S.D.)	1985 (S.D.)	1986 (S.D.)	1987 (S.D.)
1	Badger Rapid	8.0	71.65 (1.65)	69.69 (2.52)	70.55 (1.82)	59.65 (5.59)	69.03 (3.95)
2	20 Mile	20.0	66.74 (3.53)	68.78 (3.14)	64.29 (3.07)	67.47 (4.54)	69.20 (2.19)
3	Shinumo Wash	29.0	70.01 (3.00)	69.10 (3.16)	68.62 (3.03)	68.24 (5.14)	72.57 (1.95)
4	Anasazi Bridge	43.5	73.28 (1.24)	70.55 (1.83)	71.13 (1.80)	71.61 (1.79)	72.72 (2.24)
5	Lower Nankoweap	53.0	73.21 (2.33)	64.91 (3.16)	69.33 (2.66)	66.67 (3.51)	71.36 (1.85)
6	Awatubi	58.1	72.40 (1.34)	64.48 (5.73)	66.97 (3.31)	64.96 (4.21)	70.90 (2.46)
7	Lava Canyon (Chuar)	65.5	70.66 (0.83)	65.91 (4.05)	68.56 (3.81)	67.24 (2.87)	beach gone
8	Unkar (gone)	72.2	68.93 (2.67)	67.70 (2.28)			
9	Nevills Rapid	75.5	72.00 (1.91)	66.80 (4.87)	72.21 (1.35)	70.94 (2.98)	69.77 (3.12)
10	Hance Rapid	76.5		66.87 (5.14)	63.82 (2.92)	65.00 (4.12)	69.12 (3.56)
11	Grapevine	81.1	71.91 (1.43)	67.62 (2.18)	67.39 (2.95)	69.38 (3.95)	71.25 (1.04)
12	Granite Rapid	93.2	68.20 (2.49)	68.48 (3.28)	62.35 (3.50)	68.55 (2.06)	67.52 (1.40)
13	Lower Bass Camp	108.5	66.53 (2.39)	63.38 (5.69)	64.46 (1.69)	67.87 (3.71)	70.31 (3.46)
14	114 Mile	114.0		69.22 (2.06)	63.77 (2.39)	71.44 (2.30)	deleted
15	122 Mile	122.0		71.16 (2.15)	68.55 (2.65)	71.44 (2.30)	beach gone
16	Forster	122.8	70.04 (3.05)	68.65 (5.16)	69.74 (0.74)	73.27 (1.93)	67.98 (1.43)
17	Bearock	131.0		70.54 (3.40)	68.20 (2.02)	71.50 (1.64)	69.49 (1.68)
18	Dubendorff	132.0	69.12 (3.36)	70.22 (2.51)	69.63 (2.35)	69.62 (1.76)	71.07 (2.51)
19	Deer Creek	136.0	67.82 (2.03)		65.46 (1.38)	66.68 (2.16)	65.43 (2.30)
20	Poncho's Kitchen	137.0	65.91 (3.11)	65.90 (3.79)	67.20 (3.81)	69.43 (3.04)	69.32 (2.00)
21	Upper National Canyon	166.5	71.22 (0.96)	68.95 (3.00)	73.31 (0.98)	beach gone	beach gone
22	Lower National Canyon	166.6	69.39 (2.73)	63.59 (3.00)	67.10 (2.42)	69.23 (1.66)	65.62 (2.17)
23	Lower Lava Falls	179.0	69.39 (2.60)		67.74 (1.65)	67.63 (2.92)	72.87 (3.17)
24	186 Mile	186.0		72.06 (1.50)	70.95 (2.18)	69.54 (1.23)	71.43 (1.11)
25	195 Mile	195.0					71.91 (1.71)
26	Parashant	198.5		63.94 (4.77)	68.39 (2.68)	beach gone	beach gone
27	Indian Canyon	207.0				71.09 (1.52)	72.18 (2.11)
28	Granite Park	208.8	69.70 (3.78)	68.93 (2.17)	69.88 (2.13)	69.97 (2.48)	69.56 (4.52)
29	Pumpkin Bowl	213.0	73.66 (0.94)	70.83 (1.75)	68.63 (2.41)	69.54 (1.81)	69.17 (2.60)
30	Trail Canyon	219.0		72.18 (1.45)	68.78 (3.38)	beach gone	beach gone
31	220 Mile	220.0	67.50 (2.61)	67.71 ( )	66.93 (2.28)	68.67 (1.74)	69.18 (1.94)

Table XII-2. t test for level of significance of differences between 1984 and 1987 sand discoloration measurements for Grand Canyon beaches. t test significance level is 2.101.

Campsite Number	Campsite Name	t Value				Significant Difference Compared to			
		1983	1984	1985	1986	1983	1984	1985	1986
1	Badger Creek	3.502	0.820	2.001	9.603	Yes	No	No	Yes
2	20 Mile	3.253	0.575	6.770	9.603	Yes	No	Yes	Yes
3	Shinumo Wash	3.641	4.859	5.594	5.140	Yes	Yes	Yes	Yes
4	Anasazi Bridge	0.950	3.406	2.499	5.186	No	Yes	Yes	Yes
5	Lower Nankoweap	2.863	9.123	3.020	6.402	Yes	Yes	Yes	Yes
6	Awatubi	2.435	7.838	2.066	5.178	Yes	Yes	No	Yes
7	Lava Canyon (Chuar 3)	the beach is gone							
8	Unkar	the beach is gone							
9	Nevills Rapid	3.145	3.325	3.647	1.497	Yes	Yes	Yes	No
10	Hance Rapid	no data	2.414	6.583	4.701	No	Yes	Yes	Yes
11	Grapevine	1.330	6.402	6.105	2.645	No	Yes	Yes	Yes
12	Granite Rapid (Granite 4)	1.091	1.403	7.385	1.751	No	No	Yes	No
13	Lower Bass Camp	4.947	7.248	8.147	2.880	Yes	Yes	Yes	Yes
14	114 Mile	no data	delete - river protocol						
15	122 Mile	the beach is gone							
16	Forster	3.198	0.924	3.949	9.263	Yes	No	Yes	Yes
17	Bedrock	no data	1.474	2.118	3.484		No	Yes	Yes
18	Dubendorff	2.545	1.200	2.064	2.217	Yes	No	Yes	Yes
19	Deer Creek	3.632	no data	0.049	1.870	Yes		No	No
20	Poncho's Kitchen	4.775	4.500	2.780	0.154	Yes	Yes	Yes	No
21	Upper National Canyon	the beach is gone							
22	Lower National Canyon	5.385	2.823	2.183	5.831	Yes	Yes	Yes	Yes
23	Lower Lava Falls	4.584	no data	0.833	2.591	Yes		No	Yes
24	186 Mile	no data	1.235	0.836	3.902		No	No	Yes
25	195 Mile	no data - new beach							
26	Parashant	the beach is gone							
27	Indian Camp		no data		1.810				No
28	Granite Park	0.153	0.771	0.392	0.490	No	No	No	No
29	Pumpkin Bowl	7.538	2.518	0.762	0.557	No	Yes	No	No
30	Trail Canyon	the beach is gone							
31	220 Mile	2.492	no data	3.463	0.840	Yes		Yes	No

Table XII-2.4. Composite results of sand discoloration analysis of all campsites sampled in Grand Canyon, 1983-1987 (means only).

	Sand Discoloration				
	1983	1984	1985	1986	1987
# Campsites (n) =	22	27	28	26	24
$\bar{x}$ =	69.96	68.07	67.99	68.71	69.95
s =	2.27	2.55	2.64	2.76	2.01

Table XII-2.5. t test for level of significance of differences between the composite means of sand discoloration measurements for Grand Canyon beaches, 1983-1987. t test significance level is 2.010.

Years	df	t value	Significant difference
1984-1983	47	2.723	Yes
1985-1983	48	2.814	Yes
1986-1983	46	1.763	No
1987-1983	44	0.015	No
1985-1984	53	0.111	No
1986-1984	51	0.879	No
1987-1984	49	2.785	Yes
1986-1985	52	0.980	No
1987-1985	50	2.878	Yes
1987-1986	48	1.797	No

Table XII-2.6. t test for level of significance of differences between the sand discoloration of the beaches, terraces, and filter papers and the sand discoloration samples for the Grand Canyon for 1987. t test significance level is 2.010.

Campsites (n) = 24 df = 46

	Sand Samples	Beaches	Terraces	Filter Paper
mean ($\bar{x}$)	69.95	70.81	70.10	74.11
Standard deviation (s)	2.00	3.59	3.28	1.44

Charcoal and human debris accumulations are presented in Table XII-3. The differences in charcoal levels between 1987 and 1986 are as follows: thirteen beaches showed an increase, six beaches showed a decrease, and three beaches showed no change. The differences in charcoal levels between 1987 and 1985 are as follows: fifteen showed an increase, five showed a decrease, and three showed no change. The differences in charcoal levels between 1987 and 1984 area as follows: thirteen showed an increase, three showed a decrease and four showed no change. The differences in charcoal levels between 1987 and 1983 are as follows: fifteen showed an increase, no beaches showed a decrease, and four beaches showed no change.

The difference in human debris levels between 1987 and 1986 are as follows: eleven beaches showed an increase, seven beaches showed a decrease, and five beaches showed no change. The difference in human debris levels between 1987 and 1985 are as follows: fourteen beaches showed an increase, three beaches showed da decrease, and five beaches showed no change. The differences in human debris levels between 1987 and 1984 are as follows: eleven beaches showed and increase, four beaches showed a decrease, and five beaches showed no change. The differences in human debris levels between 1987 and 1983 are as follows: fifteen beaches showed an increase, one beach showed a decrease, and four beaches showed no change. The results of a t test showed no significant differences between the levels of charcoal between the transect samples and the beaches or terraces. The levels of human debris showed no significant differences between the transect samples and the beaches or terraces for 1987. There was a significant difference between the levels of charcoal and human debris of the transect samples for 1987 (Table 3.1). No comparisons could be made to previous years due to lack of data.

CONCLUSION

The Colorado River beaches in 1987 appear to have suffered a deterioration in cleanliness compared to previous years. The results of the sand discoloration tests show a slow but steady deterioration from 1984 through 1987. The most significant changes are seen between 1987, and both 1984 and 1985. there is no significant difference in sand discoloration between 1986 and 1987. This study indicates that the level of charcoal and human litter found on the beaches are steadily increasing. The levels of charcoal found compared to human litter for 1987, are significantly greater. This data indicates that the increasing levels of charcoal found, may be responsible for the increased sand discoloration, and the deterioration of the beaches. Due to variables encountered during the field testing, it is impressive to find that over the five year study, with a very large number of samples, the results have been very consistent and significant.

The results of this study support that initial hypothesis that Grand Canyon camping beaches have deteriorated since the 1983 flood scoured them clean. This is attributed to human use.

Table XII-3. Results of charcoal and human litter accumulations analysis of beach campsites in Grand Canyon 1983-1987 (means only).

Beach No.	Campsite Name	River Mile	Charcoal cm/m2 1983	1984	1985	1986	1987	Human Litter m2 1983	1984	1985	1986	1987
1	Badger Rapid	8.0	0.8	2.5	0.2	0.2	10.4	0.1	0.2	0.0	0.3	0.4
2	20 Mile	20.0	0.1	0.0	0.3	0.0	0.2	0.0	0.2	0.2	0.0	0.0
3	Shinumo Wash	29.0	0.0	0.0	0.0	0.0	0.6	0.0	0.1	1.0	0.1	0.5
4	Anasazi Bridge	43.5	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.1
5	Lower Nankoweap	53.0	0.0	0.2	0.6	0.6	6.9	0.0	0.4	0.0	0.0	0.8
6	Awatubi	58.1	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.3	0.1	0.5
7	Lava Canyon (Chuar)	65.5	0.1	1.6	1.3	4.5	beach gone	0.0	0.3	0.0	0.2	beach gone
8	Unkar	72.2	0.0	0.2	beach gone			0.0	0.1	beach gone		
9	Nevills Rapid	75.5	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
10	Hance Rapid	76.5		0.2	0.9	1.5	3.6		0.0	0.0	0.0	0.2
11	Grapevine	81.1	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
12	Granite Rapid	93.2	0.0	0.0	0.0	0.0	2.1	0.1	0.0	0.0	0.4	0.2
13	Lower Bass Camp	108.5	0.0	1.5	0.4	0.5	3.8	0.1	2.2	0.0	0.5	0.6
14	114 Mile	114.0		0.2	0.0	0.1	delete		0.1	0.0	0.5	delete
15	122 Mile	122.0		0.0	0.0	1.0	beach gone		0.3	0.2	0.1	beach gone
16	Forester	122.8	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
17	Bedrock	131.0		0.0	0.3	0.5	0.0		0.1	0.0	0.1	0.0
18	Dubendorff	132.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.3
19	Deer Creek	136.0	0.2		2.0	1.8	1.0	0.1		0.0	0.6	0.4
20	Poncho's Kitchen	137.0	0.0	0.0	0.1	1.3	0.8	0.0	0.4	0.1	0.8	0.4
21	Upper National Canyon	166.5	0.0	0.0	0.0	beach gone		0.0	0.2	0.2	beach gone	
22	Lower National Canyon	166.6	0.0	0.0	0.0	0.2	1.3	0.0	0.0	0.2	0.7	0.5
23	Lower Lava Falls	179.0	0.3		0.7	1.6	3.7	0.0		0.0	0.9	0.0
24	186 Mile	186.0		0.2	0.6	0.8	0.0		0.0	0.0	0.0	0.0
25	Parashant	198.5		0.0	0.0	beach gone			0.2	0.3	beach gone	
26	145 Mile	145.0					0.0					0.1
27	Indian Camp	207.0					0.0				0.0	0.1
28	Granite Park	208.8	0.0	0.1	0.0	1.2	1.9	0.0	0.1	0.0	0.1	0.1
29	Pumpkin Bowl	213.0	0.0	0.0	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.0
30	Trail Canyon	219.0		0.1	0.0	beach gone			0.0	0.0	beach gone	
31	220 Mile	220.0	0.0	0.4	0.0	0.0	1.4	0.0	0.2	0.0	0.0	0.4

Table XII-3.1. t test for level of significance of differences between charcoal and human litter measurements for Grand Canyon, 1987. t test significance level is 2.01.

		Charcoal	(STD Dev)	Human Litter	(STD Dev)
# beach samples (n)	=	24		24	
mean samples $\bar{x}_S$	=	1.65	(2.52)	0.23	(0.23)
mean of beaches $\bar{x}_B$	=	3.16	(8.73)	0.21	(0.41)
mean of terraces $\bar{x}_T$	=	1.41	(3.33)	0.29	(0.62)

Comparison	t Value	df	t test	significant difference
charcoal $\bar{x}_S : \bar{x}_B$	1.42	46	1.42	No
charcoal $\bar{x}_S : \bar{x}_T$	0.31	46	0.31	No
human litter $\bar{x}_S : \bar{x}_B$	0.08	46	0.08	No
human litter $\bar{x}_S : \bar{x}_T$	0.21	46	0.21	No
charcoal human litter $\bar{x}_S : \bar{x}_S$	2.73	46	2.73	Yes

STATISTICAL METHODS

The student must calculate for each data set (sand discoloration, charcoal contamination, and human litter) from each beach the following: a) the mean or average to determine the central tendency of the sample, b) the standard deviation to measure the degree of variability in the sample, and c) the t value to determine whether the difference between this year's results and a previous year's results is significant.

Notation

$\bar{x}$ = datum (single sample)

$\bar{x}$ = mean or average of data

n = number of samples

n-1 (or DF) = degree of difference (statistical device used to adjust for inherent bias in sampling)

s = standard deviation

Σ = sum

Procedure

For each data set:

Step 1. Calculate mean

$$\bar{x} = \frac{\Sigma x}{n}$$

Step 2. Calculate standard deviation

$$s = \sqrt{\frac{\sum x^2 - (\sum x)^2/n}{n - 1}}$$

Step 3. Calculate standard error

$$s\bar{x}_1 - \bar{x}_2 = \sqrt{\frac{s^2_1}{n_1} + \frac{s^2_2}{n_2}}$$

Step 4. Calculate t value

$$t = \frac{\bar{x}_1 - \bar{x}_2}{s\bar{x}_1 - \bar{x}_2}$$

Step 5. Compare calculated t value to critical t value from table. Critical value is at axis of level of significance (.05) and degree of difference $(n - 1)_1 + (n - 1)_2$. If the calculated value is larger than the critical value, there is a significant difference between the means. If the calculated value is smaller than the critical value, there is not a significant difference between the means.

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CHAPTER XIII

TEMPERATURE GRADIENTS OF SELECTED BEACHES ALONG THE COLORADO RIVER BETWEEN LEES FERRY AND DIAMOND CREEK

Mary M. Graf

INTRODUCTION

Temperature has long been a topic of interest in the Grand Canyon region. While past studies have concentrated on areas of population in the area, such as Lees Ferry, Phantom Ranch and Pierce Ferry (Seller, et. al., 1985 and Green, 1962 and 1964) it has been only recently that research on actual beach sites within the Grand Canyon has occurred (Smith IN Beus and Carothers, 1985, and Weber IN Beus and Carothers, 1986).

Air and surface temperatures, in part, regulate animal and reptile movements, and impact upon the human visitors to the canyon corridor, too. Plant distribution is affected by temperature gradients; the entire ecological system of the Colorado River is tied into the fluctuations of weather and temperature. It is therefore of interest to continue study and gain a better understanding of theat the time of placement. Wet/dry readings were taken with a sling psychrometer at river's edge and at the talus slope edge both in the evening and the following morning. Dew point and relative humidity were then figured from these readings using a standard scale. Soil thermometers measured soil temperature 4 inches (10.3 cm) below ground surface at the stations nearest and farthest from the river. These readings were taken in the evening and again in the morning.

River temperatures were taken in the evening 39.5 inches (1m) from shore. However, due to the variation in river depth 1m from shore, these readings may not accurately reflect the actual mid-channel river temperatures used in this study in 1985 and 1986.

Readings in all areas at National Beach (RM 166.6) were taken twice, during a two night stop at that location.

RESULTS

As expected, variations in temperature existed at all beaches sampled. The hours from 6-7p.m. to 6-7a.m. the following morning exhibited these variations over the hours when camper use would be the highest.

Comparing temperature recordings of highs and lows at river's edge to those taken at the edge of the talus slope, supports the idea that temperatures farther from the river tend to be higher (Table XIII-1). The greatest difference was seen at National Beach (RM 166.6). Both days of readings show a wide variation between highs and lows; Day 1 showed an 18°F difference in high readings over the 36m transect from river to talus. Day 2 showed a 20°F difference for the same reading. Lows exhibited a like difference, with Day 1 lows from river's edge to talus, 13°F variation. Because of rain, Day 2 exhibited only a 3°F difference overall in low readings.

The transect at Cremation Canyon (RM 87.0) showed the smallest difference between stations; only 4°F reading for the lows. This was the shortest transect, of just 14m.

The pattern appeared to hold true for each beach. The lowest readings were consistently near the water's edge, and the higher readings nearer the talus slope. Where the edge of the talus was shaded for much of the day (RM 194.0), readings taken at the station next to talus station supported these findings.

Of interest to beach users is the difference found between a camp near the river's edge and the nearest talus slope. On average for all beaches, there was a 10°F difference in high recordings between the river and talus. Lows taken from the river to talus transect averaged 7°F difference overall. The beach with the greatest difference between river and talus was National (RM 166.6). Highs on both evenings showed an 18°F difference between river and talus, and a 20°F difference on Day 22. This beach used a 36m transect. The 14m beach of Cremation Canyon at RM 87.0 showed the smallest difference of 4°F between river and cliff face.

Findings appear to support the hypothesis that temperature on a given beach is a factor of distance from the cooling influences of the river. The highest temperatures found in this August study were those farthest from the beach and located closest to the talus edge of the beach.

Humidity readings were highest in the mornings, and averaged about 46% higher overall than the lower evening readings. There appeared to be no significant difference in the humidity readings taken at river's edge and then again taken on the talus slope edge. Humidity change appears to be a factor of time of day, rather than location, at least for the beach camp areas.

The average temperature for the trip was a high of 87°F and a low of 65°F. While these temperatures may seem low for August, these are evening readings, taken in the 12 hours that campers are most likely to occupy the beaches. The high readings tended to come in the evenings (6-7p.m.) after the thermometers were placed, and the lows early in the morning hours before the 6-7a.m. readings were taken.

CONCLUSION

As supported by the findings, the highest temperatures overall tended to be the highs recorded at the talus edge, farthest from the river. The beaches with more depth posted more of a temperature difference than the narrowest transects, such as RM 87.0. Variations in lows displayed the same tend, but showed a small fluctuation of difference overall than the high readings.

As slope was shown in the 1985 study to have no significant effect on the temperature readings, the slope reading was noted for recording purposes only. Because water temperature measurements could not be taken consistently in mid-channel as in years past, these readings were not figured into the study, but

Table XIII-1. Summary of Temperature Data.

River Mile	Lenghth	River Edge Hi	River Edge Low	Talus Edge Hi	Talus Edge Low	PM Humidity	AM Humidity	Slope	Average Hi	Average Low
20.0	40M	88	68	88	72	39.5%	63%	4.6°	88.4	70.6
53.0	48M	80	64	88	70	40.5%	81%	5.8°	83.2	66.9
63.5	60M	67	64.5	82.4	66	50.0%	74%	4.2°	83	68.5
87.0	14M	102	74	106	78	18.0%	56.5%	3.9°	104	76
120.0	47.5M	80	64	86	82	61.0%	61%	5.7°	84	74
166.6#	36M	86	77	104	90	21.0%	42.5%	2.4°	92	85
166.6	36M	84	69	104	72	100%	66.5%	2.4°	92.5	70.8
194.0	84M	92	62	75*	70*	30.5%	69%	2.1°	93	96.6
220.0	48M	86	70	98	78	24.0%	61%	1.72°	98.4	77.7

Two days were spent at beach 166.6

* Shaded most of the day, about 25° less than other station readings

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As slope was shown in the 1985 study to have no significant effect on the temperature readings, the slope reading was noted for recording purposes only. Because water temperature measurements could not be taken consistently in mid-channel as in years past, these readings were not figured into the study, but recorded on the field notes for reference.

As August tends to be the rainy season, one or two rainy day readings would skew the humidity averages, for this reason 100% humidity readings were not factored into the averages.

Those using the test beaches as overnight stops will note the difference in temperature ranges found from the cooling effects of the river's edge to the hotter talus slope. High readings showed a 10°F average difference, and a 7°F difference was noted in the low readings. With August temperatures a factor in camper comfort, group leaders may suggest camp placement accordingly.

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CHAPTER XIV

COLORADO RIVER
BEACH CAMPSITE INVENTORY
GRAND CANYON NATIONAL PARK, ARIZONA

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INTRODUCTION

The Grand Canyon Colorado River beach campsites were inventoried during the summer of 1987. The campsites were classified according to camper capacity, shoreline composition, degree of active erosion, and flash flood potential.

Before 1963, and the completion of Glen Canyon Dam, the yearly floodwaters from the Rocky Mountains would bring sediment into the Grand Canyon and replenish the eroded campsites. Since 1963 this sediment has been trapped in Lake Powell, leaving the campsites to be eroded by flash floods, wind, and human contact.

This report presents the results of the summer 1987 inventory of the Colorado River beach campsites between Lees Ferry and Diamond Creek. This information is compared to information gathered during the 1983 fall inventory (Brian and Thomas, 1983).

METHODS

Between 29 July and 8 August 1987, 49 Colorado River beach campsites between Lees Ferry (River Mile 0) and Diamond Creek (RM 225.8) were inventoried. Locations prohibited to camping were not included in the inventory. This survey was made in conjunction with the annual Northern Arizona University Research Expedition.

Each beach surveyed was given an on-site inspection (Figure XIV-1). Investigators discussed the results of each beach survey to insure consistency. Only campsite beaches were surveyed.

Camps are identified by mileage downstream from Lees Ferry with an accuracy of 0.1 mile, and by common or topographic name when possible. "L" refers to left bank and "R" refers to right bank when looking downstream.

The size or capacity of the beach refers to the area open to camping, cooking, and group use. "Small" is defined as a camp area large enough to accommodate a 15-20 person group, "medium" a 21-30 group, and "large" a 31-40+ person group. The maximum allowable size of a river party is 16 for private groups and 36 passengers (crew is additional) for commercial groups.

Three types of shoreline composition were noted: vegetation, rock armoring, and sand. Three types of shoreline erosion were noted: active cutbanks, inactive cutbanks, and no erosion.

In both these studies, composition and erosion, high and low water, i.e. time of day of survey, were significant in obtaining consistent results.

Beach equilibrium was determined, with regard to its

RIVER CAMPSITE INVENTORY

DATA FORM

River Mile ______________ L R Date ________________

Camp Name ______________ Recorder ______________

______________________ ______________

(Draw map on back if needed)

Capacity: Small Medium Large

Shoreline Composition (%)

_______Vegetated by: ______________________________

_______Rock armoring: ledge boulders rocks

_______Sand

Erosion of Shoreline (%)

_______Active cutbanks @ _______M in height

_______Inactive cutbanks @_______M in height

_______No erosion

Beach equalibrium: Stable In flux Unstable

Flash Flood Potential: None Low Medium High

Approximate beach profile slope: ______________%

Other comments:

Figure XIV-1. Amended campsite inventory form for future campsite monitoring.

potential to flash flood.

The beach campsites were evaluated using subjective methods by investigators.

RESULTS

1987 Inventory

A total of 49 potential Colorado River beach campsites were identified (Table XIV-1, Appendix 1) between Lees Ferry and Diamond Creek (excluding areas prohibited to camping). All category determinations were calculated by using the major feature for each variable at each survey site as the indicator, e.g., Shoreline Composition: Vegetated-20%, Rock armoring-35%, Sand-45%, would be considered a sand shoreline for reporting purposes.

Large campsites comprise 37%, medium camps 28% and small camps 35%. The left side of the river corridor yielded 53% of the total beaches. A majority of the beaches (37%) showed no evidence of shoreline erosion, while 35% indicated inactive signs of erosion, and the remaining 28% actively eroding. Many of the shorelines, 49% were sand, while 37% were primarily rock and 14% vegetation.

Twenty-seven categories (Table XIV-2) were created by a 3x3x3 matrix (capacity x erosion type x erosion potential). This array of categories is of limited use as the criteria of erosion type and erosion type and erosion potential are subjective ratings. However, two observations can be made. First, in all class sizes, a majority of campsites exhibited inactive or no erosion. This indicates that the beaches may have reached stability or equilibrium at the time of the study. Second, in the no erosion/low erosion and active/high erosion potential categories, there was no significant difference between the various sized beaches. The data did indicate that while not that much higher, small beaches did have the higher percentage in each category. Ultimately, one would expect that all beaches will continue to change at a similar rate.

Table XIV-3, Figure XIV-2 explain and diagram each of the Reaches used to catalog the studied beaches. A Reach is approximately 30 river miles in length (X = 28.2 miles). A 30 mile Reach is approximately the average distance a motor-powered boat will travel in a day or an oar-powered boat will travel in two days. By regulation, a trip may not average over 40 miles per day (National Park Service, 1981).

A comparison of campsites identified in both the 1983 and 1987 surveys yielded a total of 47 beaches. A further comparison of the 47 campsites (Table XIV-4) in the small, medium, and large size categories throughout the canyon, shows a 142% increase in the small campsites while both the medium and large show declines, 7% and 33%, respectively, over the 4 year interval. This result indicates a general decrease in camp sizes after the 1983 flood. When viewed by Reach, (Figure XIV-3) there is an overall increase in small campsites in all Reaches except Reach 2, 3 and 4. The medium size campsites indicated a shift downstream with the appearance of some in Reach 5.

Change in campsite capacity (Table XIV-5, Figure XIV-4) shows the size capacity change in the 47 matched campsites after 4

Table XIV-1. Summary of the 1987 Colorado River Beach Campsites.

	Number	Percent	Total
Capacity			
Small	17	35%	
Medium	14	28%	
Large	18	37%	49
Shoreline Composition			
Vegetation	7	14%	
Rock	18	37%	
Sand	24	49%	49
Erosion Type			
Active	14	28%	
Inactive	17	35%	
None	18	37%	49
Beach Equilibrium			
Stable	21	43%	
In Flux	3	6%	
Unstable	25	51%	49
Flash Flood Potential			
None	14	29%	
Low	19	39%	
Medium	11	22%	
High	5	10%	49

APPENDIX I

(COMPUTER PRINTOUT OF 1987 DATA)

Legend:

River Mile	=	Distance downstream from Lees Ferry (miles)
Side	=	Side of river when viewed downstream: "L" = left, "R" = right
Date	=	Indicates data collected 29 July to 8 August 1987
Size	=	Camp area large enough to accommodate a river party
1 = small	=	15-20 person group
2 = medium	=	21-30 person group
3 = large	=	31-40+ person group
Actual Erosion	=	Type of erosion present
1 = active	=	cut banks, unstable
2 = inactive	=	cut banks, stabilized
3 = none	=	no erosion apparent
Beach Equilibrium		
1 = stable	=	no erosion
2 = influx	=	deposition taking place
3 = unstable	=	erosion noticeable
Sand Discoloration Study		
human impact		Y = yes survey took place N = no did not survey
Beach Profile Study		Y = yes N = no

Table XIV-2. 3x3x3 Matrix (Capacity x Erosion Type x Erosion Potential) for the 49 campsites surveyed in 1987.

Capacity - Erosion Type	Erosion Potential			
	Low	Medium	High	Total
Small - Active	0	0	6 (100%)	6 (35%)
Small - Inactive	2 (50%)	0	2 (50%)	4 (24%)
Small - No Erosion	5 (71%)	2 (29%)	0	7 (41%)
Medium - Active	0	0	3 (100%)	3 (23%)
Medium - Inactive	4 (57%)	0	3 (43%)	7 (54%)
Medium - No Erosion	1 (33 1/3%)	0	2 (66 2/3%)	3 (23%)
Large - Active	1 (17%)	0	5 (83%)	6 (32%)
Large - Inactive	2 (40%)	0	3 (60%)	5 (26%)
Large - No Erosion	5 (62%)	1 (13%)	2 (25%)	8 (42%)

	Small	Medium	Large	Total
No Erosion/Low Erosion	5 (29%)	1 (8%)	5 (26%)	11 (22%)
Active/High Erosion	6 (35%)	3 (23%)	5 (26%)	14 (29%)

Table XIV-3. Summary of the eight reaches used for campsite analysis.

Reach	Average Distance (miles)	Mileage From Lees Ferry	Descriptive Distance	Physiographic Reach Province
1	31.5	00-31.5	Lees Ferry to South Canyon	Upper Marble Canyon
2	29.6	31.6-61.2	South Canyon to Confluence	Lower Marble Canyon
3	28.7	61.3-90.0	Confluence to Horn Creek	Furnace Flats and Upper Granite Gorge
4	30.9	90.1-121.0	Horn Creek to Black-tail Canyon	Upper Granite Gorge
5	22.4	121.1-143.5	Blacktail Canyon to Kanab Creek	Great Thumb
6	35.8	143.6-179.4	Kanab Creek to Lava Falls	Muav Gorge
7	29.3	179.5-208.8	Lava Falls to Granite Park	Hurricane Fault Zone
8	16.8	208.9-225.7	Granite Park to Diamond Creek	Lower Granite Gorge

Table XIV-4. A comparison of size change for the number of small, medium, and large campsites for 47 selected campsites over 4 years.

	Campsite Capacity			
Year	Number of Small	Number of Medium	Number of Large	Total
1983	7	13	27	47
1987	17	12	18	47
Change	+10	-1	-9	0
% Change	142%	-7%	-33%	0

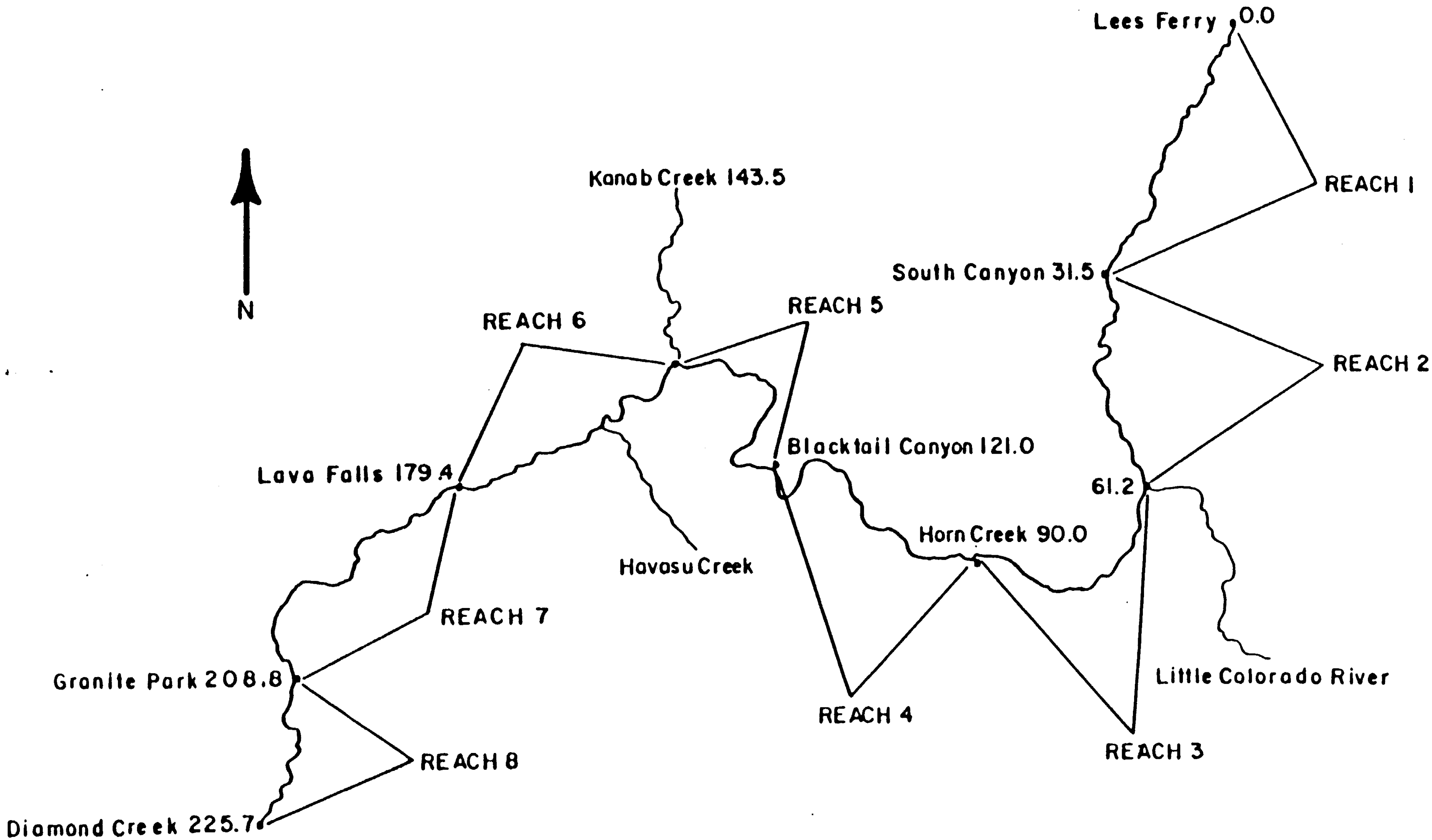

Figure XIV-2. Map of the Colorado River through Grand Canyon National Park, illustrating the eight 30-mile reaches.

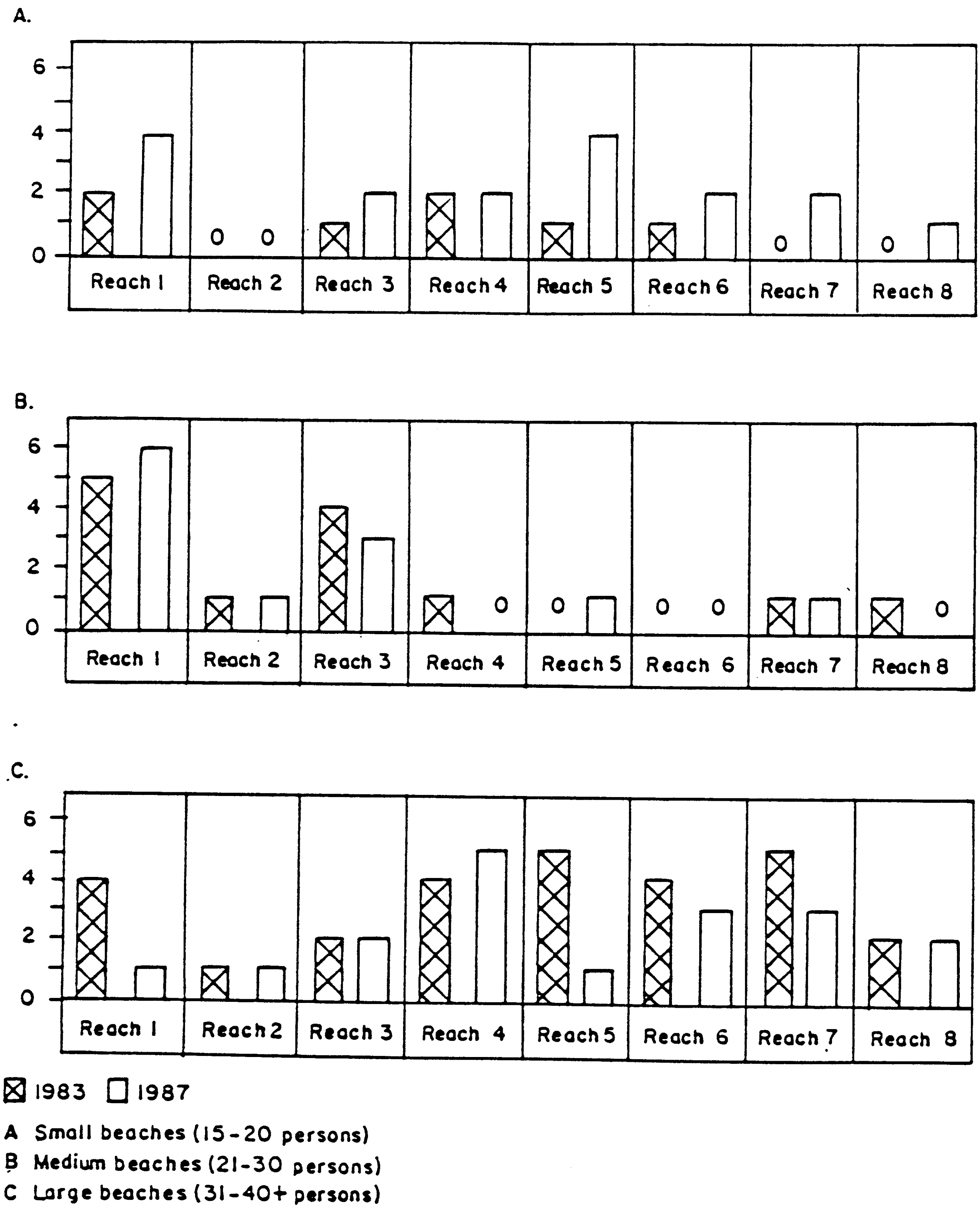

Figure XIV-3. A comparison of 47 matched campsites between 1983 and 1987 by eight 30-mile reaches.

Table XIV-5. 1987 Colorado River beach campsite inventory.

Reach	River Mile	Side	Camp Name	Size[1]	Erosion[2]	Beach Equilibrium[3]	Sand Discoloration Study	Beach Profile Study
1	7.8	L	Badger	2	2	1	Y	N
	11.3	R	Soap Creek	2	1	3	N	N
	18.0	L	18 Mile Wash	2	1	3	N	N
	18.2	L		1	3	2	N	Y
	19.2	L	19 Mile Canyon	1	3	2	N	Y
	20.0	L		2	2	1	Y	N
	29.0	L	Shinumo Wash	2	2	1	Y	N
	31.3	R		2	3	1	N	N
	31.5	R		3	3	1	N	N
	34.8	L	Nautiloid	2	2	3	N	Y
	40.9	R	Upper Buck Farm	1	2	3	N	N
	41.1	R	Lower Buck Farm	1	3	1	N	N
	43.5	L	Anasazi Bridge	2	1	3	Y	N
2	56.4	R	Kwagunt	3	3	1	N	N
	58.1	R	Awatubi	2	2	1	Y	N
3	61.1	R	Upper Little Colorado	1	1	3	N	N
	61.8	R	Lower Little Colorado	1	2	3	N	Y
	63.5	R	Carbon Creek	2	1	3	N	N
	75.5	L	Neville's	3	3	2	Y	Y
	76.5	L	Upper Hance	1	1	3	N	N
	76.5	L	Hance Rapids	2	2	3	Y	N
	81.1	L	Grapevine	3	1	3	Y	Y
	85.6	L	Cremation	2	3	1	N	N
4	93.2	L	Granite	1	2	3	Y	Y
	108.3	L	Lower Bass	3	3	3	Y	N
	120.0	R	Upper Blacktail	3	2	3	N	Y
	120.2	R	Lower Blacktail	1	2	1	N	N
	122.0	R	122 Mile Creek	3	1	3	Y	Y
	122.8	L	Forester	3	3	1	Y	Y
	123.5	L	Enfilade	3	1	3	N	N
5	131.0	R	Bedrock	1	3	1	Y	Y
	132.0	R	Dubendorff	1	2	3	Y	N
	136.0	L	Deer Creek Falls	1	3	3	Y	N
	137.0	L	Upper Poncho's Kitchen	3	1	3	Y	N
	137.0	L	Middle Poncho's Kitchen	2	1	3	N	N
	137.0	L	Lower Poncho's Kitchen	1	2	3	N	N
6	151.6	R	Ledges	1	3	1	N	Y
	151.7	R	Last Chance	1	1	3	N	N
	166.6	L	Lower National	3	2	3	Y	Y
	168.0	R	Fern Glen	3	3	1	N	N
	179.9	R	Lower Lava Falls	3	3	1	N	Y
7	186.0	R		3	1	1	Y	N
	190.2	L		1	1	3	N	Y
	194.0	L		3	3	3	N	N
	198.5	R		2	3	3	Y	N
	207.0	R	Indian Creek Canyon	1	3	1	N	N
	208.5	L	Granite Park	3	1	3	Y	Y
8	212.8	L	Pumpkin	3	2	3	Y	N
	219.9	R	220 Mile	3	2	1	Y	Y

1. 1=Small; 2=Medium; 3=Large. 2. 1=Active; 2=Inactive; 3=None. 3. 1=Stable; 2=Influx.; 3=Unstable

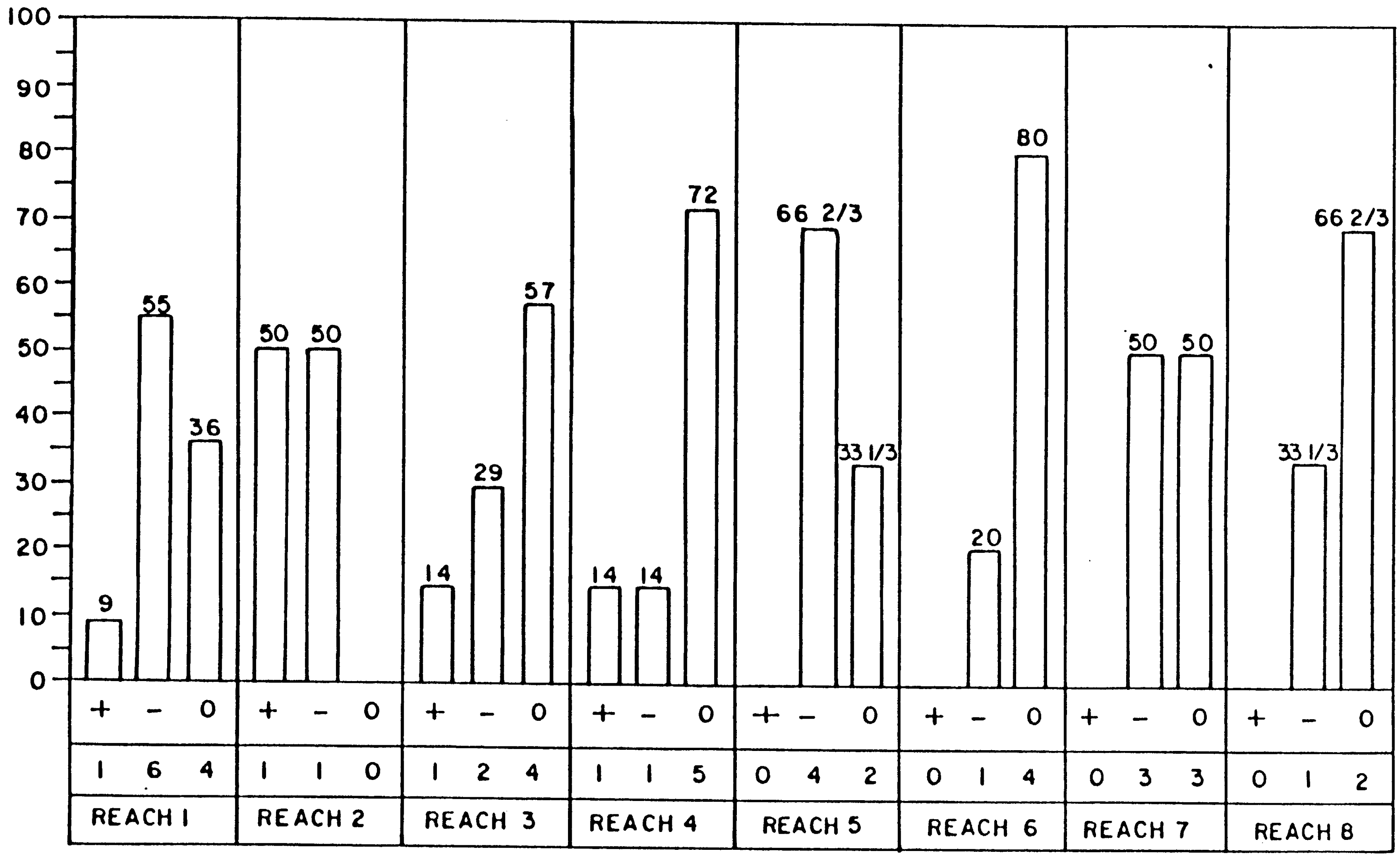

Figure XIV-4. Summary by percent of 47 matched campsite beaches within eight reaches by size increase (+, N = 99%); size decrease (–, N = 40%); and no size change (0, N = 51%).

years by Reach. Positive identification of the causal agent is impossible to determine. Also, investigator bias, judgment of campsite selection criteria, and mileage error, necessarily affect the inventory results. Mileages were determined by using Stevens 1983 River Guide. Most beaches (51%) exhibited no discernible change in size, while a disproportionate 40% showed a decrease in size and only 9% indicated an increase in campsite capacity. A large decrease in size would be predicted, as beaches are not replenished by seasonal flood waters due to sediment deposition and entrapment in Lake Powell, and flow regulation at Glen Canyon Dam. Erosion caused by river currents, sheet wash, aeolian movement, tributary flash floods and footstep-induced mass wasting, results in degradation of beaches (Laursen and Silverton, 1976; Valentine and Dolan, 1979). However, two factors have somewhat counteracted the erosional tendency: decreased post-dam flows, and stabilized vegetation (Howard and Dolan, 1981).

CONCLUSION

A comparison between the 1983 data and that collected in 1987 was difficult due to a variety of factors. Campsite selection criteria and field methods differed between the studies. Bias was introduced by the investigators' personal experience and judgment in applying qualitative estimates. River flow and fluctuation also produced erroneous measures of shoreline erosion and composition. During the study period, river flow varied from an estimated low of 12,000 cfs to a high of 32,000 cfs. Mileage designations were also somewhat difficult to measure due to differences in the various river guide books used.

Due to the findings that there was a 142% increase in the small campsite category, it is reasonable to assume that active erosion is taking place and that the system is not in equilibrium. Even in the absence of high flows, the number, size, and distribution of beaches in Grand Canyon can be expected to change in the near future. The dynamic nature of the Colorado River, though impeded by upstream dams, impoundments, and regulated flow, continues to act as "normal" much to the bewilderment of managers and scientists.

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CHAPTER XV

THE PREHISTORIC RIM-TO-RIVER ROUTE AT BRIDGE OF SIGHS

Robert Dawson

INTRODUCTION

For at least 4000 years, Indians have hiked in the Grand Canyon, and they continue to do so today. Their efforts to get from rim to river were, and are, limited largely by the scarcity of breaks in the Coconino Sandstone and Redwall Limestone. While little is known of the routes used by Desert Culture people thousands of years ago, there is abundant evidence of routes used by another group circa 100 A.D.

This Indian culture, usually referred to as the "Anasazi" but more appropriately, the "Hi sát sē nōm," left a legacy of rim-to-river routes which are being rediscovered as modern explorers probe more and more of the Canyon's secrets. Since the Hopi Indians of today are the direct descendants of the Hi sát sē nōm ("our people who lived here long ago"), it is distressing to them to continually hear others use the Navajo term, "Anasazi" ("the old ones who used to live here--but not any more"). This is a subtle but rather important difference.

Judging from the large number of often precipitous prehistoric trails in the Canyon, it seems likely that few possible routes went undiscovered.

Why rim-to-river travel was undertaken, and to what extent, must be determined on scant evidence. There is evidence that some agriculture occurred at Nankoweap and Unkar beach areas. Granaries and mescal pits are found thoughout the Canyon. Perhaps at least some journeys were for no more urgent purpose than to explore the environs of the Canyon.

Whatever the reasons, the Indians traveled in and out of the Canyon, it seems of some value to document known routes. Perhaps the most recently discovered route, at the Bridge of Sighs, (Figure XV-1) was first noted in May 1984 by Dave Dawson. It was during an expedition led by Steve Emslie in search of Pleistocene condor remains in the heretofore unexplored caves of the Redwall Limestone. Emslie and Larry Coates had gone to the top of the Redwall just opposite Redwall Cavern and traversed downstream to Bridge of Sighs Canyon. There they dropped a fixed rope down the drainage in the Redwall and then walked back to the boat. The group camped at a small beach at approximately RM 35.5. The next day the group walked down river to Bridge of Sighs Canyon, where two investigators jumarred up the fixed rope to look at some caves. Poles observed sticking out of the north canyon wall proved to be too high to be driftwood, were evidence of a route.

In May, 1985, Dave and I hiked the route from rim to river down 36.8-Mile Canyon. Harvey Butchart (personal communication, 1986) described a way to the top of the Redwall but had not done the rest of the route. We were able to follow his route

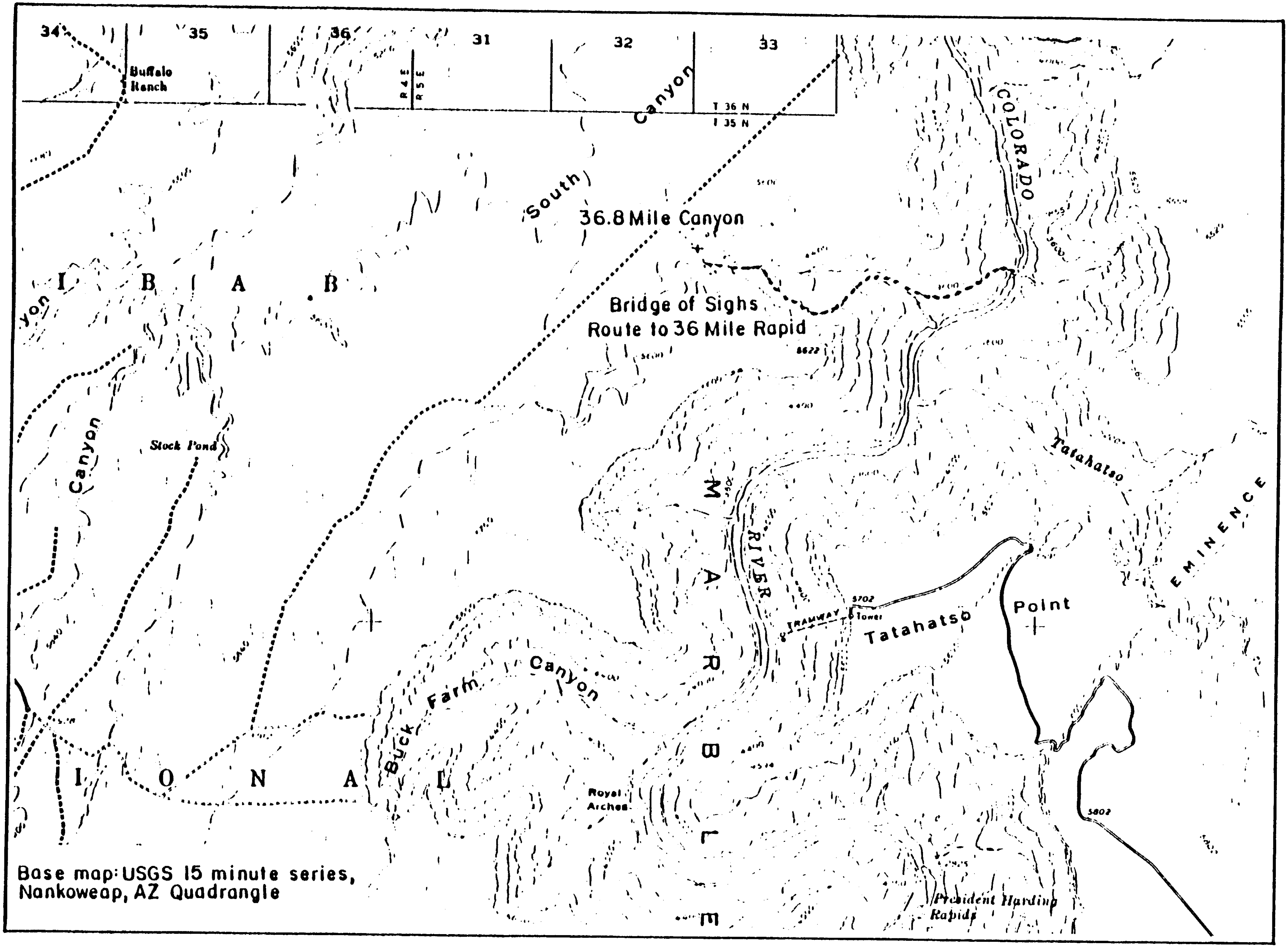

Figure XV-1. Route to Bridge of Sighs.

description to the top of the Redwall, then headed up river until we found the Bridge of Sighs. It is understandable why Butchart didn't find a way through the Redwall at this significant canyon, as it appears impossible looking down from the top.

At this point the route was familiar to Dave, and I was treated to a storybook descent. Bridge of Sighs Canyon is only about 150 yards long and runs more or less east and west through the Redwall. We entered on the south side, got into the bed of the drainage and descended along the base of a cliff to a small cave about five feet high and three feet wide.

We turned on our head-lamps and followed a trapezoidal tunnel which went straight into the Redwall about 50 feet. An opening on the right leads about 20 feet to a small chamber about 15 feet in diameter, on the floor of this chamber is a tube 20 inches in diameter which spirals counterclockwise. We raised our arms over our heads and slid down this nearly vertical tube for about 15 feet and dropped about four feet to the floor of another small horizontal cave. We could see daylight filtering in and we went on hands and knees about 50 feet out to the face. Here we found the wooden pegs, about three inches in diameter and 30 inches long, solidly placed in cracks. Five additional pegs lead up the face and indicate that the Indians chose to continue a route up the face as an alternative to the cave system route. We found good hand and foot holds to help our descent about 80 feet down the face to the drainage bed. From there it was just a scramble with a short section of chimney down to the river.

Standing on the right bank, one can look across the river and see a small one-room ruin just above the old high water line. A similar ruin occurs on the right bank about 100 yards downstream.

Dave and I did the route again in October 1986 and had a much easier time finding our way through the Supai. This time we made the round trip in under eight hours. In July 1987, participation in a NAU class on geology and biology of the Grand Canyon afforded an opportunity to further document this unique prehistoric route with the help of two our boatmen, Brian Dierker and Lisa Long.

We paused at the wooden pegs and for the first time I noticed how intricately the trail had been constructed over the pegs. About an eight-foot section remains in almost perfect condition. On top of the pegs, running at about a 20 degree slope, the trail is constructed of large flat rocks and dirt.

Going up the tube is considerably more difficult than going down because the tube has few hand and foot holds. Lisa and I had little trouble, but Brian, who is 6'6", found it difficult to bend his knees backward in the spiraling tube.

A thick coating of soot on the ceiling of the upper cave suggests that the Indians either lived in it or used torches to light their way (or both). We continued to the top of the Redwall and then returned. A flash of light reflecting off a one-inch rectangular calcite crystal embedded in the limestone just above the entrance, gave the whole experience a "Raiders of the Lost Ark" touch!

Hi sát sē nōm routes that go down from one rim, commonly link up on the other side of the river with a route out to the opposite rim (i.e., the Anasazi Bridge route and the Eminence Break route). The Bridge of Sighs route seems to fit that pattern, but the route from river to rim on the left bank remains to be explored.

CHAPTER XVI

SOCIOLOGICAL DATA REPORT

Vicky Lynn Powell

INTRODUCTION

During the NAU Colorado River Expedition, July 29 through August 8, 1987, data were collected on the number of daily boat and aircraft contacts. Other observations were made on campsite and attraction point contacts, and a log of all beach stops was kept. The results of these data are to be compared with previous year's data. We are looking for trends, upward or downward, in the number of boat and aircraft contacts one person may experience on a river trip through the Grand Canyon. We are also looking for areas of congestion. Where on the river are the most contacts made? Is it consistently high in those areas?

METHOD

Schedule

Each time this observer's boat stopped, the following information was recorded: river mile and name of location, time of arrival and departure and reason for stopping. Data were kept on xeroxed forms. Next year it would be a tremendous improvement if all 5 forms could be transferred to a weatherproof, pocket-sized notebook. Regular paper on a clip-board was cumbersome and inconvenient.

Boat Contacts

Each time this observer had contact with another boat, the following information was noted: river mile, time of day, duration of contact, number of boats and people, oar or motorized craft, private or commercial, number of times the party was seen before and type of contact (river to river, shore to river, river to shore or shore to shore).

Next year's study and collection of data should include the name of the commercial group contacted. This observer found it much easier to record multiple contacts with the same group after noting the tour group's name.

Aircraft

Previous and current studies required the observer to both hear and see an aircraft before it could be included in the data. Military aircraft and jets were not included.

Next year's study should include data on the duration of the noise of each aircraft experienced. Also, data should include a tally of aircraft "heard only". A majority of the members of this research expedition agreed that it was the sound, not necessarily the sight, of an aircraft that intruded on the solitude of the canyon.

Campsites and Attraction Points

Upon arrival at an attraction point, the following data was recorded: location, date, arrival and departure times, duration of stay and the number of people seen, including our own group. The following information was collected for each campsite we used: day, location, whether we camped alone or within sight and or sound of others, if we had to share a campsite and whether or not it was an alternate camp.

RESULTS AND DISCUSSION

Schedule

During the 11 day river trip, a total of 41 stops were made. At 28 of those stops beach research was conducted. Three stops were made to observe the rapids and 7 stops were made at attraction points. The expedition had a one day lay over at National Canyon for a full day of research and oral reports. All stops recorded by this observer are identified on Table XVI-1, labeled TRIP SCHEDULE. The reader needs to be aware that other boats on this expedition may have made more or less stops, and at different locations. These data reflect one observer's experience.

Boat Contacts

We had a total of 87 river contacts, 68 being with commercial groups and 19 with private. Of the 87 contacts, 32 were shore to river contacts due to the many beach stops necessary for research. This is consistent with previous studies. The largest number of contacts was on day 10, when we traveled 25 miles, from RM 195 to RM 220. We stopped 4 times that day, twice at attraction points (Donkey Springs and Three Springs). This may account for the high number of contacts (18) that day. In 1986, the expedition had traveled 44 miles and experienced a high boat contact of 14. Table XVI-1, labeled GROUP CONTACTS and Figure XVI-1, labeled DAILY BOAT CONTACTS 1982, 1986 and 1987, present data on group contacts along the river. Figure XVI-2, labeled TOTAL NUMBER OF BOAT CONTACTS, presents data on group contacts over the past 6 years.

Aircraft Contacts

The reader should be aware that because the observer was riding in a motorized raft and hiking in narrow canyons, many planes were missed either because they were not heard or they were not seen. Included in this year's report for the first time, are data on planes heard but not seen (Table XVI-2).

The largest number of seen and heard planes came on days 4 through 6 as we were traveling through the Inner Gorge section of the canyon. The National Canyon area also had numerous aircraft flying overhead; however, many were not recorded because the observer spent a full day in a narrow canyon where the field of view was limited. Many planes were also missed on day 4 due to cloudy conditions. Information on aircraft seen and heard is presented on Table XVI-3, labeled AIRCRAFT ENCOUNTERS.

Campsites and Attraction Points

Five of our ten nights on the river we camped alone. The

TABLE XVI-1. GROUP CONTACTS

DAY	MILES COVERED	RIVER MILE	RIV-RIV P	RIV-RIV C	RIVER-SHO P	RIVER-SHO C	SHORE-RIV P	SHORE-RIV C	SHORE-SHORE P	SHORE-SHORE C	TOTAL P	TOTAL C	TOTAL T
1	20	20							4	5	4	5	9
2	32	52		2		2		6		2		12	12
3	11.5	63.5				1		3				4	4
4	23.5	87				1		2		1		4	4
5	33.1	120.1		1	1	2		1		6	1	10	11
6	16.9	137				1	1	7		1	1	9	10
7	29.6	166.6		2		1		1	1	1	1	5	6
8		166.6						3				3	3
9	28.4	195	1	1		2	1	1			2	4	6
10	25	220	4	4	1	3	2	2	1	1	8	10	18
11	5	225						2	2		2	2	4
TOTAL			5	10	2	13	4	28	8	17	19	68	87

P=PRIVATE, C=COMMERCIAL, T=TOTAL

TABLE XVI-2. AIRCRAFT ENCOUNTERS

DAY	MILES COVERED	RIVER MILE	SIN ENG	MUL ENG	HELI COP	TOTAL
1	20	20	4			4
2	32	52	4	1		5
3	11.5	63.5	9	4	2	15
4	23.5	87	11	16	3	30
5	33.1	120.1	9	9	12	30
6	16.9	137	10	21	3	34
7	29.6	166.6	5	1		6
8	0	166.6		9		9
9	28.4	195	2	17		19
10	25	220		1		1
11	5	225		1		1
TOTALS			54	80	20	154

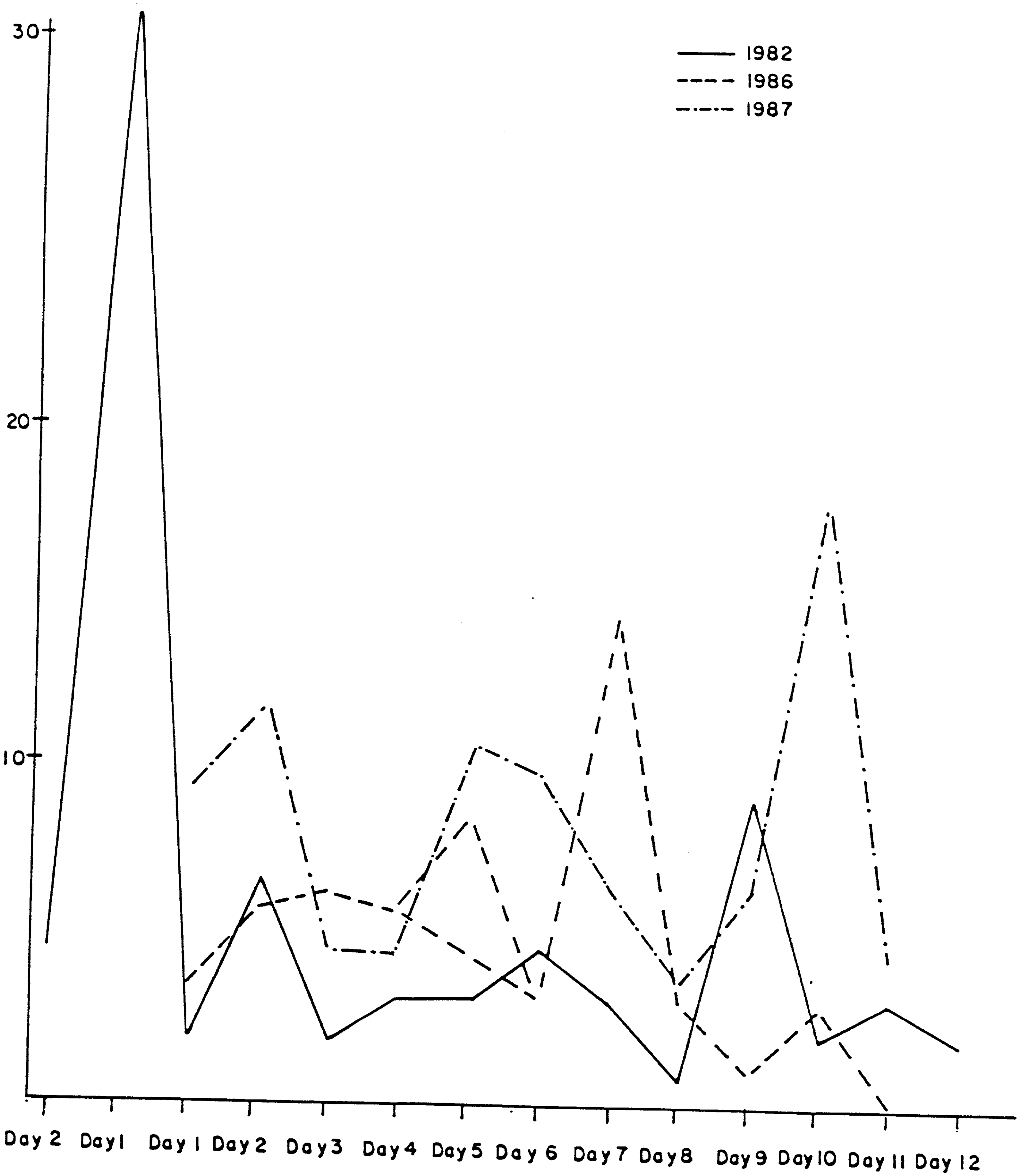

Figure XVI-1. Boat contacts, 1982, 1986 and 1987.

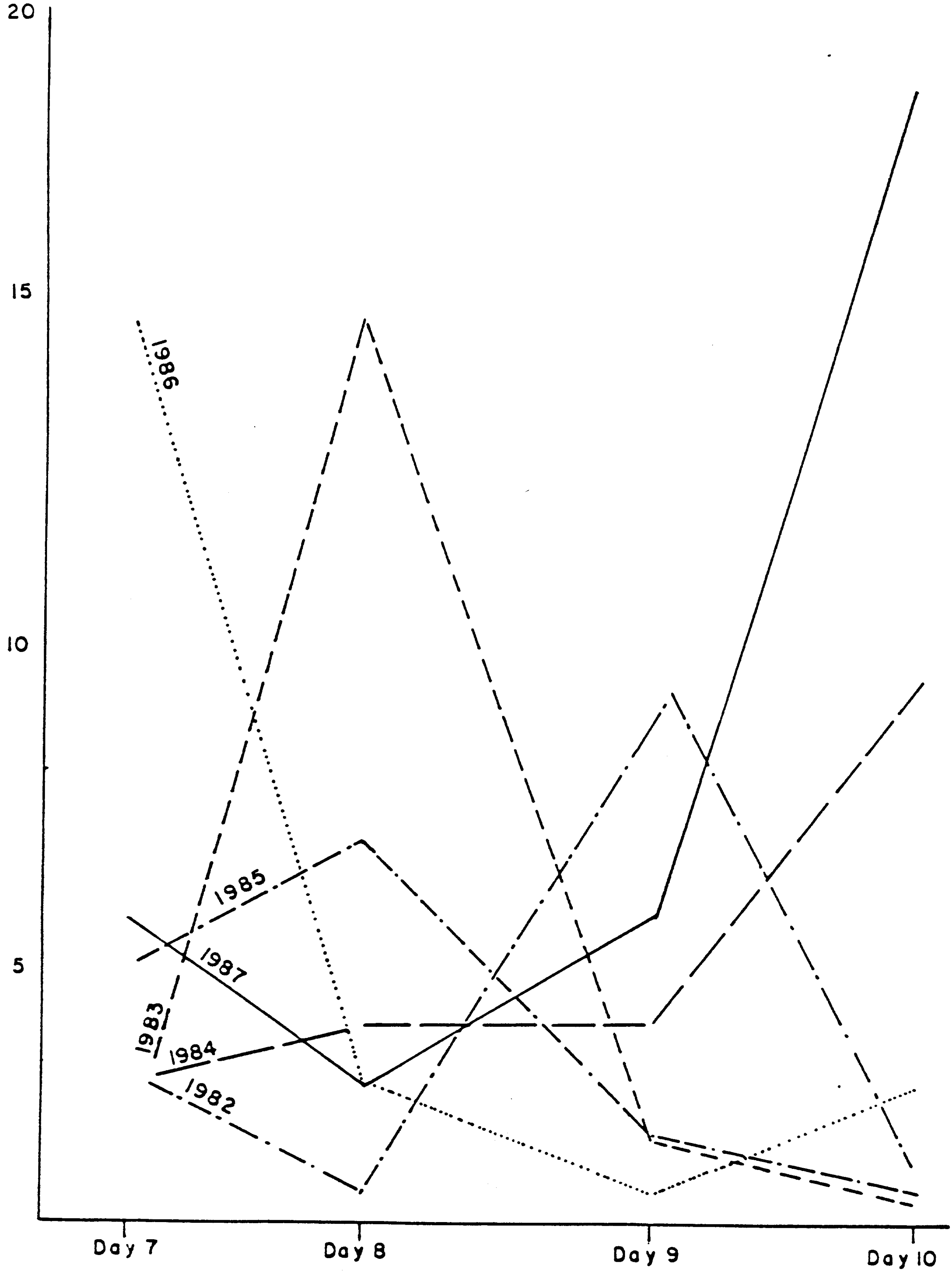

Figure XVI-2. Total boat contacts, 1982 - 1987.

Table XVI-4. Average group and aircraft encounters.

1. Group contacts per day.

River-River			River-Shore			Shore-River			Shore-Shore			Total		
P	C	T	P	C	T	P	C	T	P	C	T	P	C	T
.45	.9	1.36	.18	1.18	1.36	.36	2.54	2.9	.72	1.54	2.27	1.72	6.18	7.9

2. Aircraft encounters per day.

Single Engine seen/heard only		Multi-engine seen/heard only		Helicopter seen/heard only		Total seen/heard only	
4.9	6.27	7.27	10.54	1.8	2.0	14	18.8

Table XVI-5. Summary data for each trip day for years 1983-1987.

Day	1982			1983			1984			1985			1986			1987		
	M	C	A	M	C	A	M	C	A	M	C	A	M	C	A	M	C	A
	4.0	4	3	-----------			-----------			-----------			-----------			-----------		
	19.0	31	13	-----------			-----------			-----------			-----------			-----------		
1	19.0	2	7	20.0	4	0	24.0	4	1	19.8	3	0	20.0	3	1	20.0	9	4
2	15.0	6	3	32.2	3	3	29.0	6	4	38.4	4	5	32.5	5	4	32.0	12	5
3	24.5	2	2	0.0	0	8	7.5	3	4	0.0	3	11	5.6	6	2	11.5	4	15
4	26.0	3	4	19.8	3	4	15.0	5	4	35.5	3	12	5.4	5	10	23.5	4	30
5	27.5	3	13	21.4	6	17	21.0	3	12	28.4	1	14	28.6	8	15	33.1	11	30
6	0.0	4	8	29.4	2	31	25.5	3	38	15.0	3	8	29.9	3	45	16.9	10	34
7	13.0	3	7	0.0	3	38	0.0	3	29	29.6	5	5	44.6	14	25	29.6	6	6
8	17.5	1	4	43.2	14	7	44.0	4	8	0.0	7	18	0.0	3	18	0.0	3	9
9	16.0	8	5	42.4	2	28	0.0	4	10	27.4	2	16	29.9	1	18	28.4	6	19
10	28.5	2	5	16.1	1	2	42.8	9	10	26.0	1	6	23.5	3	18	25.0	18	1
11	5.5	2	1	-----------			-----------			-----------			----------			-----------		
12	26.0	3	3	-----------			55.0	2	2	5.5	0	1	5.0	0	0	5.0	4	1
Total		74	78		38	138		46	122		32	96		51	156		87	154

M = mileage covered that day   C = group contacts   A = aircraft