COLORADO RIVER INVESTIGATIONS #9
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Northern Arizona University

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TABLE OF CONTENTS

Chapter		Page
	Introduction	i
1.	Human Impact Study on the Beaches of the Colorado River in the Grand Canyon	1
2.	Topographic Changes on Selected Beaches in the Grand Canyon, 1989-1990	25
3.	Beach Failure	51
4.	Lizard Distribution and Density Studies Along the Colorado River in Grand Canyon National Park	62
5.	Grand Canyon Rodent Populations 1990	77
6.	Comparative Water Potential in Riparian Plant Species of the Grand Canyon National Park, Arizona	84
7.	Riparian Plant Community Structure in the Grand Canyon	104
8.	Level of Radioactive Uranium in Colorado River Sediments	119
9.	Sedimentary Structures in Failed and Nonfailed Beaches and Bars of the Colorado River in the Grand Canyon	123
10.	Invertebrate Species Associated with Various Vegetation and Habitat Types in the Colorado River Corridor, Grand Canyon National Park	141
11.	Photographic Record of Beaches in the Grand Canyon from 1983 to 1990	150
12.	Colorado River Beach Campsite Inventory Grand Canyon National Park, Arizona	153
13.	Sociological Data Report	165

INTRODUCTION

This report presents the results of investigations conducted on beaches in Grand Canyon as part of a graduate course--Geology 601, Biology 680--offered in July-August, 1990, by Northern Arizona University. The course is designed as a workshop for science teachers from southwestern U.S. and is financially supported by grants the National Science Foundation (Grant #TPE-8954615) and Arizona Board of Regents with logistics and instructional support from the Grand Canyon National Park, Bureau of Reclamation, Union Pacific Resources Company and Museum of Northern Arizona.

The program included classroom,laboratory and short field trip instruction in geology and biology (2 weeks), an 11-day river trip through Grand Canyon, and preparation of research reports and teaching activities (10 days). On the river trip, each participated in an least one research investigation under the direction of Stanley S. Beus or Lawrence E. Stevens, the senior scientists, or Frank B. Lojko, research coordinator, in the course. Most of the 13 investigations reported here are parts of ongoing studies to address problems relative to resource management of the fragile sandy beaches used as campsites in the Grand Canyon.

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CHAPTER I

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

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INTRODUCTION

Within the past twenty 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 and hikers.

Although located fifteen miles upstream of the national park boundary, Glen Canyon Dam changed the nature of the Colorado River flowing through the Grand Canyon. Post-dam changes in water flow, water temperature, and sediment discharge have 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 the 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 (GCNP 1981). These stabilized patterns of water flow established during the past twenty years have been disrupted only once when unexpected high waters and the ensuing floods occurred in 1983.

Given the above considerations, the present challenges to developing an adequate system for resource management along the river corridor of Grand Canyon National Park include: 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 (GCNP 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.

Heavy recreational use in other parks has caused changes in plant species composition and vegetation density and diversity (Johnson, et al. 1977). Preliminary data from Grand Canyon (Aitchison, et al. 1979) 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 compositon) that were deposited during pre- dam flood discharges. In the twenty 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 Grand 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, 25 Colorado River campsites in Grand Canyon were selected for the purpose of monitoring levels of recreational impact. In 1980-81, nine additional beaches in the fifteen miles of Glen Canyon below Glen Canyon Dam were evaluated for levels of human impact. Since 1976, the original Grand Canyon sites have been monitored and re-evaluated several times (Carothers, et al. 1984). 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, including seventeen of the beaches evaluated in 1982 and five new beaches, were compared to the 1982 data. Elevèn 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, 1987, 1988, 1989, and 1990 studies are indicated in Table I-1.

OBJECTIVES

The objectives of this 1990 study are to:

1. Collect data on the degree of sand discoloration on 14 previously sampled beaches along the Colorado River corridor (1984-1990),

2. Collect data on the incidence of charcoal greater than or equal to 1 cm and human litter on 14 previously sampled beaches along the Colorado River corridor (1984-1990),

3. Compare data from objectives 1 & 2 with the findings from studies conducted in 1984-1990 to assess human impact on beaches after they were cleaned in the 1983 flood.

HYPOTHESIS

Human impact on selected beaches along the Colorado River corridor will result in significant increases in sand discoloration and increases in charcoal and human litter.

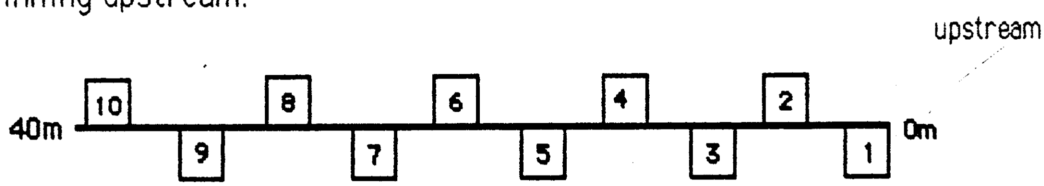
METHODS

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 a 40-meter transect line could not be established, the longest possible line was run and the distance recorded. Compass readings, illustrations, and photographs of previous reports should be used in locating the transect lines.

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 and the side of the river was written on a chalkboard and included in the photograph. Ex:

3. Ten 1-square meter plots were laid out equidistant from each other in an alternating pattern along the transect line. When a forty meter transect line could not be established shorter intervals of equal distance were used. This year's study used the same intervals as the 1989 study.

4. Each one square meter plot was inspected by hand sifting through the surface sand. All pieces of charcoal greater than or equal to 1 cm 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. Any damp sand was collected and dried out before it was tested. All samples were labeled with the beach name, the river mile, and the plot number when they were collected. Plots were always numbered 1-10 beginning upstream.



5. Sand samples were also collected at the sand/water interface and from the terrace above the beach at the old high water line. On several beaches sand samples were taken under the canopy of a mature tamarisk tree.

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 container.

7. A piece of No. 7 coarse grade filter paper was placed in the lid of the apparatus with the hatched side up, and sifted material was 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. The wire mesh was cleaned with a toothbrush after each sample was shaken.

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

> The Colorgard 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. 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 reflectivity of the filter paper should be measured and recorded each time the reflectometer is calibrated.

10. Means and standard deviations of the reflectometer readings from the ten transect samples were calculated for each beach that was sampled. These were then tabulated with the data from 1984-1990. T-score calculations at a 0.05 level of significance were used to compare the 1989 reflectometer readings with the 1990 reflectometer readings.

RESULTS

Fourteen beaches were sampled in 1990. All of these were compared to 1989. The levels of sand discoloration as measured by reflectometer readings are presented in Table I-1. For purposes of comparison, this data is presented with equivalent figures from 1989. Due to lack of available time or erosion six beaches were deleted from the study. No transect lines were changed.

In comparing the 1990 and 1989 sand analyses, one beach showed an increase in sand discoloration, but not at a 0.05 level of significance; and nine showed an increase at a 0.05 level of significance. Three beaches showed a decrease in sand discoloration at a 0.05 level of significance; and one showed a decrease, but not at a 0.05 level of significance. (See data sheets for each beach.)

Results of the charcoal and human litter accumulation are summarized in table I-2 for the years 1984-1990. In comparing the 1989-1990 data, nine beaches showed an increase in the incidence of charcoal greater than 1 cm, and five showed a decrease. In comparing the 1989-1990 data, five beaches showed an increase in the amount of human litter, eight showed a decrease, and one showed no change. These comparisons of human litter and charcoal debris were not analyzed using T-score calculations to determine the level of significance.

CONCLUSIONS

The Colorado River beaches in 1990 appear to have increased in human litter compared to the previous year. The results of the sand discoloration tests show a slow but steady increase from 1984 through 1990. Based on this data, it is concluded that human impact is a factor in increased discoloration on the beaches.

The study indicates that the levels of charcoal and human litter found on the beaches increased from 1989 to 1990. The levels of charcoal found are considerably greater than the amount of human litter found for 1990. These data indicate that the increasing levels of charcoal may be responsible for the increased sand discoloration. It is also possible that discoloration may be due to organic materials such as tamarisk duff.

It should also be noted that some beaches appeared to be more contaminated with human litter and charcoal debris than the transect line samples indicated. This may be due to changing use patterns on the beaches.

The results of this study support the initial hypothesis that selected Grand Canyon camping beaches have shown an increase in both sand discoloration and the incidence of charcoal and human litter since the 1983 flood scoured them clean.

RECOMMENDATIONS

Perhaps factors other than human use are influencing the data obtained in this study. In order to better differentiate between human impact and other factors on the sand discoloration levels we recommend: 1) samples be taken under established tamarisk trees or other vegetation, 2) samples of sifted sand with low reflectometer readings be saved and brought back for laboratory analysis.

Because the present transect lines no longer consistently cross the most heavily impacted portions of the beaches, we recommend that future investigators consider relocating some transect lines. We also recommend that a sampling of human litter be taken at the termination point of each campsite due to the observation of large accumulations of human litter in these areas. Much of this accumulation appears to be related to prevailing wind direction.

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Equipment list

Reflectometer II + battery; (extra battery)
500-1000 small whirl packs
Transect line (40 meter tape)
2 magic markers (waterproof)
3-one square meter frames, collapsible
5 plastic sand sifters
filter paper (#7 coarse grade) 12 per beach
2 tweezers (to pick up filter paper)
2 toothbrushes (to clean stainless steel mesh apparatus)
12 large sample bags (to store samples)
5-150 micron stainless steel mesh apparatus
1 table with legs
calculator with statistical mode
pad for writing, pencils, pencil sharpener
table of T-scores
1 clip board
chalkboard and chalk, to record location
black and white film, camera
umbrella
previous year's beach sand contamination report, including data sheets of each beach
photos of previous year's transect lines
epoxy glue to repair mesh screens
computer diskettes
blank data sheets
Apple StatPak program to calculate T-scores
Cricket graphing program to display data
previous year's report and tables on Macintosh diskettes

Table I-1 Results of sand discoloration analysis of beach campsites in Grand Canyon, 1984-1990 (means only)

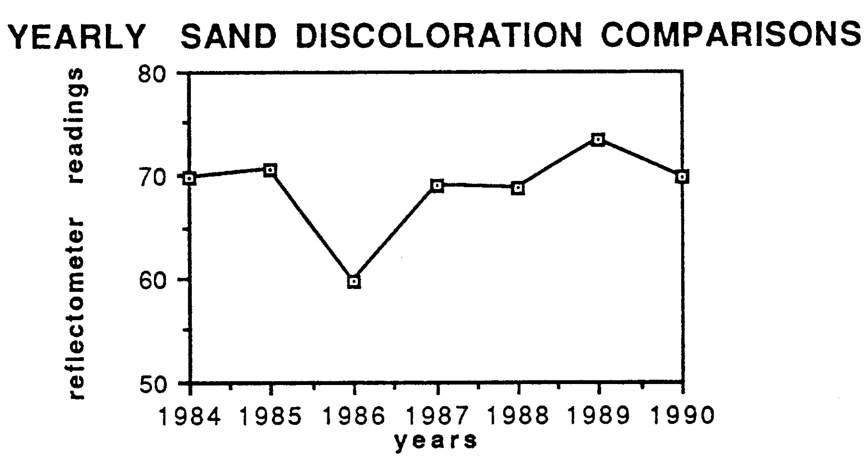
Site No.	Campsite Name	River Mile	1984 (S.D.)	1985 (S.D.)	1986 (S.D.)	1987 (S.D.)	1988 (S.D.)	1989 (S. D.)	1990 (S. D)
			Sand Discoloration (Standard Deviation)						
1	Badger Rapid	8.0	69.69 (2.52)	70.55 (1.82)	59.65 (5.59)	69.03 (3.95)	68.76 (2.86)	73.42 (1.43)	69.7 (2.1)
2	20 Mile	20.0	68.78 (3.14)	64.29 (3.07)	67.47 (4.54)	69.20 (2.19)	deleted		
3	Shinumo Wash	29.0	69.10 (3.16)	68.62 (3.03)	68.24 (5.14)	72.57 (1.95)	67.42 (3.22)	64.64 (0.69)	69.5 (2.5)
4	Anasazi Bridge	43.5	70.55 (1.83)	71.13 (1.80)	71.61 (1.79)	72.72 (2.24)	deleted		
5	Lower Nankoweap	53.0	64.91 (3.16)	69.33 (2.66)	66.67 (3.51)	71.36 (1.85)	65.67 (2.73)	62.28 (1.73)	70.8 (2.0)
6	Awatubi	58.1	64.48 (5.73)	66.97 (3.31)	64.96 (4.21)	70.90 (2.46)	69.61 (3.47)	73.21 (2.66)	73.8 (2.8)
7	Lava Canyon (Chuar)	65.5	65.91 (4.05)	68.56 (3.81)	67.24 (2.87)	beach gone	beach gone		
8	Unkar	72.2	67.70 (2.28)						
9	Nevills Rapid	75.5	66.80 (4.87)	72.21 (1.35)	70.94 (2.98)	69.77 (3.12)	67.68 (3.20)	70.98 (2.28)	
10	Hance Rapid	76.5	66.87 (5.14)	63.82 (2.92)	65.00 (4.12)	69.12 (3.56)		67.62 (1.96)	70.5 (2.9)
11	Grapevine	81.1	67.62 (2.18)	67.39 (2.95)	69.38 (3.95)	71.25 (1.04)	67.98 (1.42)	67.15 (0.77)	
12	Granite Rapid	93.2	68.48 (3.28)	62.35 (3.50)	68.55 (2.06)	67.52 (1.40)	58.66 (3.47)	54.38 (3.08)	69.7 (2.9)
13	Lower Bass Camp	108.5	63.38 (5.69)	64.46 (1.69)	67.87 (3.71)	70.31 (3.46)	63.00 (2.56)	61.56 (1.09)	68.7 (3.4)
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	69.47 (2.28)	69.87 (2.47)	68.3 (3.8)
16	Forster	122.8	68.65 (5.16)	69.74 (0.74)	73.27 (1.93)	67.98 (1.43)	66.54 (4.04)	66.29 (1.38)	63.2 (2.0)
17	Bedrock	131.0	70.54 (3.40)	68.20 (2.02)	71.50 (1.64)	69.49 (1.68)	68.19 (2.55)		
18	Dubendorff	132.0	70.22 (2.51)	69.63 (2.35)	69.62 (1.76)	71.07 (2.51)	71.83 (1.50)	river protocol	
19	Deer Creek	136.0		65.46 (1.38)	66.68 (2.16)	65.43 (2.30)	68.43 (3.70)	63.96 (1.18)	
20	Pancho's Kitchen	137.0	65.90 (3.79)	67.20 (3.81)	69.43 (3.04)	69.32 (2.00)	66.35 (2.32)	62.19 (1.46)	68.8 (3.7)
21	Upper National	166.5	68.95 (3.00)	73.31 (0.98)	beach gone	beach gone			
22	Lower National Canyon	166.6	63.59 (3.00)	67.10 (2.42)	69.23 (1.66)	65.62 (2.17)	66.21 (2.09)	61.63 (0.99)	77.9 (1.4)
23	Upper Lava	179.0					71.73 (1.70)		
24	Lower Lava Falls	180.0		67.74 (1.65)	67.63 (2.92)	72.87 (3.17)	69.43 (1.56)	69.32 (1.45)	
25	186 Mile	186.0	72.06 (1.50)	70.95 (2.18)	69.54 (1.23)	71.43 (1.11)	64.65 (1.51)	70.87 (2.39)	
26	Helicopter Pad	187.2					63.53 (2.07)		
27	194 Mile	194					66.69 (1.56)	71.99 (1.45)	75.2 (1.0)
28	195 Mile	195				71.91 (1.71)			
29	Parashant	198.5	63.94 (4.77)	68.39 (2.68)	beach gone	beach gone			
30	Indian Canyon	207.0			71.09 (1.52)	72.18 (2.11)	69.17 (2.85)	70.06 (1.21)	
31	Granite Park	208.8	68.93 (2.17)	69.88 (2.13)	69.97 (2.48)	69.56 (4.52)	69.04 (2.54)	61.71 (2.27)	73.3 (3.6)
32	Pumpkin Bowl	213.0	70.83 (1.75)	68.63 (2.41)	69.54 (1.81)	69.17 (2.60)	66.52 (2.25)	72.32 (1.31)	
33	Trail Canyon	219.0	72.18 (1.45)	68.78 (3.38)	beach gone	beach gone			
34	220 Mile	220.0	67.71 ( )	66.93 (2.28)	68.67 (1.74)	69.18 (1.94)	64.97 (1.51)	70.30 (1.91)	65.1 (3.0)

Table I-2 Results of charcoal and human litter accumulations analysis of beach campsites in Grand Canyon 1984-1990 (means only).

Site No.	Campsite Name	River Mile	Charcoal cm/m2 1984	1985	1986	1987	1988	1989	1990	Human Litter m2 1984	1985	1986	1987	1988	1989	1990
1	Badger Rapid	8.0	2.5	0.2	0.2	10.4	5.7	9.6	19	0.2	0.0	0.3	0.4	0.2	0.7	.1
2	20 Mile	20.0	0.0	0.3	0.0	0.2				0.2	0.2	0.0	0.0			
3	Shinumo Wash	29.0	0.0	0.0	0.0	0.6	0.7	0.4	0.5	0.1	1.0	0.1	0.5	0.1	0.2	.1
4	Anasazi Bridge	43.5	0.0	0.0	0.2	0.2				0.0	0.0	0.0	0.1			
5	Lower Nankoweap	53.0	0.2	0.6	0.6	6.9	4.8	1.5	4.7	0.4	0.0	0.0	0.8	0.2	0.5	.4
6	Awatubi	58.1	0.0	0.0	0.0	1.3	0.8	0.3	0.8	0.0	0.3	0.1	0.5	0.2	0.1	.1
7	Lava Canyon (Chuar)	65.5	1.6	1.3	4.5	beach gone		0.3		0.0	0.2	beach gone				
8	Unkar	72.2	0.2	beach gone						0.1	beach gone					
9	Nevills Rapid	75.5	0.3	0.0	0.0	0.0	0.8	0.6	1.1	0.0	0.0	0.0	0.1	0.0	0.1	.2
10	Hance Rapid	76.5	0.2	0.9	1.5	3.6		3.1		0.0	0.0	0.0	0.2		0.0	
11	Grapevine	81.1	0.0	0.0	0.0	0.5	0.6	0.2	2.0	0.0	0.0	0.0	0.0	0.2	0.4	.3
12	Granite Rapid	93.2	0.0	0.0	0.0	2.1	0.8	1.08		0.0	0.0	0.4	0.2	0.6	1.9	
13	Lower Bass Camp	108.5	1.5	0.4	0.5	3.8	3.5	2.67	.5	2.2	0.0	0.5	0.6	0.3	1.22	.3
14	114 Mile	114.0	0.2	0.0	0.1	delete				0.0	0.5	delete				
15	122 Mile	122.0	0.0	0.0	1.0		0.0	0.0	.1	0.2	0.1			0.0	0.7	.2
16	Forster	122.8	0.0	0.0	0.6	0.0	0.2	0.8	.7	0.0	0.0	0.0	0.0	0.0	0.0	.2
17	Bedrock	131.0	0.0	0.3	0.5	0.0	0.9			0.1	0.0	0.1	0.0	0.1		
18	Dubendorff	132.0	0.0	0.5	0.0	0.0	0.0			0.0	0.0	0.0	0.3	0.0		
19	Deer Creek	136.0		2.0	1.8	1.0	1.1	1.7			0.0	0.6	0.4	0.4	0.4	
20	Pancho's Kitchen	137.0	0.0	0.1	1.3	0.8	0.0	0.8	.1	0.4	0.1	0.8	0.4	0.0	0.7	.4
21	Upper National	166.5	0.0	0.0	beach gone					0.2	0.2	beach gone				
22	Lower National Canyon	166.6	0.0	0.0	0.2	1.3	0.1	0.5	1.1	0.0	0.2	0.7	0.5	0.1	0.0	.3
23	Upper Lava	179.0						0.0						0.3		
24	Lower Lava Falls	180.0		0.7	1.6	3.7	0.5	1.8			0.0	0.9	0.0	0.1	0.3	
25	186 Mile	186.0	0.2	0.6	0.8	0.0	0.1	0.1		0.0	0.0	0.0	0.0	0.4	0.1	
26	Helicopter Pad	187.2					0.0							0.0		
27	194 Mile	194.0					0.2	0.3	.5					0.0	0.0	.1
28	195 Mile	195.0														
29	Parashant	198.5	0.0	0.0	beach gone					0.2	0.3	beach gone				
30	Indian Canyon	207.0				0.0	0.0	0.2				0.0	0.1	0.1	0.0	
31	Granite Park	208.8	0.1	0.0	1.2	1.9	0.8	2.2	1.1	0.1	0.0	0.1	0.1	0.3	0.6	.3
32	Pumpkin Bowl	213.0	0.0	0.2	0.1	0.0	0.1	0.1		0.1	0.0	0.0	0.0	0.0	0.4	
33	Trail Canyon	219.0	0.1	0.0	beach gone					0.0	0.0	beach gone				
34	220 Mile	220.0	0.4	0.0	0.0	1.4	2.1	1.1	.7	0.2	0.0	0.0	0.4	0.0	0.9	.4

Beach name: Badger
River mile: 8.0

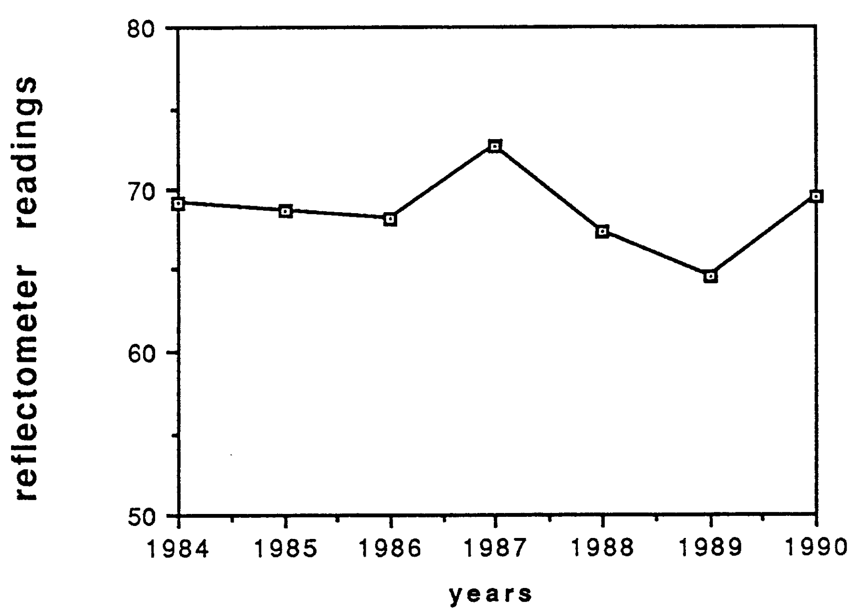
Sample #	Sand Discoloration (reflectometer reading)	
	1989	1990
1	73.1	70.9
2	70.8	71.4
3	73.5	71.9
4	71.7	69.2
5	72.9	67.6
6	74.1	70.4
7	75.7	71.7
8	74.9	65.9
9	73.8	69.4
10	73.7	68.6
Mean	73.42	69.7
Std. Deviation	1.43	2.1
T-value	4.63	-4.6
DF		9.0
Prob		0.001



Beach name: Shinumo Wash
River mile: 29

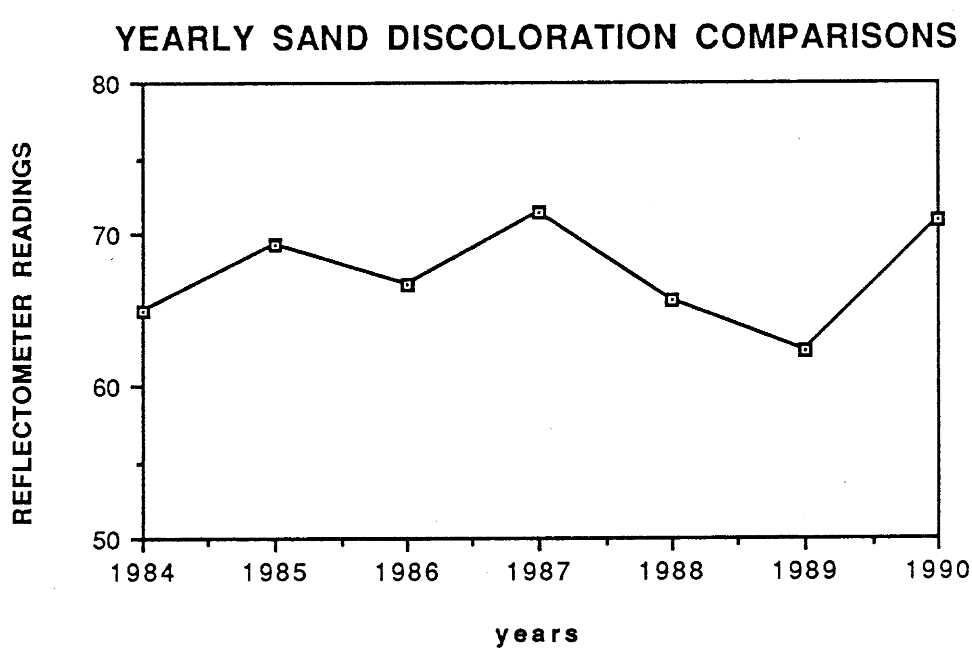
Sample #	Sand Discoloration (reflectometer reading) 1989	1990
1	63.3	70.8
2	64.8	73.8
3	64.5	70.9
4	65.2	68.9
5	66.1	67.7
6	64.3	67.9
7	65.0	72.4
8	64.4	66.7
9	64.5	66.3
10	64.0	69.9
mean	64.6	69.5
Std. Deviation	.69	2.5
T-value	-2.71	5.859
DF		9
Prob		.000

YEARLY SAND DISCOLORATION COMPARISONS



Beach name: Lower Nankoweap
River mile: 53

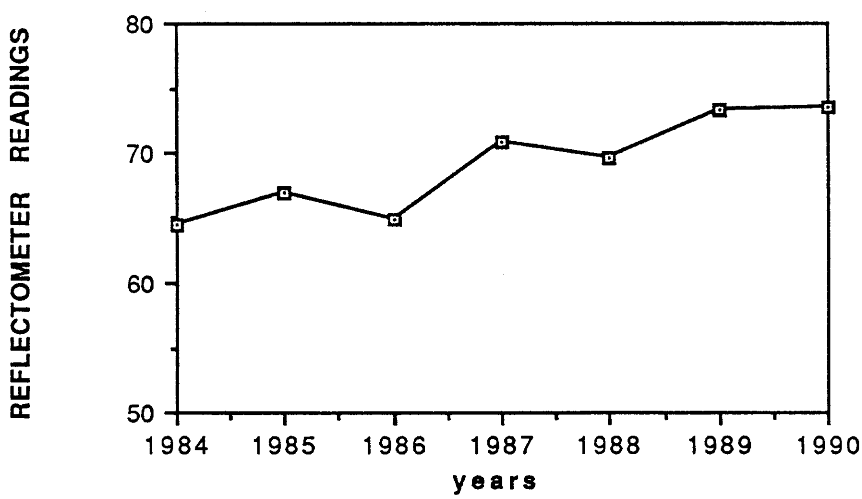
Sample #	Sand Discoloration (reflectometer reading) 1989	1990
1	60.8	70.5
2	63.2	69.8
3	62.7	73.4
4	64.9	72.1
5	62.0	68.6
6	60.3	67,8
7	63.7	73.6
8	60.6	69.1
9	64.3	71.7
10	60.3	71.2
Mean	62.3	70.8
Std. Deviation	.6	2.0
T-value	-2.95	16.1
DF		9
Prob		.000



Beach name: Awatubi
River mile: 58.1

Sample #	Sand Discoloration (reflectometer reading) 1989	1990
1	74.7	72.3
2	77.7	78.2
3	76.0	71.5
4	70.5	70.2
5	72.3	70.4
6	71.8	72.1
7	69.5	75.6
8	70.7	72.2
9	74.6	75.2
10	74,3	77.2
Mean	73.2	73.5
Std. Deviation	2.7	2.8
T-value	2.84	.302
DF		9
Prob		.770

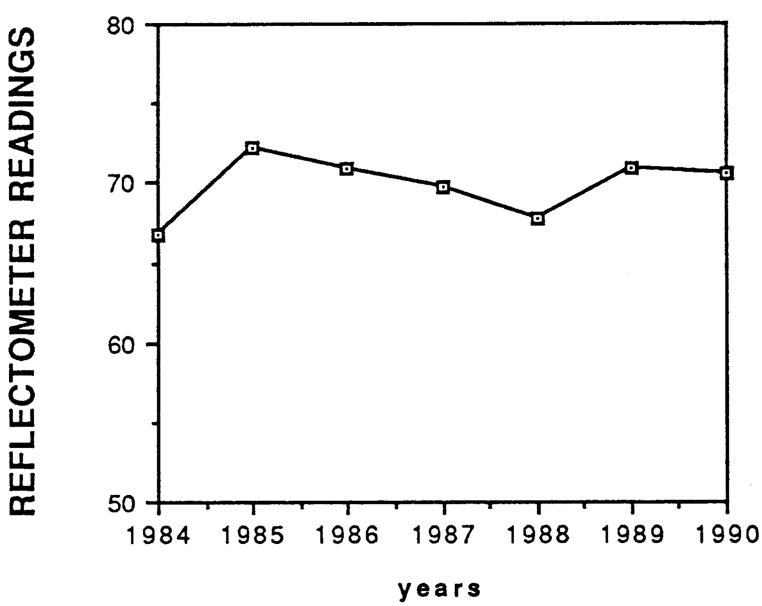
YEARLY SAND DISCOLORATION COMPARISONS



Beach name: Nevills Rapid
River mile: 75.5

Sample #	Sand Discoloration (reflectometer reading) 1989	1990
1	73.4	75.0
2	69.0	73.3
3	72.1	74.2
4	71.5	72.3
5	71.6	63.3
6	70.8	68.8
7	69.0	73.9
8	69.6	69.9
9	67.6	64.6
10	75.2	70.0
Mean	70.9	70.5
Std. Deviation	2.28	2.9
T-value	4.41	-0.341
DF		9
Prob		0.741

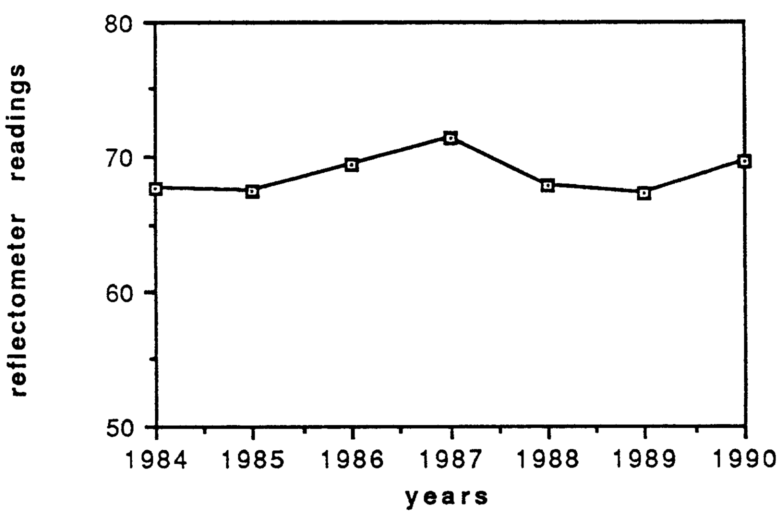
YEARLY SAND DISCOLORATION COMPARISONS



Beach name: Grapevine
River mile: 81.0

Sample #	Sand Discoloration (reflectometer reading)	
	1989	1990
1	67.0	68.9
2	67.2	70.3
3	68.0	67.1
4	67.1	70.0
5	67.7	66.4
6	65.5	69.9
7	66.2	65.9
8	67.6	70.7
9	67.5	71.3
10	67.7	66.0

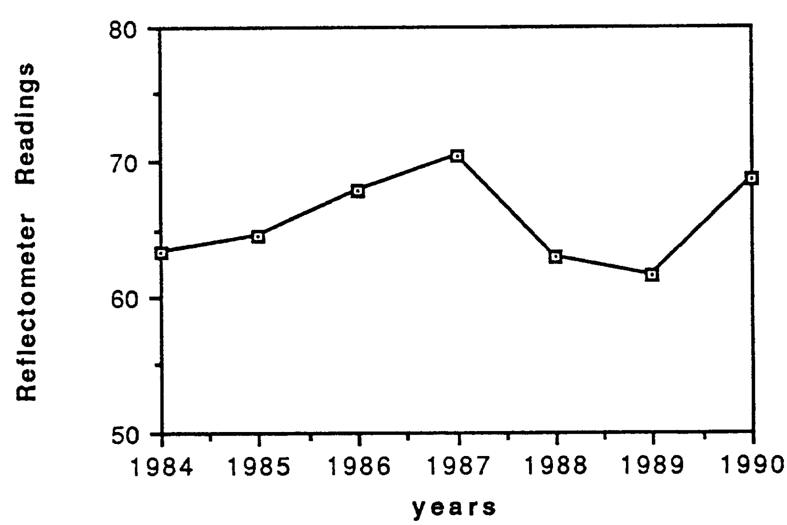
Mean	67.2	69.7
Std. Deviation	0.77	2.9
T-value	-1.7	2.3
DF		9
Prob		0.043



Beach name: Lower Bass Camp
River mile: 108.5

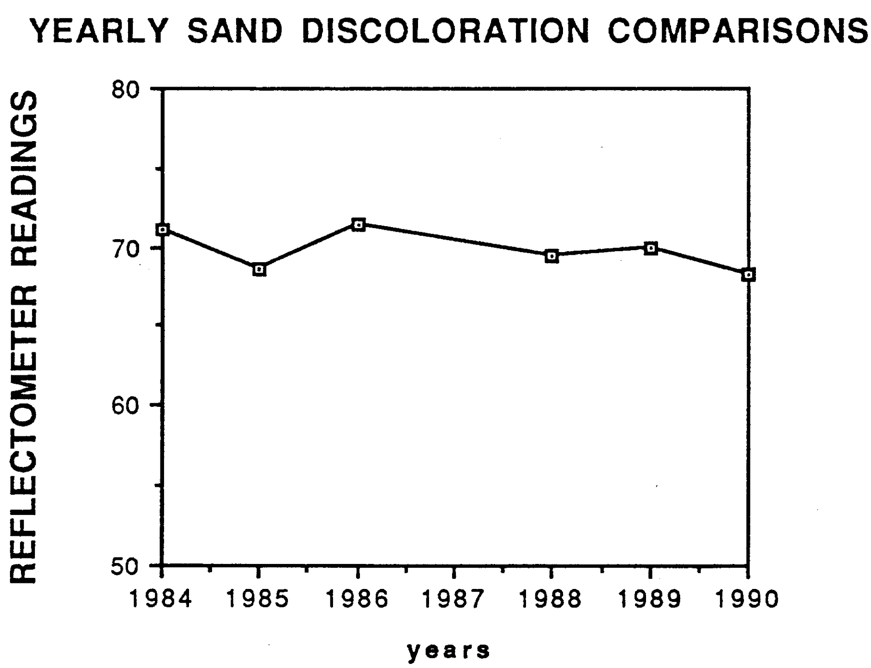
Sample #	Sand Discoloration (reflectometer reading) 1989	1990
1	61.2	71.3
2	61.0	67.0
3	61.2	68.2
4	59.6	70.8
5	63.2	70.2
6	60.9	65.3
7	61.9	67.9
8	62.3	67.7
9	62.7	63.3
10	no sample	75.4
mean	61.6	68.7
Std. Deviation	1.09	3.4
T-value	-1.83	6.223
DF		8
Prob		.000

Yearly Sand Discoloration Comparisons



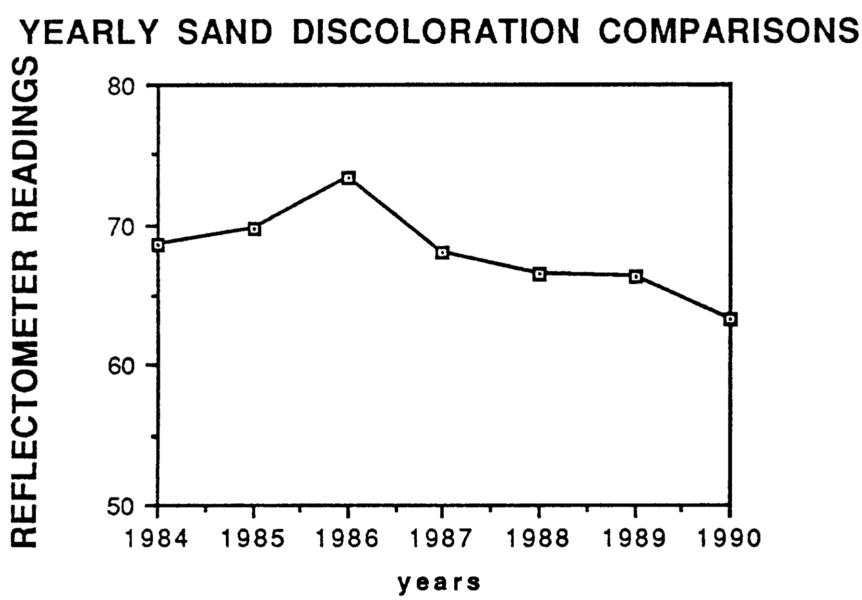
Beach name: Mile 122
River mile: 122

Sample #	Sand Disoloration (reflectometer reading) 1989	1990
1	73.8	67.7
2	72.1	73.7
3	71.0	66.8
4	70.6	66.6
5	70.0	70.0
6	70.3	71.5
7	70.1	59.5
8	67.4	69.0
9	64.9	68.5
10	68.8	69.5
mean	69.9	68.3
Std. Deviation	2.47	3.8
T-value	.32	1.15
DF		9
Prob		.28



Beach Name: Forster
River mile: 122.8

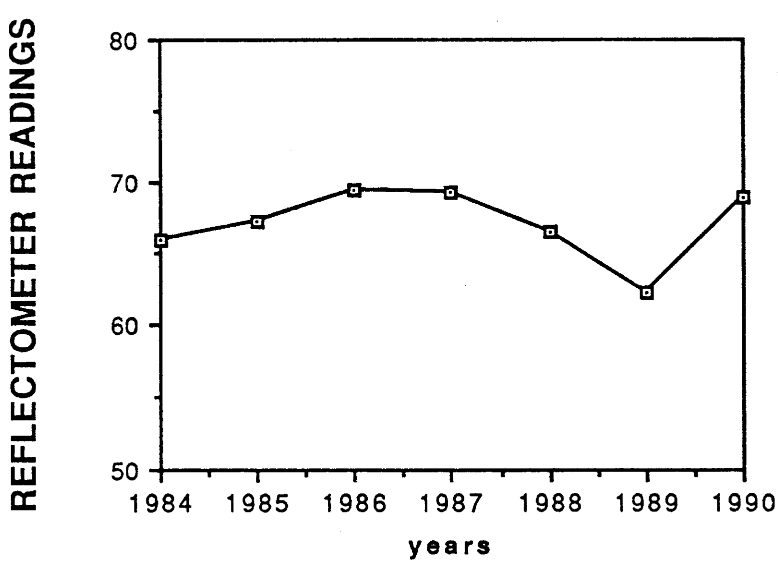
Sample #	Sand Discoloration (reflectometer reading) 1989	1990
1	67.8	72.6
2	66.4	69.5
3	64.3	71.0
4	68.8	no sample
5	65.0	69.5
6	64.9	67.5
7	66.4	69.3
8	65.8	70.7
9	67.2	73.6
10	66.3	67.8
mean	66.29	63.2
Std. Deviation	1.38	2.0
T-value	-0.17	7.086
DF		8
Prob		0.000



Beach name: Panchos Kitchen
River mile: 137

Sample #	Sand Discoloration (reflectometer reading) 1989	1990
1	62.0	70.0
2	59.3	70.4
3	61.7	69.7
4	61.2	67.4
5	61.4	71.7
6	64.6	59.0
7	63.6	70.2
8	62.2	67.4
9	63.0	70.2
10	62.9	71.7
mean	62.19	68.8
Std. Deviation	1.46	3.7
T-value	-5.99	4.482
DF		9
Prob		.002

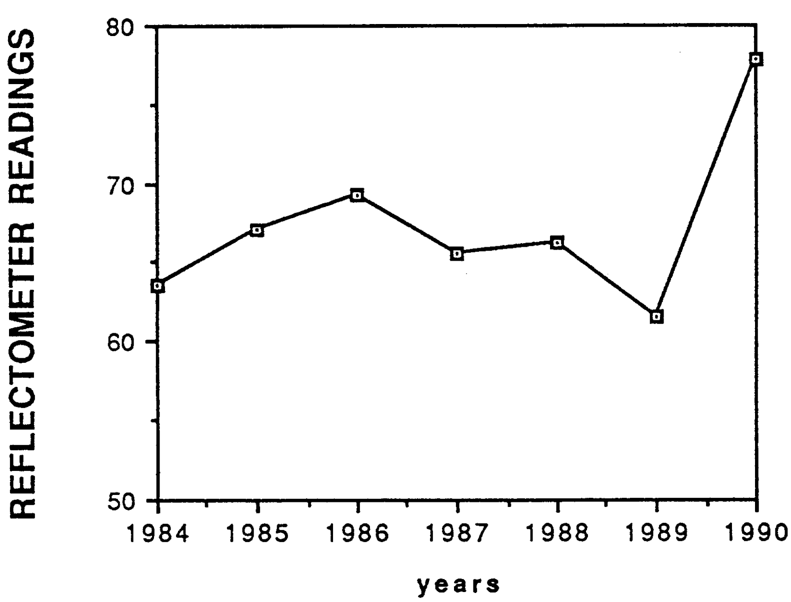
YEARLY SAND DISCOLORATION COMPARISONS



Beach name: Lower National Canyon
River mile: 166.6

Sample #	Sand Discoloration (reflectometer reading)	
	1989	1990
1	63.1	78.4
2	62.2	78.8
3	61.0	77.1
4	61.9	80.6
5	61.5	78.2
6	60.9	78,6
7	62.4	77.9
8	59.5	75.3
9	61.8	77.2
10	62.0	76.6
mean	61.63	77.9
Std. Deviation	.99	1.4
T-value	-6.74	41.83
DF		9
Prob		.000

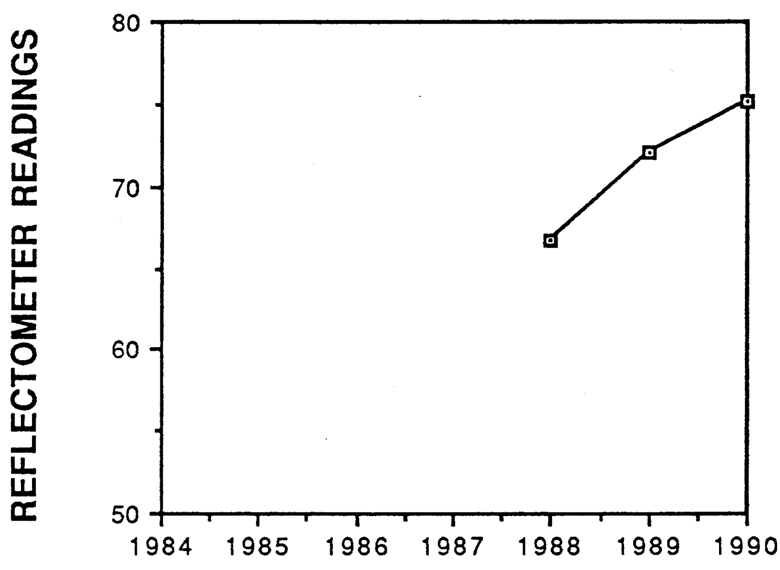
YEARLY SAND DISCOLORATION COMPARISONS



Beach name: 194 Mile
River mile: 194

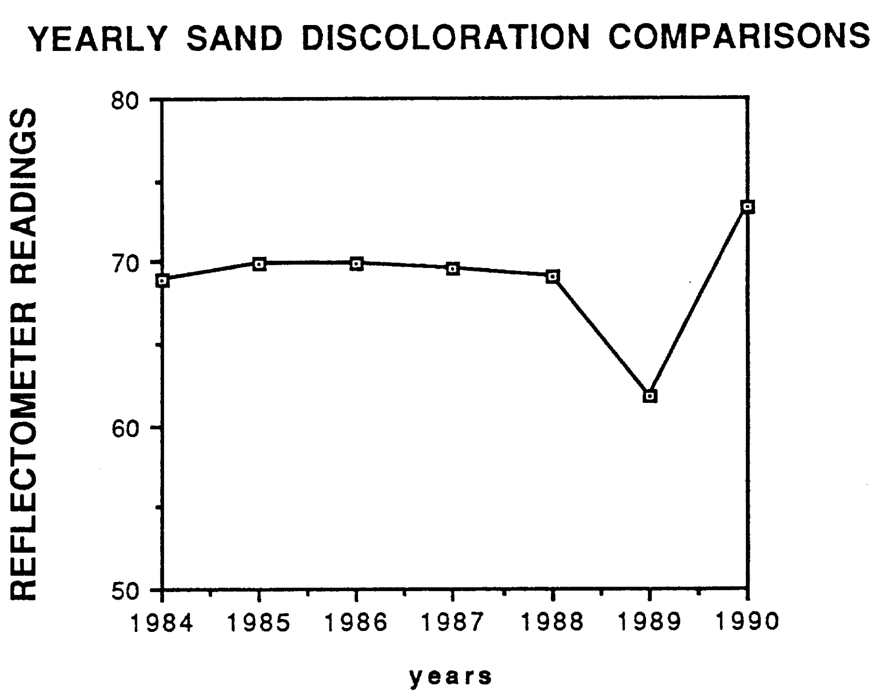
Sample #	Sand Discoloration (reflectometer reading)	
	1989	1990
1	70.1	74.5
2	72.5	74.8
3	70.7	74.3
4	69.9	76.5
5	72.4	74.4
6	73.5	74.2
7	71.3	75.1
8	73.4	75.3
9	74.0	76.3
10	72.1	77.0
mean	71.99	75.2
Std. Deviation	1.45	1.0
T-value	10.43	6.069
DF		9
Prob		.000

YEARLY SAND DISCOLORATION COMPARISONS



Beach name: Granite Park
River mile: 208.8

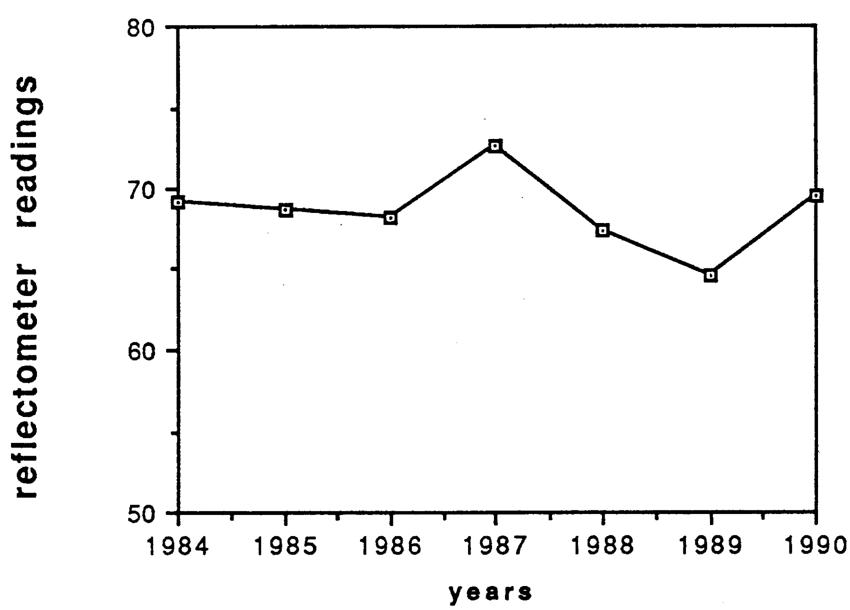
Sample #	Sand Discoloration (reflectometer reading) 1989	1990
1	60.1	76.8
2	60.5	77.4
3	60.6	72.2
4	59.2	74.2
5	61.9	70.9
6	60.0	72.0
7	65.3	74.4
8	60.6	72.9
9	63.3	73.4
10	65.6	69.0
mean	61.71	73.3
Std. Deviation	2.27	3.6
T-value	-6.37	9.0
DF		9
Prob		.000



Beach name: Mile 220
River mile: 220

Sample #	Sand Discoloration (reflectometer reading) 1989	1990
1	72.3	no sample
2	72,7	73.7
3	72.2	73.6
4	69.5	72.8
5	70.4	69.2
6	71.6	74.8
7	69.4	73.8
8	69.1	65.5
9	69.2	73.1
10	66.6	74.3
Mean	70.3	65.1
Std. Deviation	1.91	3.0
T-value	6.28	2.004
DF		8
Prob		0.080

YEARLY SAND DISCOLORATION COMPARISONS



Chapter 2

Topographic Changes On Selected Beaches In The Grand Canyon, 1989-1990

Kathryn Davis, Millard Nobumoto, Stanley Petermeier,
Joyce Scott, Jesse Udall, Allan Vanderschoot

Abstract

Traditional survey methods using photos, bench marks, transit , and rod measurements permitted comparisons of loss and gain in beach sediments.

Since the original survey, 15 of the 29 study areas (cross sections) show a loss of sediment. The 1990 study demonstrates slight gains in sediment along some beaches, whereas most have remained unchanged or continue to lose sediment.

Introduction

The beaches along the Colorado river corridor are one of the most important resources found in Grand Canyon National Park. They provide an environment for a unique and varied riparian flora and fauna. In addition the beaches add to the recreational value of the park. Since the 1963 construction of the Glen Canyon Dam these beaches have undergone considerable alteration. This alteration is of national concern prompting a five year environmental impact study as mandated by the National Environmental Policy Act of 1989.

A research team of science teachers conducted an eleven-day investigation of campsite beaches along the Colorado River in the Grand Canyon. This study, a continuation of research initiated in 1974 and conducted annually since 1982, was implemented to determine the direction, degree and speed of the alteration of selected beaches. Results of this investigation will assist management agencies of the Grand Canyon National Park to understand the positive and/or negative impact of the changes occurring as a result of the fluctuating river flows caused by the Glen Canyon Dam.

The investigation involved a transit survey along previously fixed profile lines from established benchmarks. The research team surveyed a total of 29 cross-sections on 15 beaches.

Methods

Previously established benchmarks were located (one to three per beach). Instrument stations were set (as per historical data) from which horizontal sight readings were taken, based on topography, following historical profiles. Recordings of this cross-sectional data were used to generate new beach profiles which were then compared and contrasted with past profiles.

A. Required Materials

1. 1 survey transit with box
2. 1 tripod
3. 1 100 ft. tape
4. 2 200 ft. tapes
5. 1 50 meter tape
6. 2 red and white steel pins (1 ft. in length)
7. 1 25 ft. retractable survey rod
8. 2 hand lens
9. 2 benchmark nails
10. 1 roll orange flag tape
11. graph paper
12. metal clipboard
13. machete
14. can of WD-40
15. shovel
16. chalkboard
17. chalk
18. pencil sharpener
19. pencils
20. eraser
21. umbrella
22. screwdriver
23. 3-hole paper punch
24. 4 permanent marking pens
25. file folders (one per beach)
26. calculator
27. beach profile location sheets
28. cross section data sheets
29. 3 binders (new data sheets and graph paper; historical record; photographic record)
30. camera and black and white film (1-20 exposures per beach)
31. brunton compass

B. Procedures

Legend: BS (numbered) = Benchmarks or base stations
CS (numbered) = Cross section
Instrument station, once located, is referred to as CS
HI = Height of instrument (transit barrel)

1. Locate all BS's as noted in historical data records (refer to photo history as needed). Tie flag tape to point of BS nail to increase visibility.
2. Stretch measuring tape (foot or meter tape as per previous year's recordings) between BS's; mark instrument stations using red and white pins along this line (as per historical data). Tie flag tape to pins to increase visibility.
3. Set transit on first instrument station (hereafter referred to as CS).
4. Take and record rod reading from the CS onto (toward) whichever BS is to be used for elevation data.
5. Take and record HI.
6. Orient transit barrel along the designated profile direction (refer to historical data).
7. Take and record rod readings along this profile, from CS to water line or edge of beach. Readings are taken at arbitrarily selected positions based on topography (e.g. change in slope, or change in composition of beach).

Note: If horizontal sight readings cannot be taken due to extreme slope of beaches or excessive non-removeable vegetation, adjustments must be made in the angle of the transit barrel. If there is extreme downward slope of beach in relation to BS (resulting in insufficient height of rod), adjust the barrel downward. Record the change in barrel angle and take rod reading. If there is extreme upward slope of beach in relation to BS, adjust barrel upward so as to fix on 0.00 reading of rod height, and record change of barrel angle required to achieve this reading.

8. Take and record rod readings from the same CS onto (toward) any other available BS.
9. Repeat steps 9 thru 8 with the transit set on successive cross sections.
10. See addendum 2-1 for additional procedural recommendations.

(Photo note: Photograph each new benchmark from two angles, incorporating landmark features of the beach. Photograph each cross section if there is some obvious change from previous year's photos).

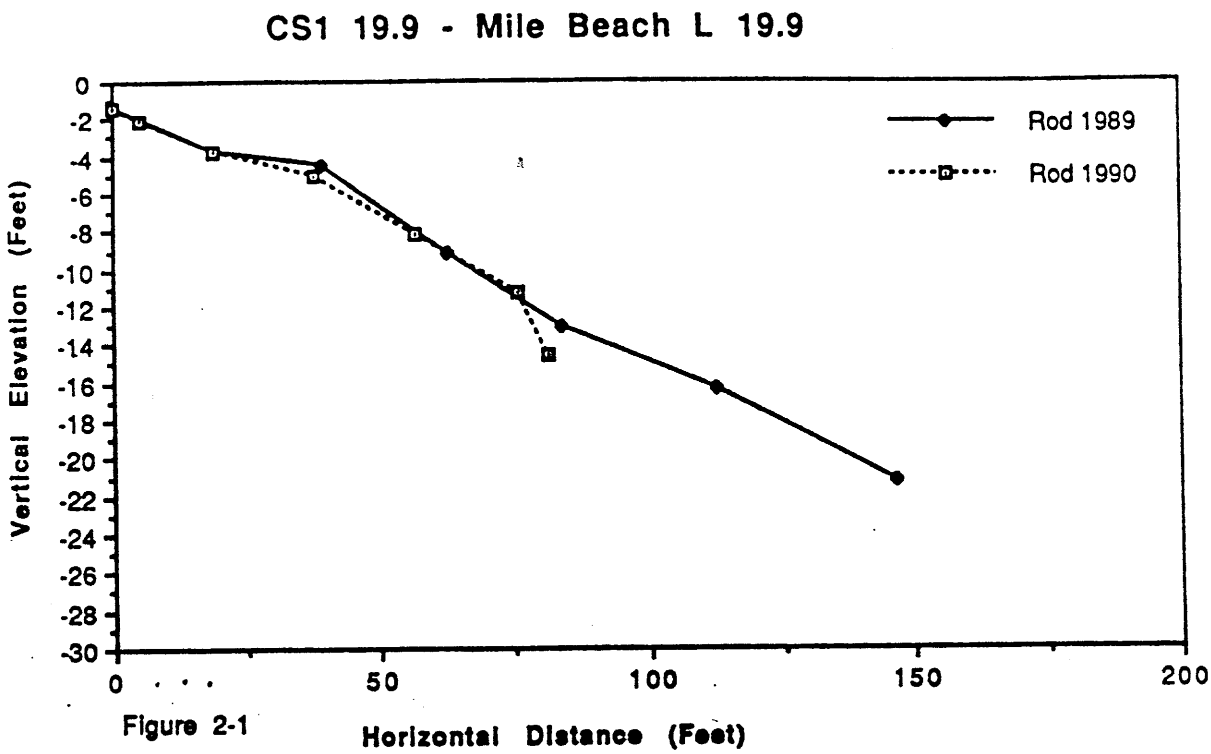


Figure 2-1

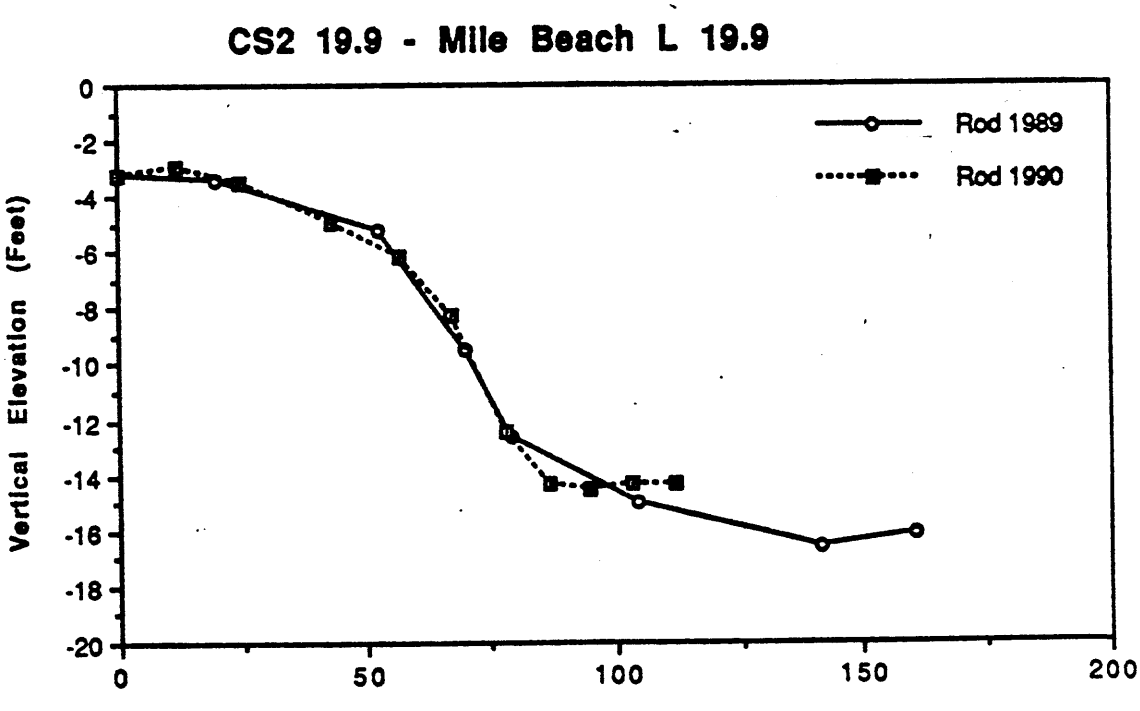


Figure 2-2

CS1 Nautiloid L 34.7

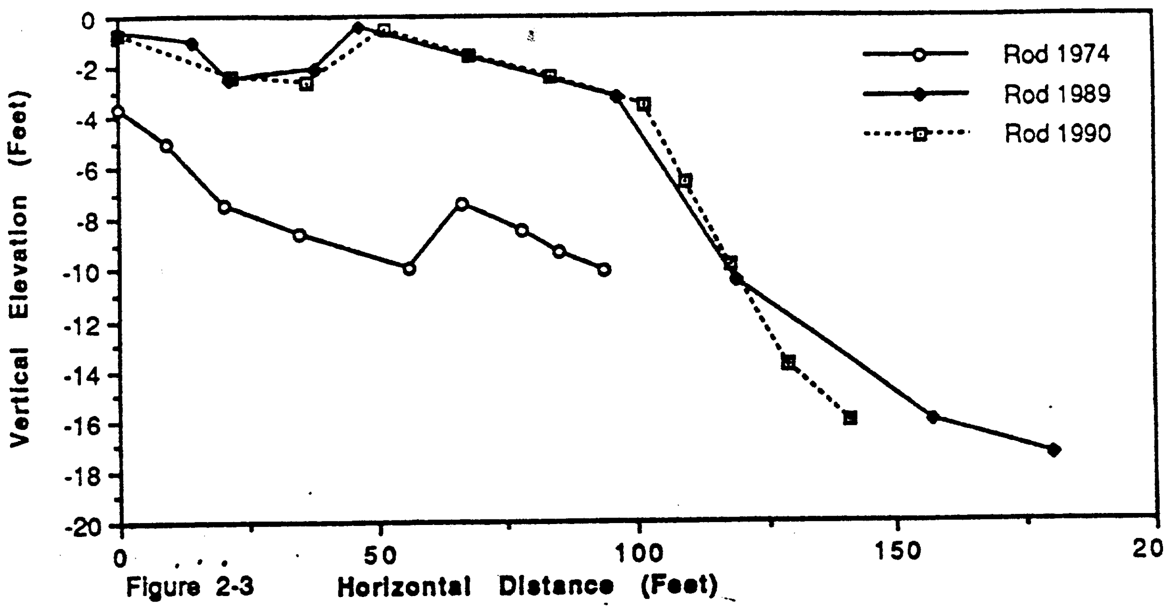


Figure 2-3

CS2 Nautiloid L 34.7

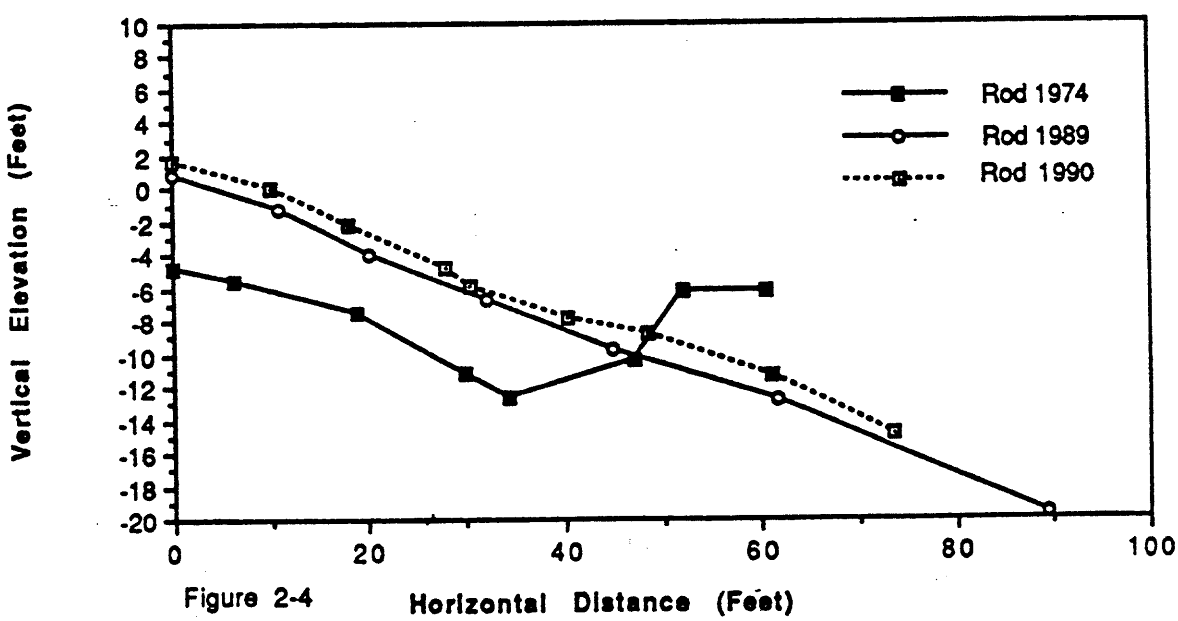


Figure 2-4

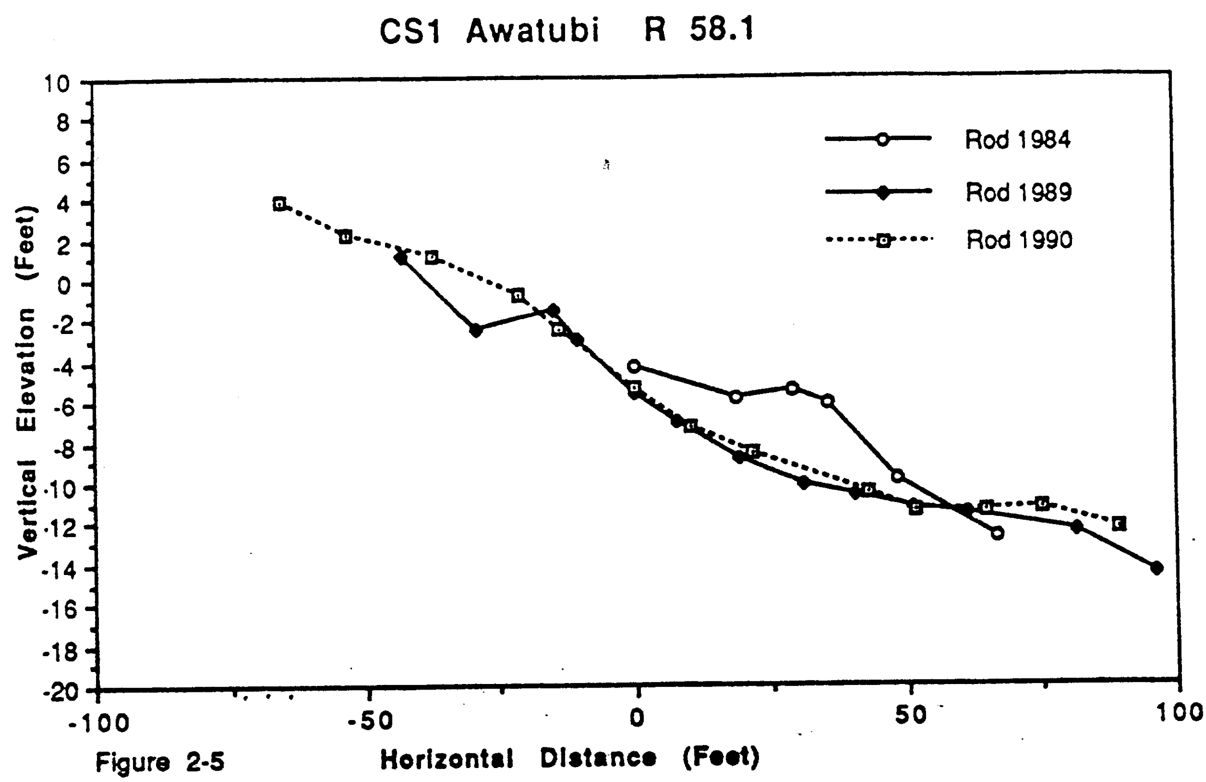


Figure 2-5

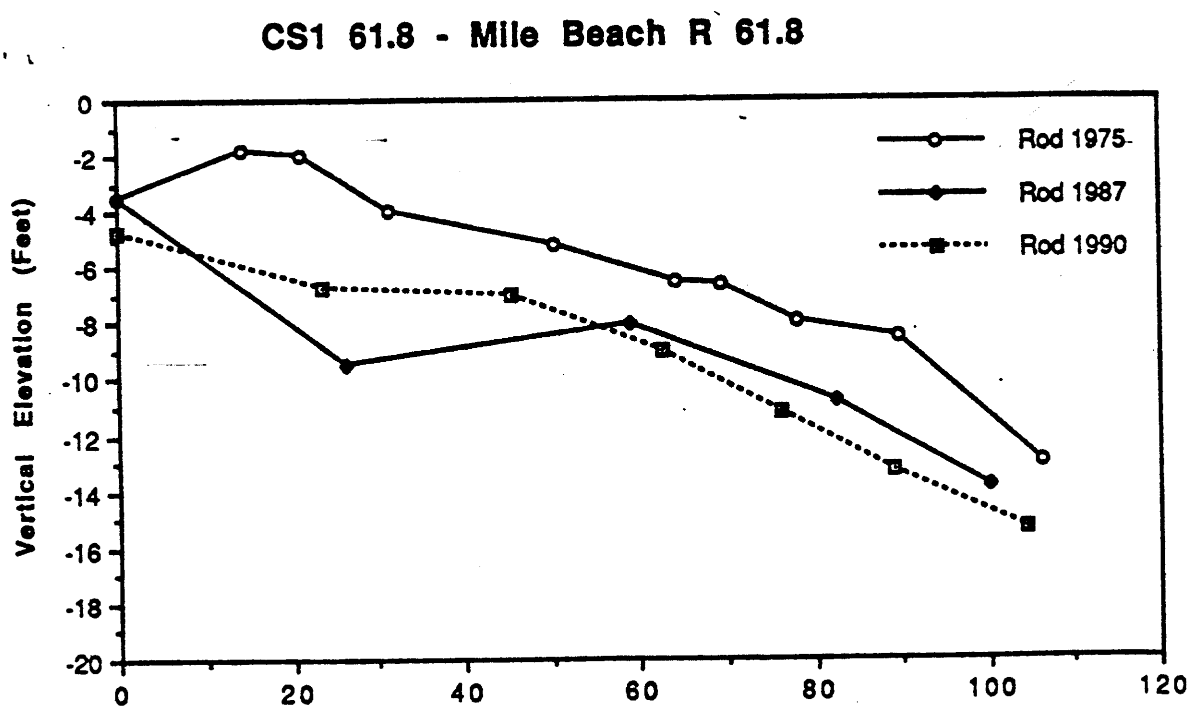


Figure 2-6

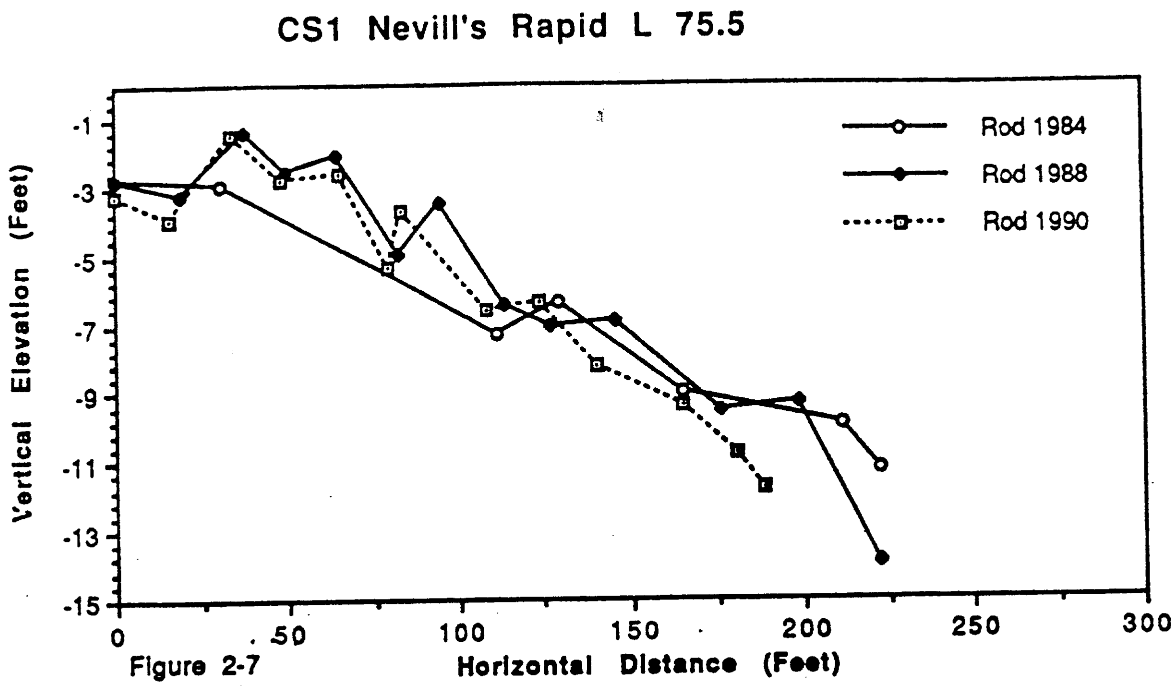


Figure 2-7

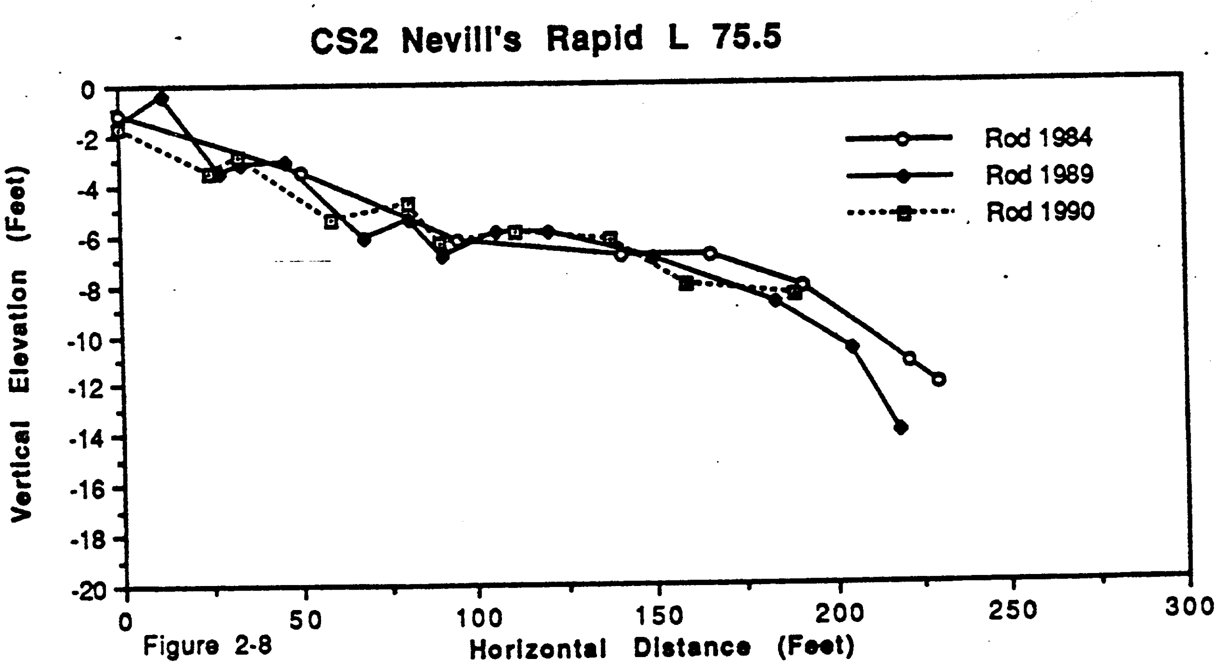


Figure 2-8

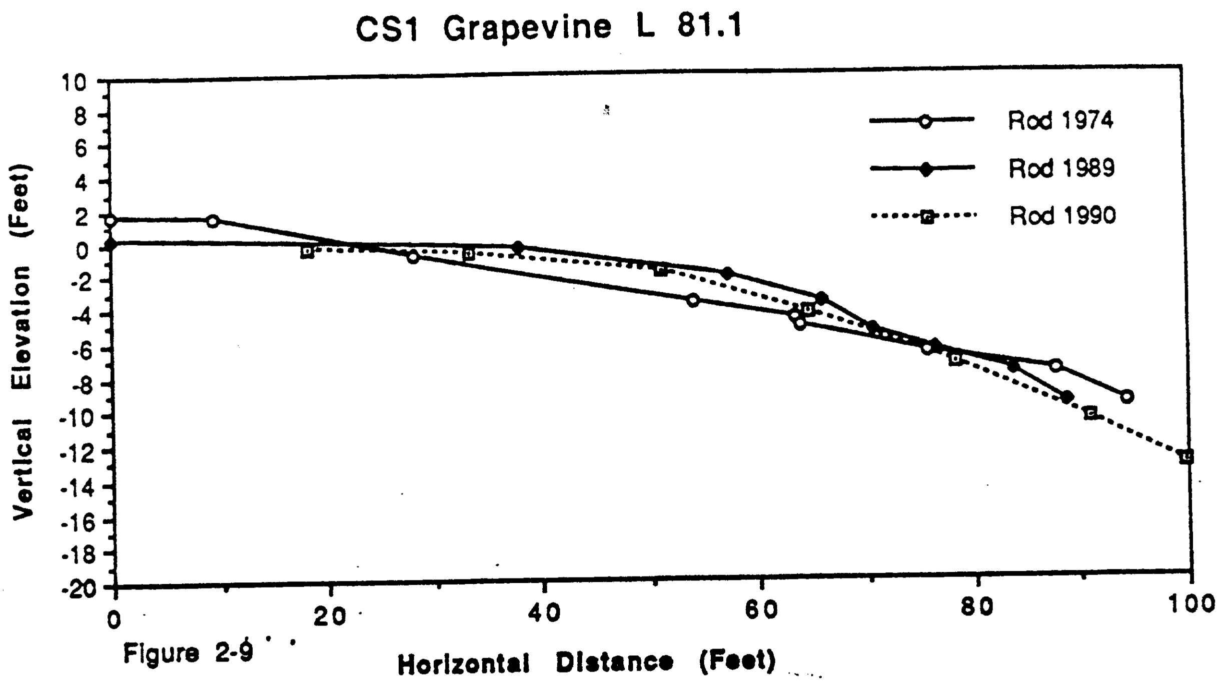


Figure 2-9

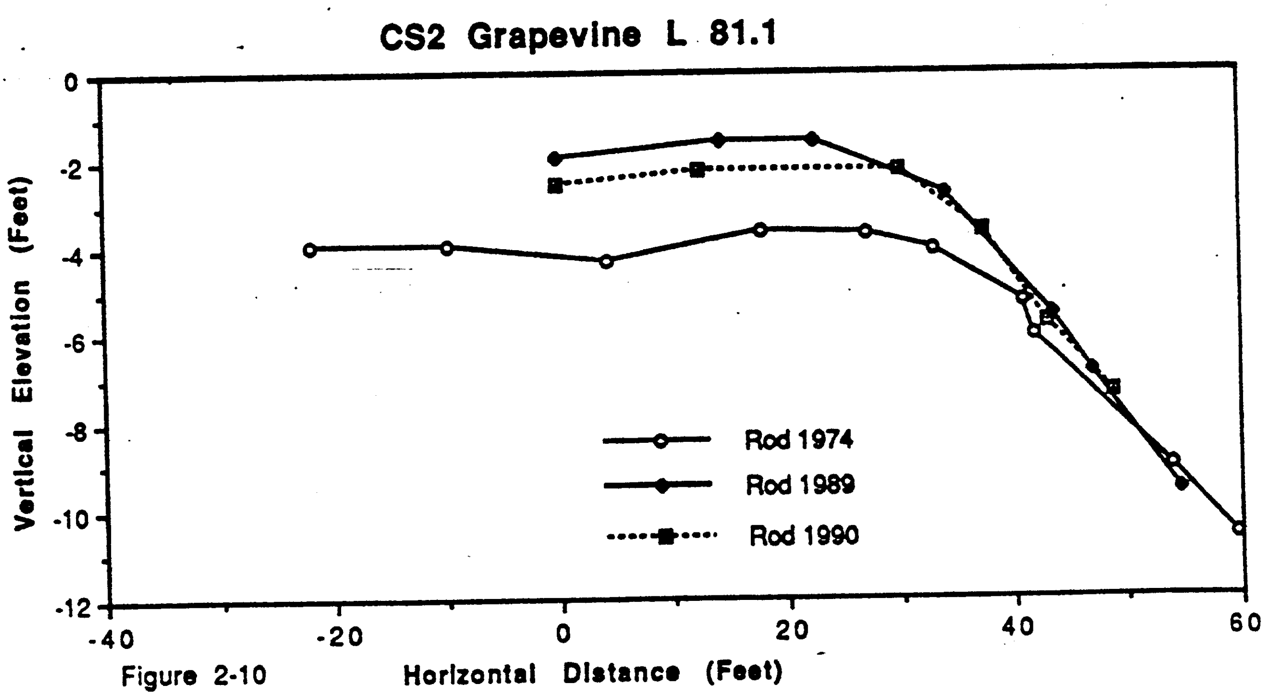


Figure 2-10

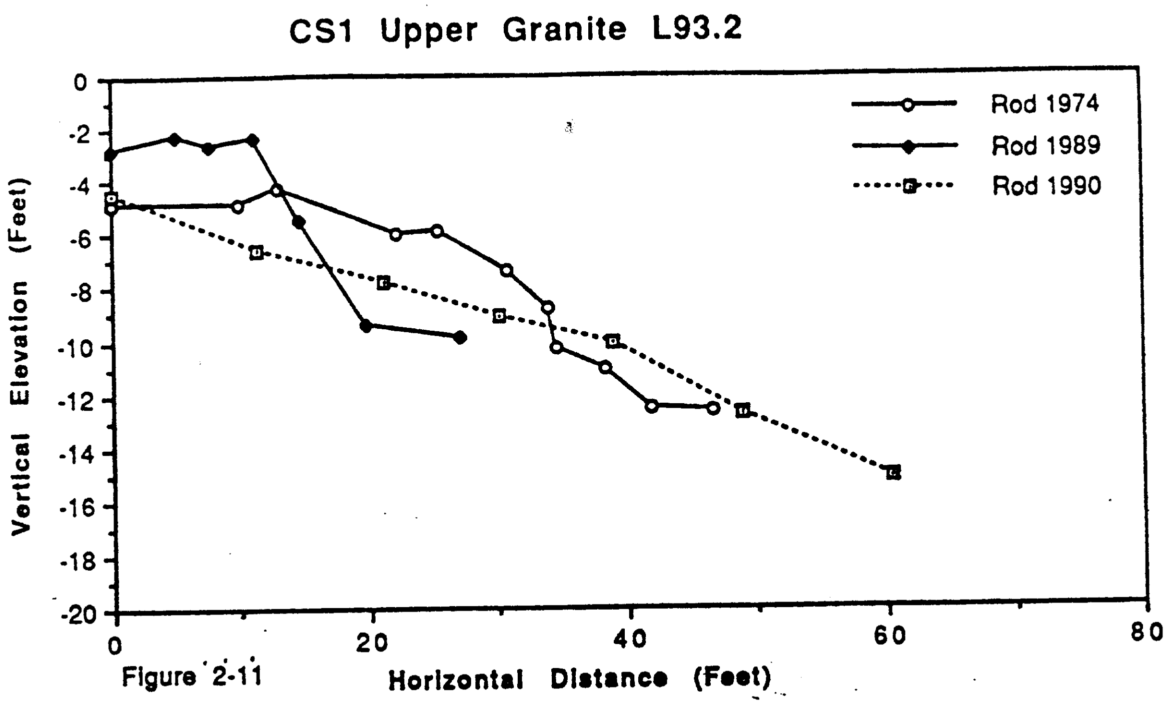


Figure 2-11

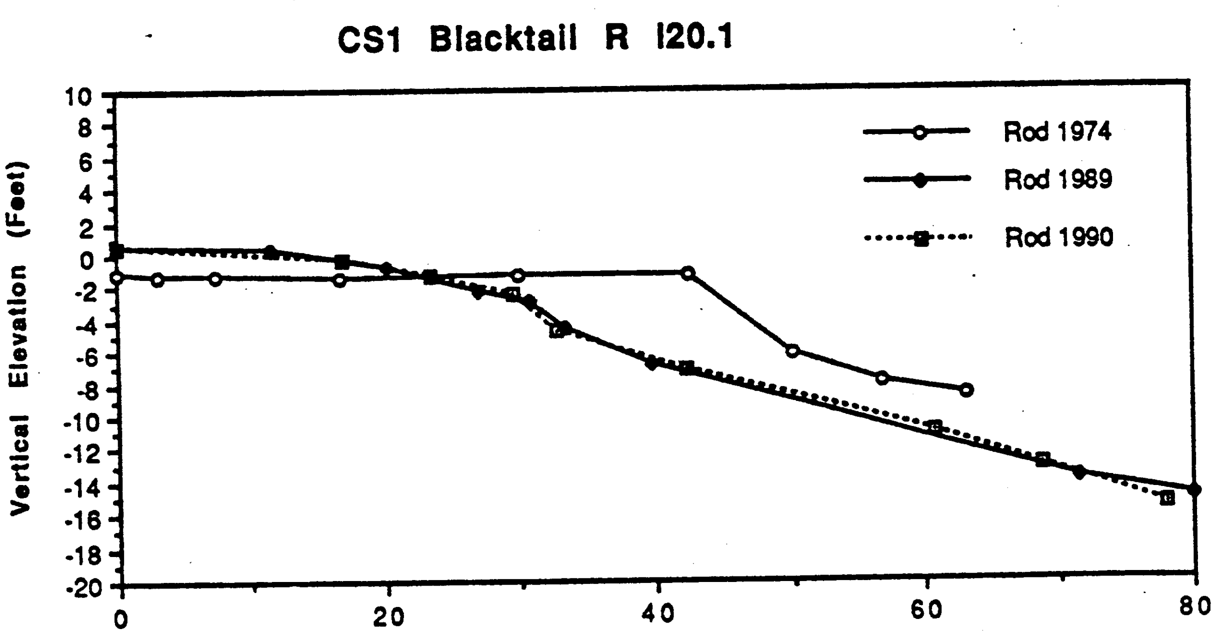


Figure 2-12

CS2 Blacktail Canyon R 120.1

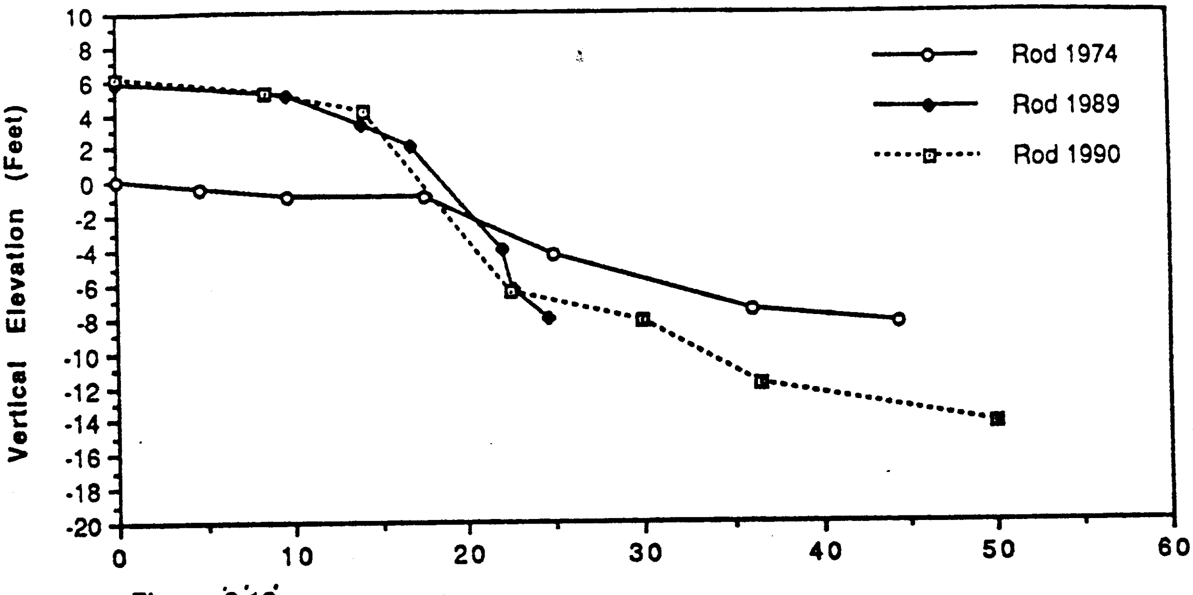


Figure 2-13

CS1 Forster R 122.8

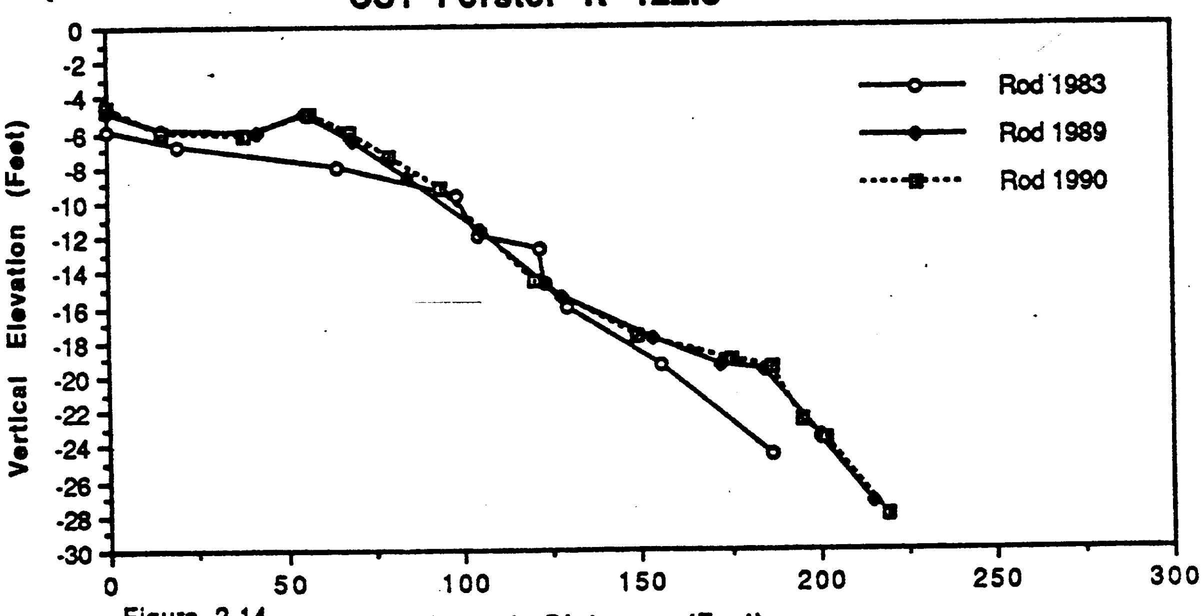


Figure 2-14

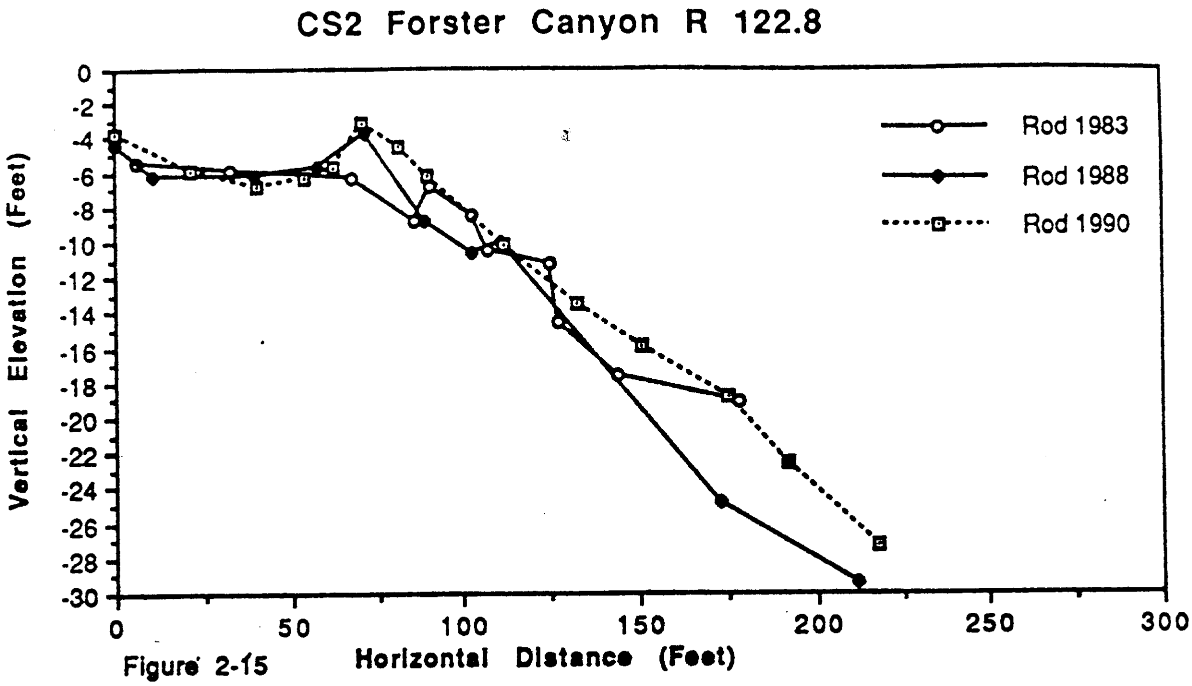


Figure 2-15

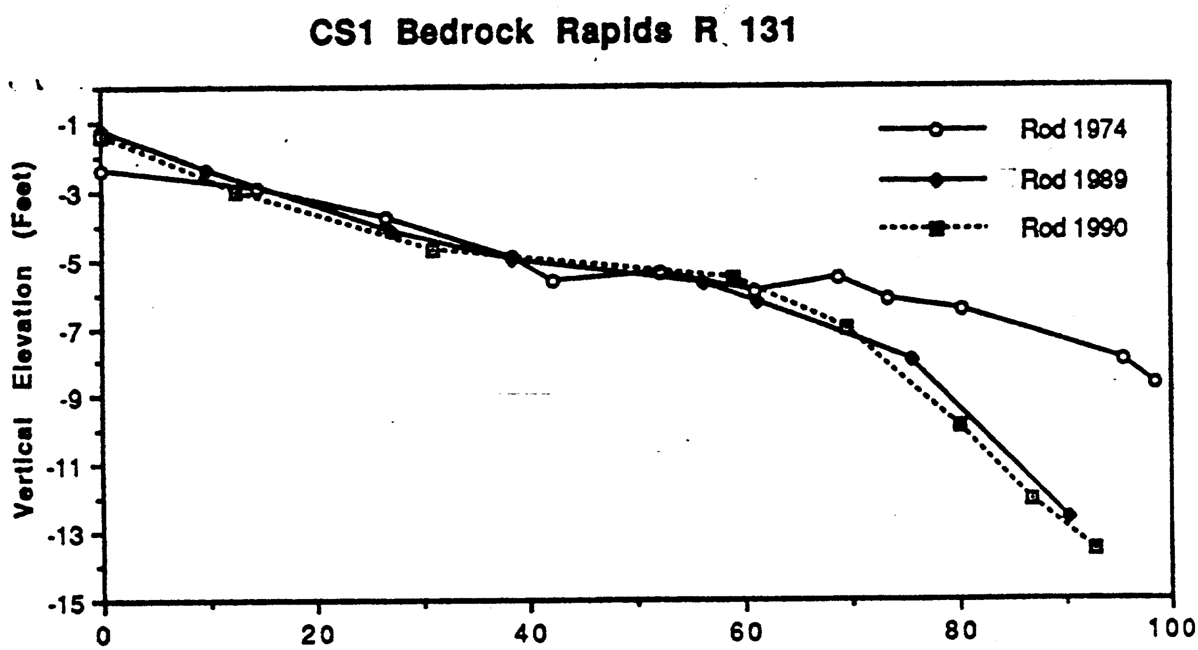


Figure 2-16

CS2 Bedrock Rapids R 131

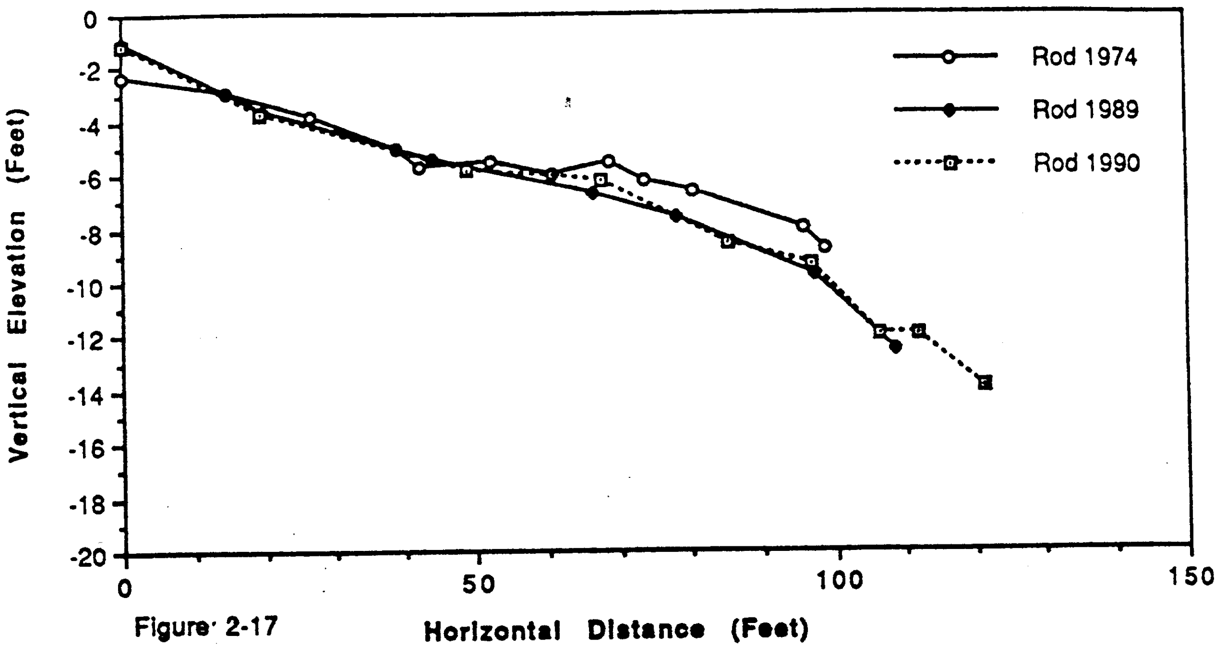


Figure 2-17

CS1 Pancho's Kitchen L 136.6

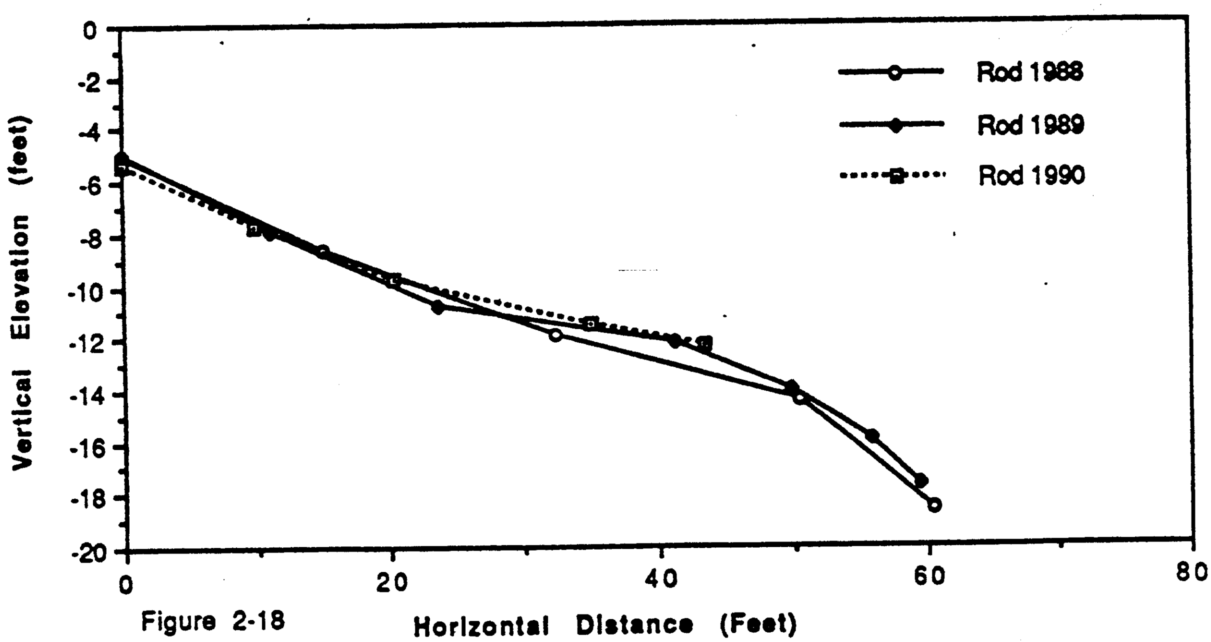


Figure 2-18

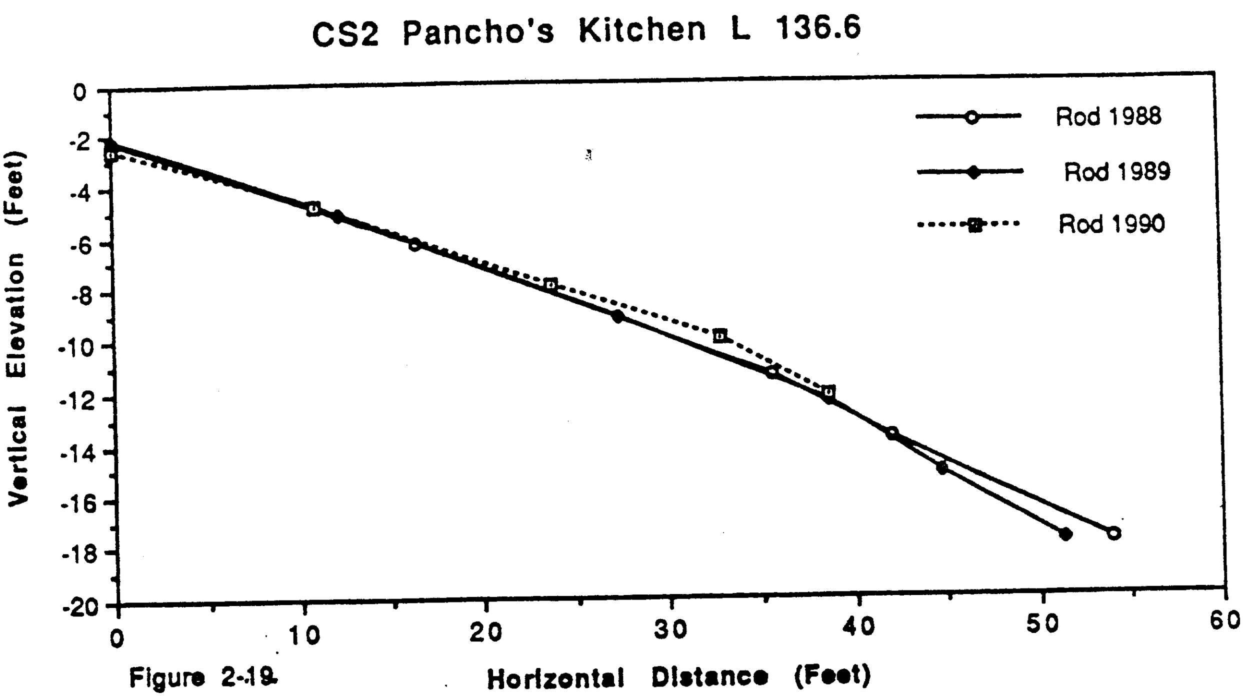


Figure 2-19

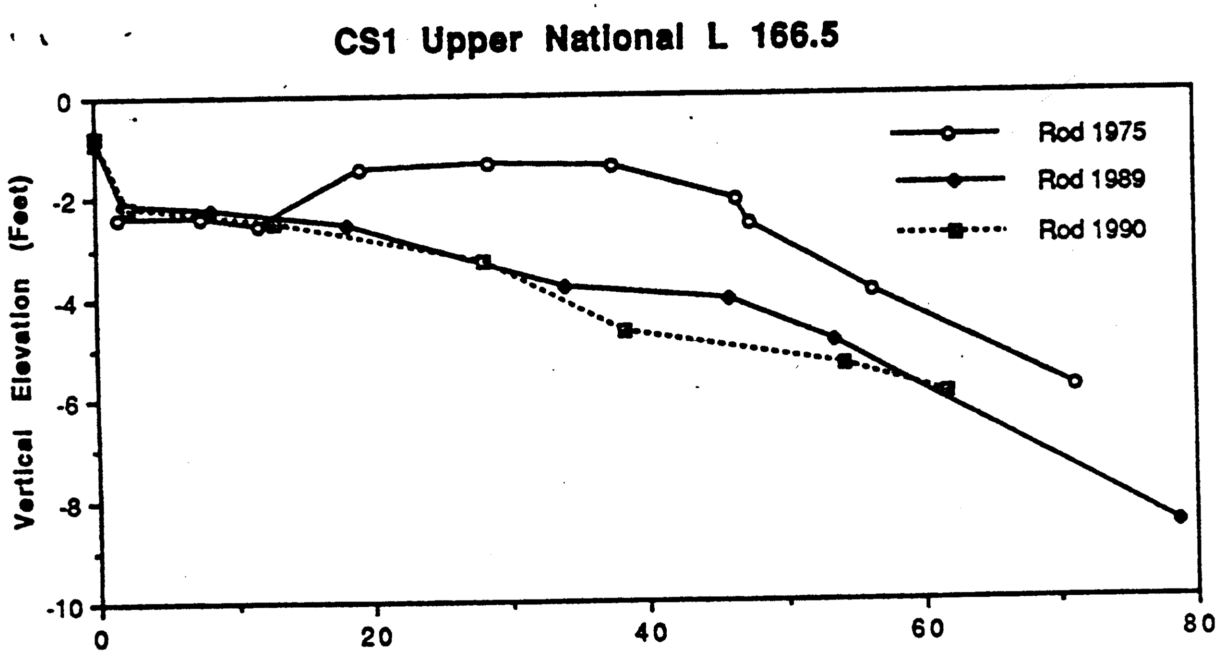


Figure 2-20

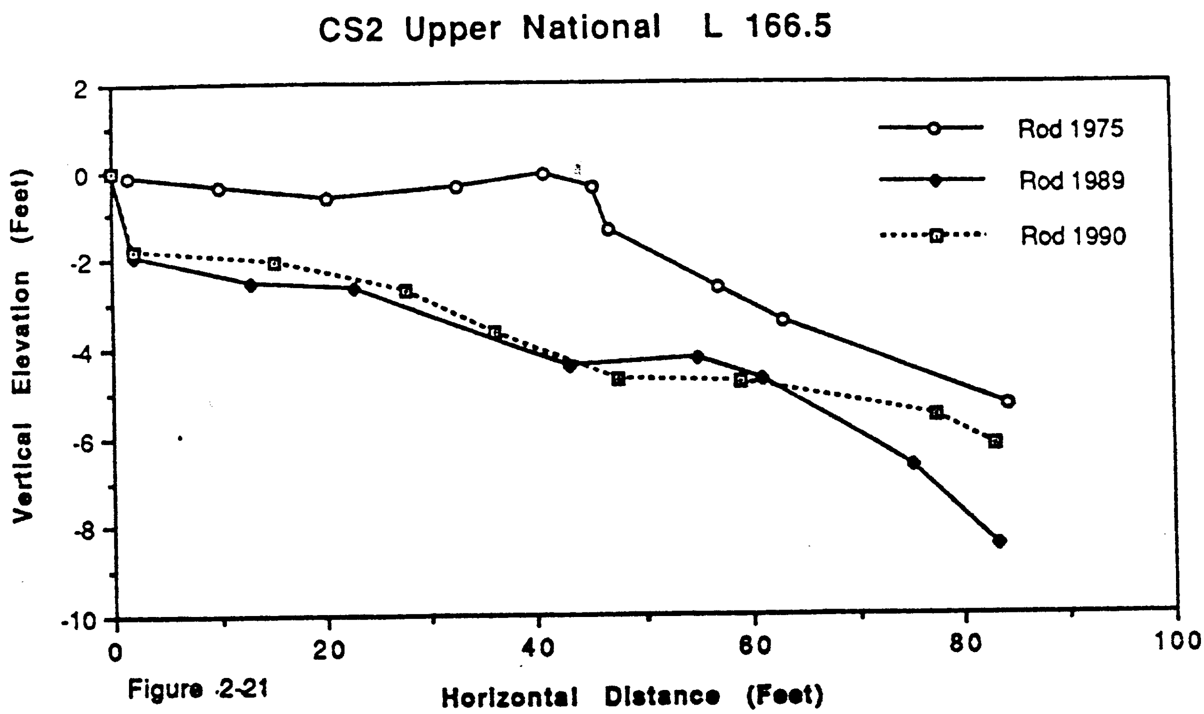


Figure 2-21

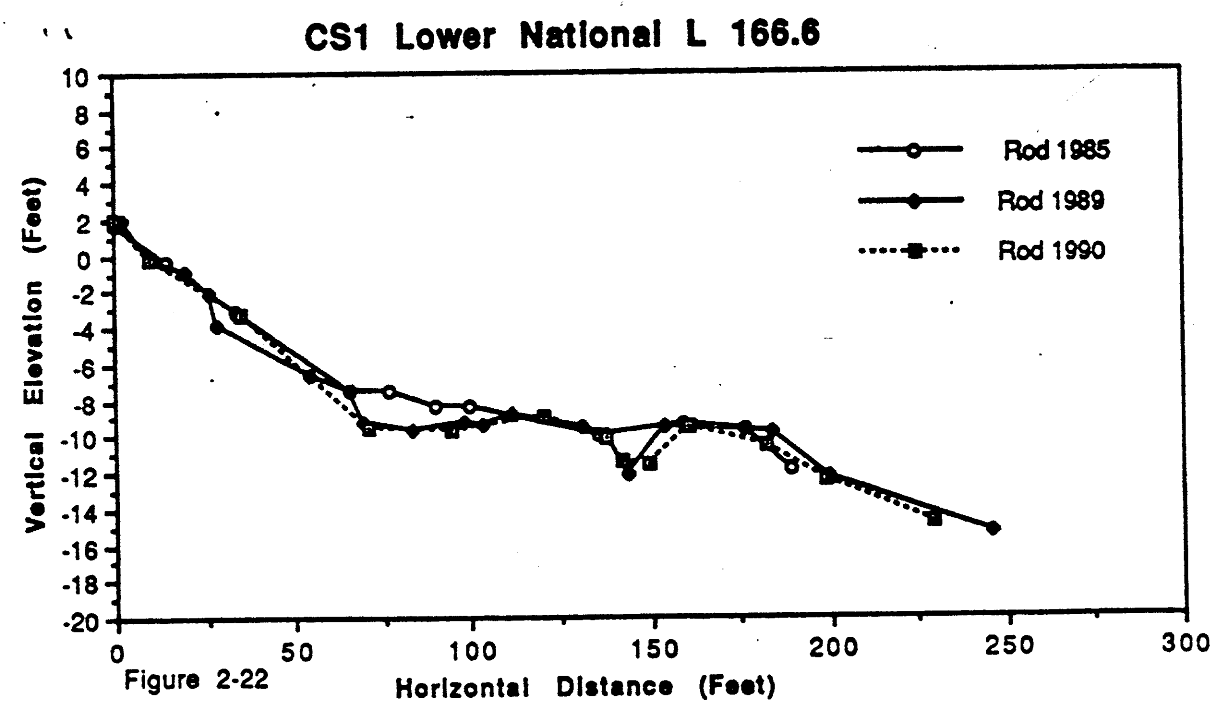


Figure 2-22

CS2 Lower National L 166.6

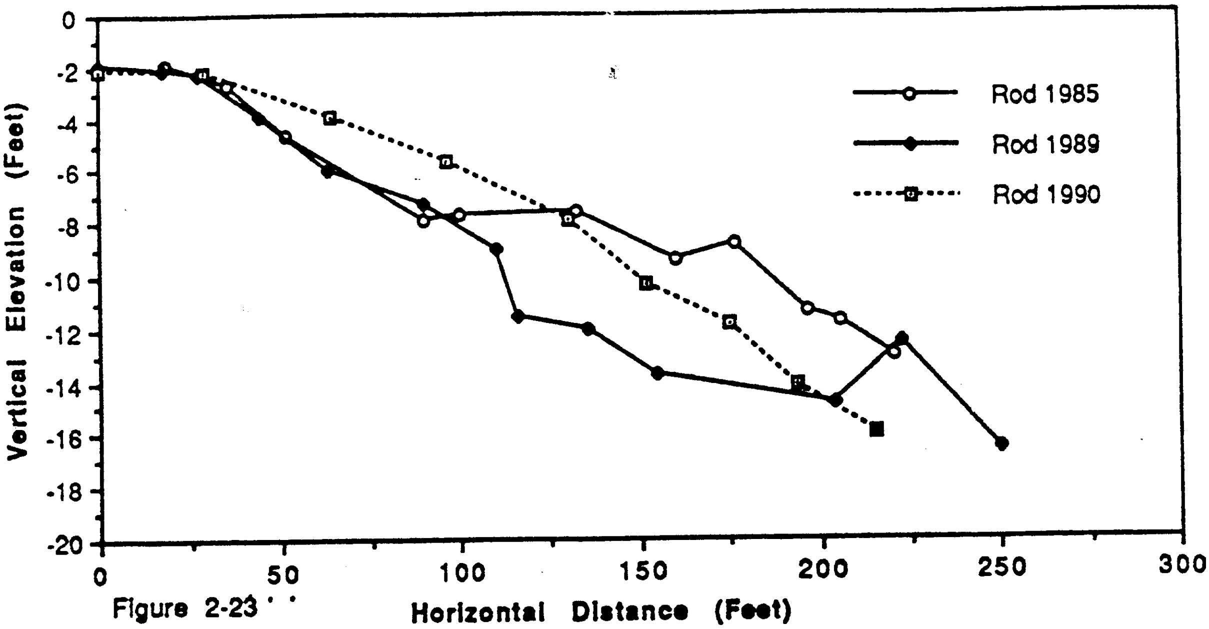


Figure 2-23

CS3 Lower National L 166.6

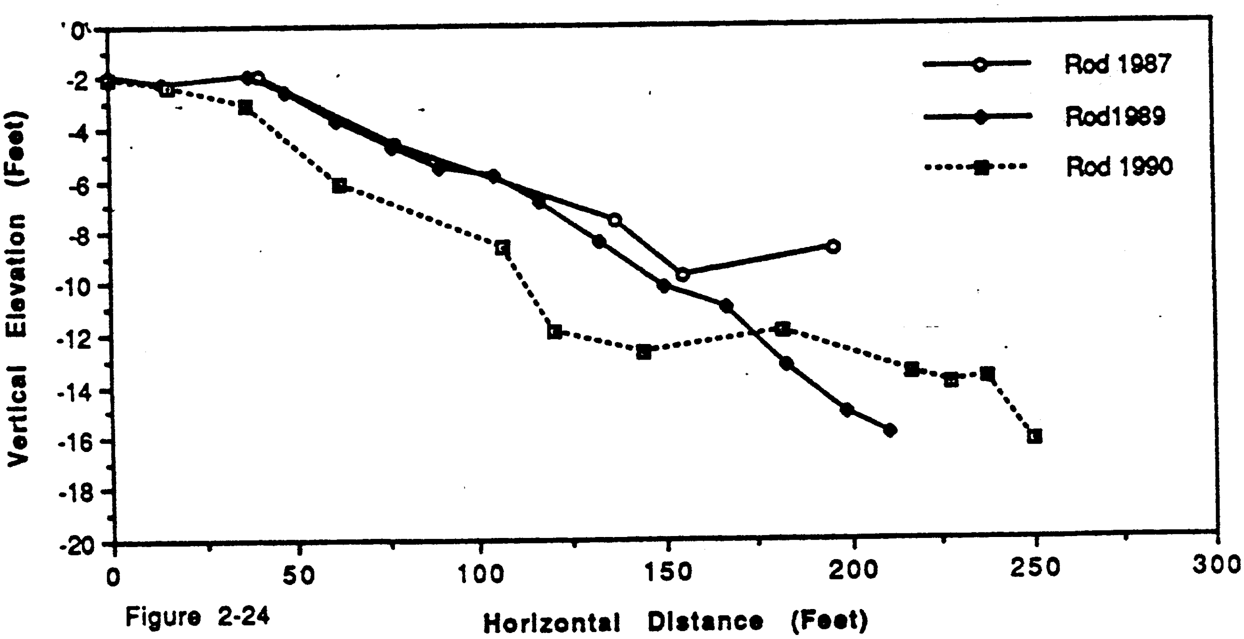


Figure 2-24

CS4 Lower National L 166.6

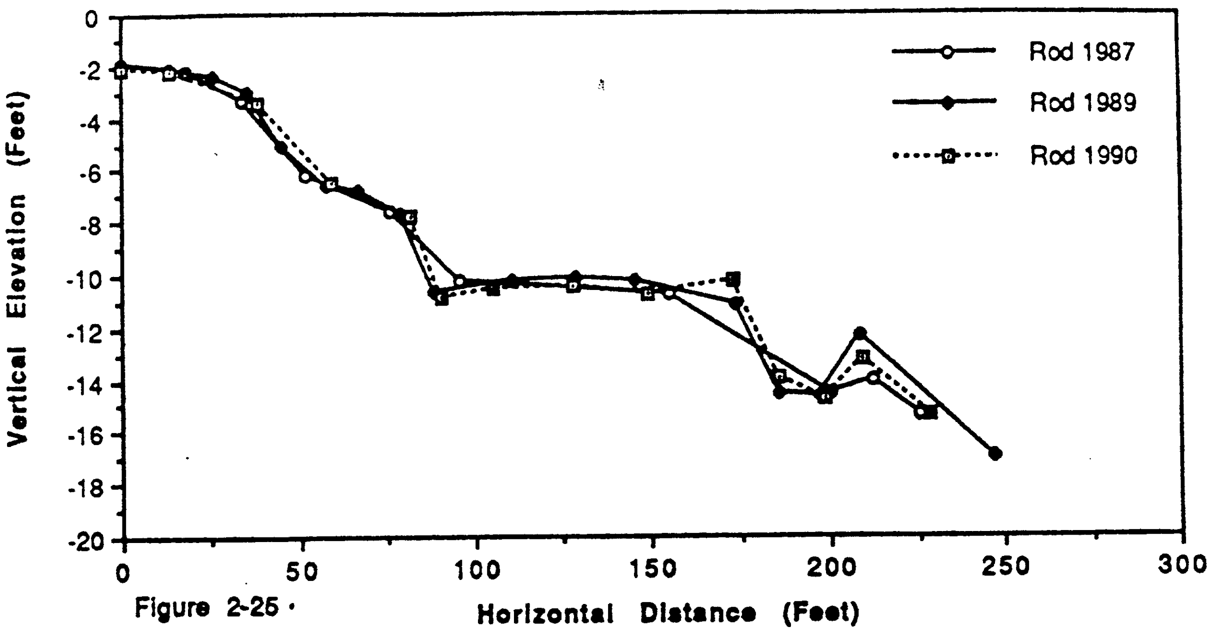


Figure 2-25

CS5 Lower National L 166.6

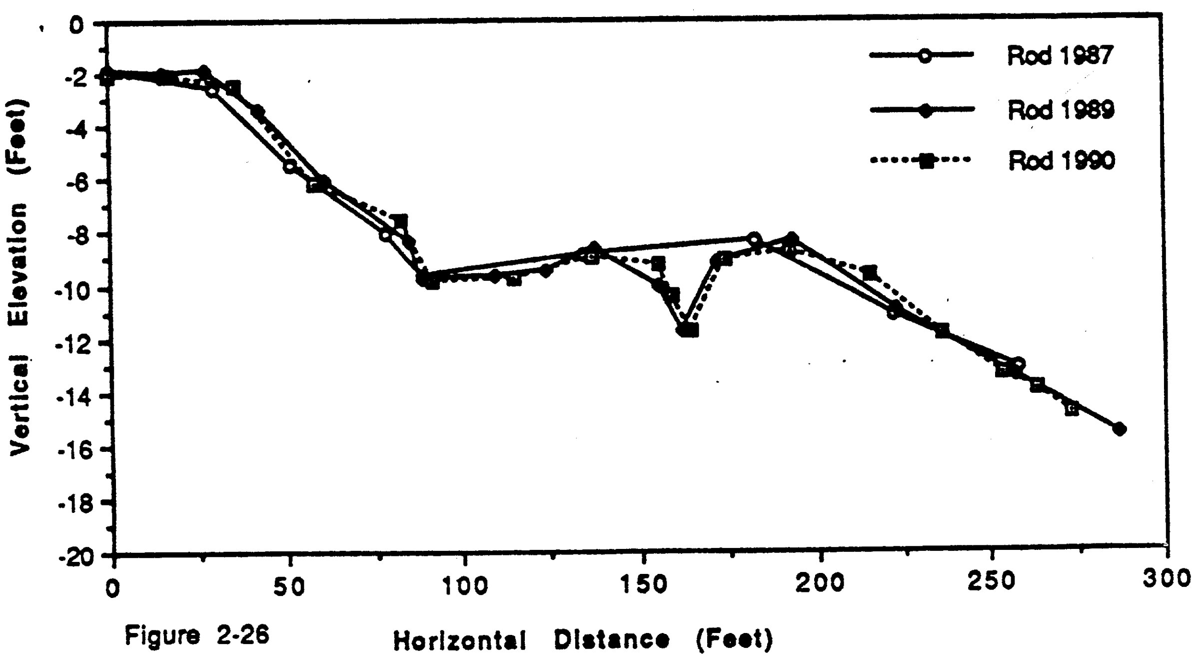


Figure 2-26

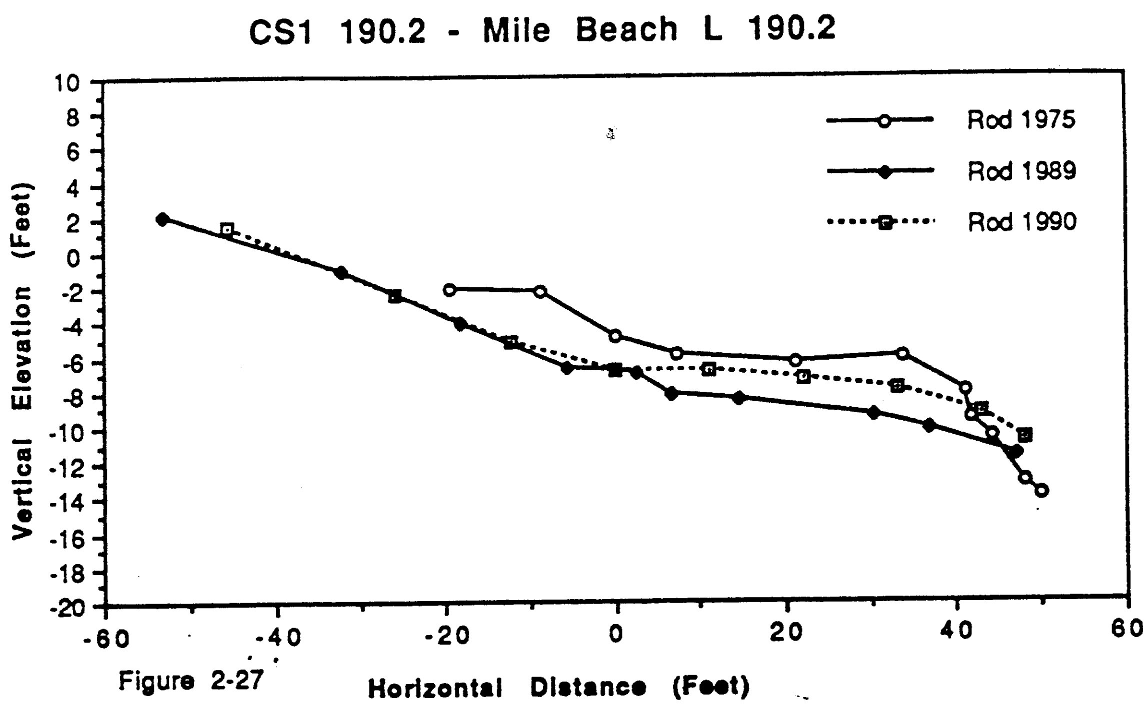


Figure 2-27

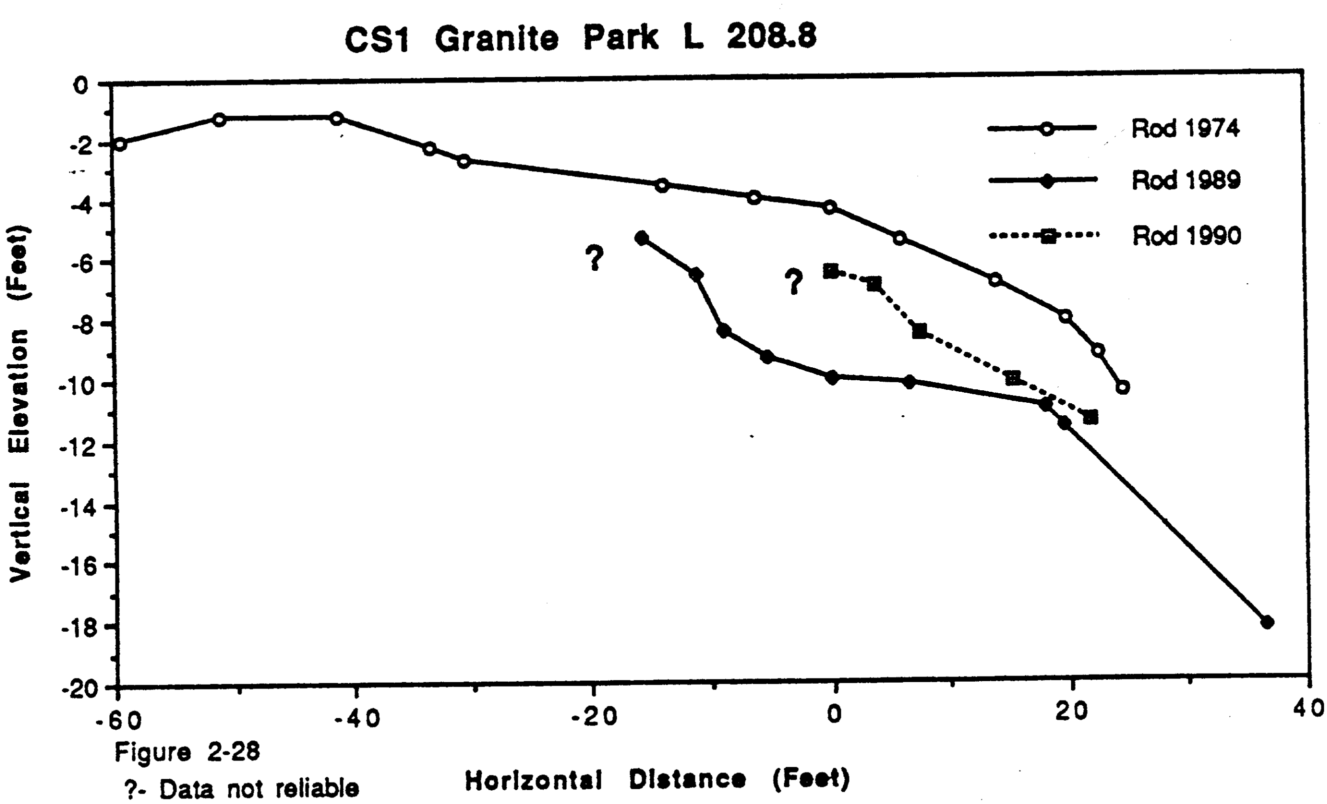


Figure 2-28

?- Data not reliable

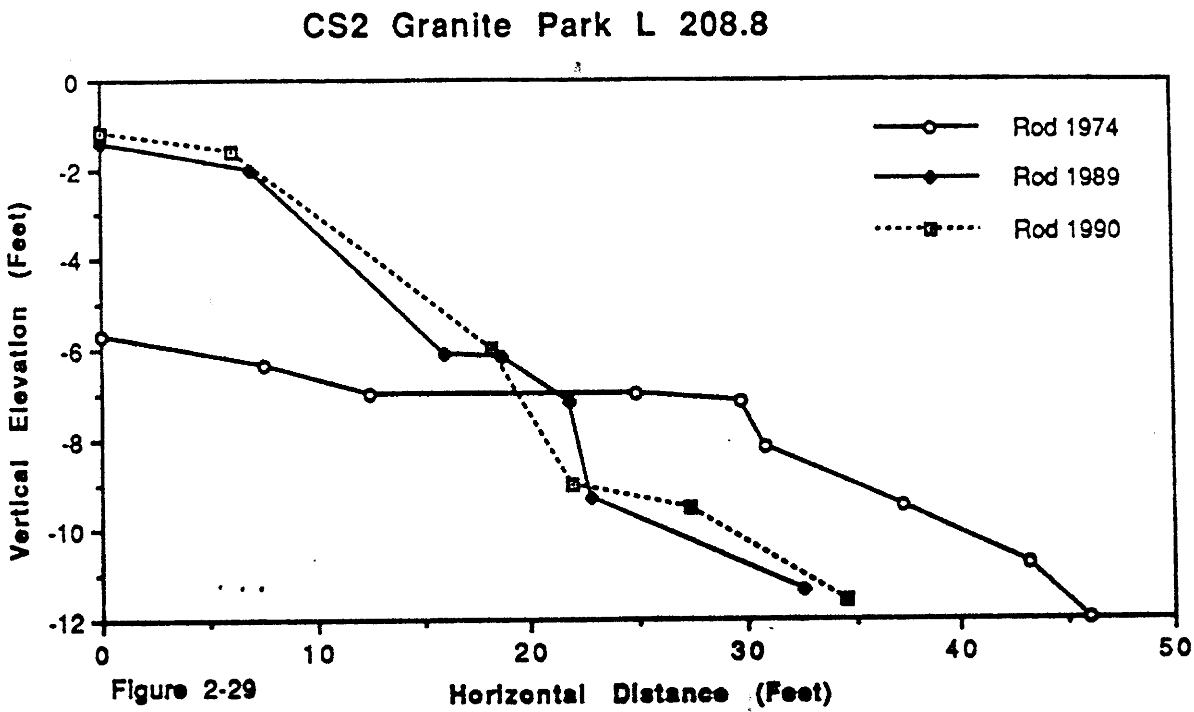

CS2 Granite Park L 208.8
Rod 1974
Rod 1989
Rod 1990
Vertical Elevation (Feet)
0
-2
-4
-6
-8
-10
-12
0
10
20
30
40
50
Horizontal Distance (Feet)

Figure 2-29

Table 2-1. Beach Profiles Surveyed.

River Mile	Beach Name	1974	1975	1980	1982	1983	1984	1985	1986	1987	1988	1989	1990
L18.2	Upper 18 Mile Wash		2			2	2	2	2	2	1		
L19.3	19 Mile Wash (gone)		2	1		2		2	2				
L19.8	19.8 Mile											2	2
L34.7	Nautiloid Canyon	2	2			2	2	2	2	2	2	2	2
R53.0	Lower Nankoweap	3	3	1		1	3	2	1	2			
R58.1	Awatubi						1		1	1	1	1	1
R61.8	Mouth of the Little Colorado	1		1		1	1	1	2	1			1
L65.5	Tanner 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	1	1	2
L81.1	Grapevine	2		2		2	1	2	2	2	2	2	2
L87.1	Lower Suspension Bridge		2	1				1					
L93.2	Upper Granite Rapid	2		1		2	2	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	2	2	2
R122.0	122 Mile Beach (new 1985)							2	2	2	2	2	
R122.8	Forster Canyon (new 1983)					3	3	3	3	2	3	1	2
L124.4	Upper 124 1/2 Canyon (gone)	2			1	1							
R131.0	Bedrock Rapid	2		2		2	2	2	2	2	2	2	2
L136.6	Pancho's Kitchen (new 1988)										2	2	2
L151.6	The Ledges (gone)	2	2			1	2	2		1			
L166.5	Upper National		2	1		1	2	2		2	2	1	2
L166.6	Lower National (new 1985)							2	5	5	5	5	5
R180.9	Lower Lava Falls	2		2		2	2	2	2	2	2		
L190.2	190 Mile		1	1			1	1	1	1	1		1
L193.9	194 Mile Beach (new 1987)									3	3	3	
L208.8	Granite Park	2	2	2	1	2	2	2	2	2	2	2	2
R220.0	220 Mile Beach (new 1985)								2	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 Beus and others (1988)
1988 data from Beus and others (1989)
1989 data from Beus and others (1990)
1990 data from this report

Table 2-2 Summary of Loss or Gain of Beach Sand

Beach	Profile	1989-1990 Inner	1989-1990 Outer	Original Inner	Original Outer	Year of Original Study
L 19.9	CS1	0.5	0.0	0.0	0.0	1989
	CS2	0.0	0.0	0.0	0.0	1989
L 34.7	CS1	0.0	-1.5	6.0	6.0	1974
	CS2	0.5	1.0	3.0	0.0	1974
R 58.1	CS1	1.0	0.0	--	-2.0	1984
R 61.8	CS1	2.0	-1.0	-4.0	-4.0	1975
L 75.5	CS1	0.0	-0.5	1.0	-1.5	1984
	CS2	0.0	0.0	0.0	-0.5	1984
L 81.8	CS1	0.0	0.0	0.0	0.0	1974
	CS2	-1.0	0.0	2.0	0.5	1974
L 93.2	CS1	-1.0	--	-1.5	0.5	1974
R 120.1	CS1	0.0	0.0	1.0	-3.0	1974
	CS2	-0.5	--	6.0	-4.0	1974
R 122.8	CS1	0.0	0.0	1.5	1.5	1983
	CS2	0.5	2.0	1.0	1.0	1983
R 131	CS1	0.0	-0.5	0.0	-3.0	1974
	CS2	0.0	0.0	0.0	-1.0	1974
R 136.6	CS1	0.0	0.0	0.0	0.5	1988
	CS2	0.0	0.0	0.0	0.0	1988
L 166.5	CS1	1.0	0.0	-1.0	-1.5	1975
	CS2	0.2	0.5	-1.5	-1.5	1975
L 166.6	CS1	0.0	0.0	-0.5	-0.2	1985
	CS2	0.5	1.0	1.5	-1.5	1985
	CS3	-1.0	0.0	-1.5	4.0	1987
	CS4	0.0	0.0	0.0	0.5	1987
	CS5	0.0	0.0	0.0	-0.5	1987
L 190.2	CS1	0.0	1.0	-3.0	-1.0	1975
L 208.8	CS1	2.0	0.2	--	--	1974
	CS2*	0.5*	0.2*	4.0*	-2.0*	

* Data not reliable

Table 2-3 Comparison of Inner Beach loss/Gain (Original Year/1989/1990)

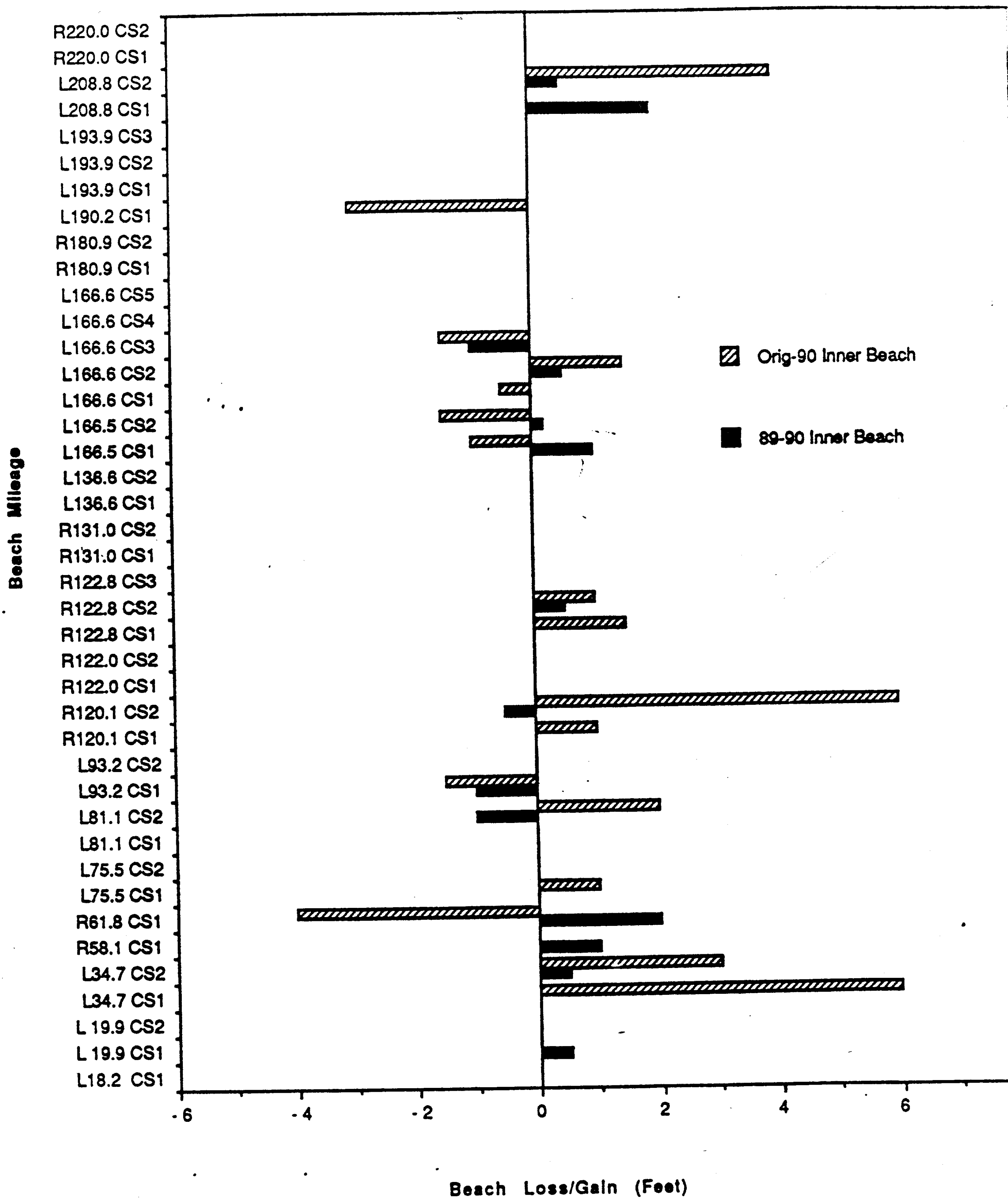
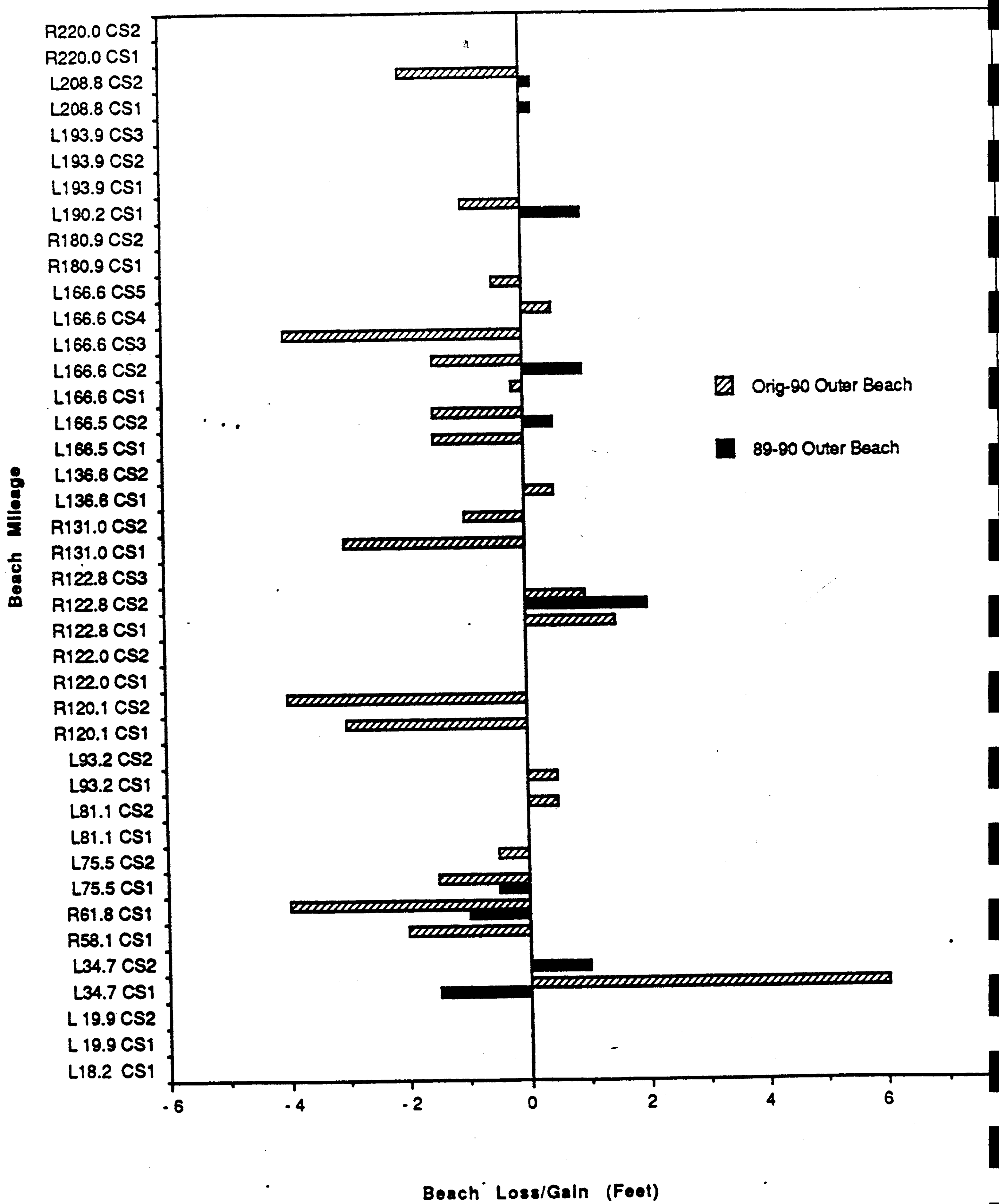


Table 2-4 Comparison of Outer Beach Loss/Gain (Original Year/1989/1990)



Results

Summary of Results
Comparison of inner beaches since 1989:
- 27.02% lost sediment
- 40.74% remained the same
- 32.24% showed a slight gain

Comparison of outer beaches since 1989
- 14.83% lost sediment
- 66.66% remained the same
- 18.51% showed a slight gain

Comparison with original survey - Inner Beaches
- 25.92% lost sediment
- 40.75% remained the same
- 33.33% showed a slight gain

Comparison with original survey - Outer beaches
- 51.85% lost sediment
- 18.53% remained the same
- 29.62% showed a slight gain

In general, losses in beach sediment recorded between the 1989 and 1990 studies are not as great as those between the 1989 and 1988 studies. While gains and losses in beach sediment continue to occur, most beaches surveyed show little change in the last year. These are general patterns and each beach profile should be looked at individually to more accurately determine what changes are occurring. (See figures 2-1 to 2-29 and tables 2-1 to 2-4).

Conclusions and Recommendations

In comparing data from the 1989 and 1990 surveys of 29 beach cross sections, we found that 11 beaches showed no significant changes, 9 beaches showed slight gains in sediment and 8 beaches showed losses in beach sediments. In comparing differences between inner and outer beaches from 1989 to 1990, we found that 8 inner beach sites and 4 outer beach sites gained sand, while 4 inner and 4 outer beach sites lost sand.

The gains in inner beach sediments are probably due to shifting wind blown sand from other areas of the beach. We would not expect to see corresponding losses and gains between inner and outer beaches as this would mean that sand was being redistributed directly along our transect lines. Some gains along outer beaches may be due to the deposition of new sediment from flash flooding side canyons but is more likely due to the redistribution of sediment from other areas of the beach. (See figures 2-11, 2-13 and 2-20).

Data from three beaches surveyed by a preceding research team were not available at the time of this report and so are not included. Data from beach 208.8 (Granite Park) may not be reliable from either the 1989 or 1990 surveys due to several factors. Results from this survey are included in the report but were not considered in making our final conclusions. Buried and unavailable benchmarks at two beaches may also be sources of some error. In addition, growth of vegetation or large erosion or deposition of sediments on some beaches required the tilting of the transit barrel. Such changes must be mathematically corrected for and also add in a small inaccuracy factor.

A comparison of each beach with its original survey is difficult, since some surveys were conducted during 1975 whereas others were not begun until the 1983 floods. It is recommended that future comparisons of all surveyed beaches be made to the post 1983 floods.

We also recommend that all profiles surveyed include points at regular intervals that will be consistent from year to year. These would be in addition to points of changing slope. Profiles should also be consistently extended to the water-line and beyond (in the case of high water levels). Lastly a consistent demarcation of what constitutes an inner and outer beach should be determined. This would eliminate any subjective or inconsistent interpretation of data.

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ADDENDUM 2-1

To Beach Profile Survey Team:

1. To increase speed and accuracy of data collection, we recommend training a crew and sticking to specific job assignments while in the field. Rotating tasks in order to learn various roles, and discover the most efficient and functional assignments for each team member can be accomplished during instructional field trips prior to the river trip.
2. To simplify your data summary and final report, we suggest the following be done as you collect your data or on layover days during the raft trip:
   a. Identify which BS is to be used for zero point on graphs and record it as ED (elevation data) on the bottom of each data sheet.
   b. Correct for barrel tilt. Accuracy of the tilt angle is most important, especially over long distances when the length of line may not be quite true (due to interference of rocks and trees, extreme sloping of beaches, sagging of the measuring tape).
3. Rod Person:
   a. Watch Transit person for directions at all times during readings
   b. Pick or plant two points (a stick, someone's shoes) to help you keep in line with the transit as you back up holding the rod
   c. Keep your hands alongside the rod so as not to block the numbers
4. Line People:
   a. Try for a true horizontal between you to eliminate slope effect on measurement
   b. Do not exceed limit of line strength as lines do break
5. Transit Person:
   a. Shoot both Base Stations on each cross section
   b. If barrel is tilted for BS, try for 0.00 reading
   c. If barrel is tilted otherwise, try for whole degree reading
6. Recorder:
   a. Prepare data sheets in advance by entering "mile - date - cross section number - campground name" at top
   b. Have old report and old data sheet for each beach
   c. Have maps at hand - get BS to CS distances from the map while in the field
   d. Under "Comments", give reasons for tilting the transit barrel; reasons for skipping a cross section; locations for each rod reading.
7. General:
   a. Practice setting up and calibrating transit before leaving for the river. This is the most time consuming aspect of the beach profile.
   b. Keep hand lenses on hand as readings are hard to make off transit without them.
   c. Make every attempt to recover buried benchmarks as they will increase the accuracy of results.
   d. Upon return from the river assign one member of team to become familiar with the graph generating software to be used. (Cricket graph on a Macintosh computer) This will make producing research reports much easier.

CHAPTER 3

BEACH FAILURE

by
Cindy Burfield
and
Kelcy Thompson

ABSTRACT

Fluctuating discharges from Glen Canyon Dam directly affect beach erosion in the Grand Canyon along the Colorado River. This study was done to find possible correlations between beach slope angle and type of beach failure. Dip angles on nonfailing, microfailing, and macrofailing (calving) beaches were measured on seventy-three sites between Lee's Ferry and Diamond Creek. Microfailure of beaches occurred as slope angle increased and was correlated with deforming bedding features. This pilot study should help the National Park Service in conducting further erosional studies on beaches along the Colorado River in the Grand Canyon.

INTRODUCTION

Erosion taking place on the beaches and bars along the Colorado River in the Grand Canyon continues on a daily basis and may be magnified by conditions of fluctuating low flows from Glen Canyon Dam. The operation of Glen Canyon Dam directly influences the stability of fluvial sediment deposits in lower Glen and Grand canyons through hydraulic erosion and aggradation (Schmidt and Graf 1987; Water Science Technology Board 1987; Stevens and Waring 1988; Schmidt et al. in prep.) Beaches in the Grand Canyon are rapidly inundated by fluctuating daily flows which may erode sand into the Colorado River causing failure to beaches. This study was concerned with the kinds of beach slope failure observed and the possible mechanisms responsible for slope failure, and may be useful in management of erosion in Grand Canyon National Park.

The objectives of this study were:

1. Observe beaches exposed during low fluctuating flows and measure the angle of slope above and below any failure found on these beaches.

2. Collect sand samples from both above and below the beach failures to find out if grain size (percent silt) is related to beach failure.

3. Relate failure types to stratigraphy at certain beaches.

METHODS

This investigation took place during the period July 25 through August 4, 1990. Because a controlled flow regime of 5,000 cfs was initiated from July 27 to August 1, the highest number of beaches were surveyed in this time frame. Twenty-nine beaches were investigated from river mile 53 to river mile 208.

Three types of beach surfaces were used in this study: nonfailure (Figure 1), microfailure (Figure 2), and macrofailure (Figure 3). Nonfailure applied to a noninterrupted sloping beach surface, microfailure referred to a slippage or slumping of the surface, while macrofailure was described as an area where erosion completely disrupted the beach slope and has resulted in mass wasting of the sediments. Data are shown in Table-.1a-.1c.

Angles of the water line were measured with an inclinometer devised for measuring the upward and downward slopes of the beach face. This instrument consisted of a level and a protractor attached to a piece of right angle aluminum molding. In the center of the protractor, a string several meters long was fixed to the head of a screw. By placing the inclinometer at water's edge and leveling it, the free end of the string could be placed upon the surface of the uppermost slope and a direct reading obtained corresponding to the angle of the beach.

To obtain the angle of the downslope surface, a reading of the depth of the water was taken at a point one meter from the water's edge. By dividing the depth by this length, an inverse tangent could then be calculated and an angle obtained. Surface samples of sediment were collected from both the upper and lower surface of each slope and placed in marked whirlpak bags. Where possible, samples from all three failure types were obtained from one beach. These samples were then returned to the lab, dried in ovens at 65 degrees Celsius, sifted for grain size, and weighed to evaluate percentage of silt.

When possible, underlying sedimentary structures were observed for possible correlation to the overlying beach surface. Photographs were taken whenever possible. In several cases, trenches dug by another investigative team were available for observation (Figures 4,5).

RESULTS

Analysis:

A multiple analysis of covariance was performmed using failure types (non, micro, macro) as a predictor, with arcsine-square root transformed percent slope above and below the failure as response variables, with distance from Lees Ferry as a covariate (Table-.2). This analysis revealed that angle above but not angle below the failure varied significantly, with steeper angles occurring on microfailing faces than on nonfailing or macrofailing faces.

Distance downstream was not shown to be a significant covariate affecting beach failure angle F (Wilks' $P > 0.05$, DF = 2,67).

Table-.1a

		FILE	TYPE(1)	ABOVE(2)	BELOW(3)	PSABOVE (4)
		PSABELOW (5)				
CASE	1	61.300	1.000	2.000	3.400	.
CASE	1	.				
CASE	2	53.900	1.000	8.000	20.800	.
CASE	2	.				
CASE	3	190.000	1.000	8.000	8.500	.
CASE	3	.				
CASE	4	119.800	1.000	20.000	19.500	0.010
CASE	4	0.006				
CASE	5	61.300	1.000	5.000	5.100	.
CASE	5	.				
CASE	6	119.300	1.000	10.000	.	.
CASE	6	.				
CASE	7	61.300	1.000	14.000	16.200	.
CASE	7	.				
CASE	8	120.100	1.000	9.000	8.500	.
CASE	8	.				
CASE	9	119.100	1.000	22.000	18.800	.
CASE	9	.				
CASE	10	99.000	1.000	20.000	21.800	.
CASE	10	.				
CASE	11	64.700	1.000	10.000	8.500	0.002
CASE	11	0.101				
CASE	12	208.900	1.000	12.000	25.600	.
CASE	12	.				
CASE	13	166.600	1.000	12.000	8.500	.
CASE	13	.				
CASE	14	208.000	1.000	5.000	4.900	.
CASE	14	.				
CASE	15	207.500	1.000	10.000	14.600	.
CASE	15	.				
CASE	16	122.000	1.000	8.000	5.100	.
CASE	16	0.002				
CASE	17	194.000	1.000	17.000	14.000	.
CASE	17	.				
CASE	18	66.200	1.000	12.000	24.200	0.006
CASE	18	0.009				
CASE	19	88.500	1.000	17.000	28.800	0.244
CASE	19	0.055				
CASE	20	93.500	1.000	8.000	7.100	0.131
CASE	20	0.120				
CASE	21	82.000	1.000	16.000	18.800	.
CASE	21	.				
CASE	22	82.000	1.000	20.000	24.700	.
CASE	22	.				
CASE	23	61.500	2.000	12.000	12.900	.
CASE	23	.				
CASE	24	61.500	2.000	17.000	24.200	.
CASE	24	.				
CASE	25	64.700	2.000	17.000	11.300	0.333
CASE	25	0.435				
CASE	26	53.900	2.000	12.000	24.700	.
CASE	26	.				
CASE	27	81.100	2.000	19.500	22.100	.
CASE	27	.				

Table-.1b

		MILE	TYPE (1)	AABOVE (2)	ABELOW (3)	PSAABOVE (4)
		PSABELOW (5)				
CASE	28	53.900	2.000	19.000	27.500	.
CASE	28	.				
CASE	29	82.000	2.000	22.000	25.600	.
CASE	29	.				
CASE	30	80.800	2.000	29.000	33.000	.
CASE	30	.				
CASE	31	88.500	2.000	20.000	34.600	0.315
CASE	31	0.322				
CASE	32	66.200	2.000	21.000	28.800	0.083
CASE	32	0.072				
CASE	33	80.500	2.000	23.000	33.000	.
CASE	33	.				
CASE	34	93.500	2.000	14.000	14.000	0.342
CASE	34	0.384				
CASE	35	64.700	2.000	25.000	27.000	0.037
CASE	35	0.037				
CASE	36	61.500	2.000	29.500	21.800	.
CASE	36	.				
CASE	37	75.200	2.000	25.000	25.600	.
CASE	37	.				
CASE	38	75.200	2.000	24.000	19.300	.
CASE	38	.				
CASE	39	67.000	2.000	10.000	16.700	.
CASE	39	.				
CASE	40	113.800	2.000	27.000	22.800	0.041
CASE	40	0.070				
CASE	41	75.200	2.000	18.000	11.300	.
CASE	41	.				
CASE	42	93.500	2.000	26.000	14.000	0.547
CASE	42	0.436				
CASE	43	124.000	2.000	21.000	7.900	.
CASE	43	.				
CASE	44	122.000	2.000	25.500	23.700	0.128
CASE	44	0.037				
CASE	45	119.800	2.000	26.000	14.600	0.205
CASE	45	0.080				
CASE	46	124.000	2.000	23.000	27.000	.
CASE	46	.				
CASE	47	122.000	2.000	40.000	27.500	0.002
CASE	47	0.022				
CASE	48	194.000	2.000	23.000	15.100	.
CASE	48	.				
CASE	49	190.000	2.000	20.000	22.800	.
CASE	49	.				
CASE	50	190.000	2.000	23.000	25.600	.
CASE	50	.				
CASE	51	166.600	2.000	13.000	8.000	.
CASE	51	.				
CASE	52	122.000	3.000	24.000	22.100	0.011
CASE	52	0.006				
CASE	53	108.300	3.000	23.000	10.800	.
CASE	53	.				
CASE	54	120.100	3.000	14.000	4.600	.
CASE	54	.				
CASE	55	119.800	3.000	15.000	24.700	.
CASE	55	.				

Table-.1c

		MILE	TYPE (1)	AABOVE (2)	ABELOW (3)	PSAABOVE (4)
		PSABELOW (5)				
CASE	56	109.500	3.000	17.000	22.300	.
CASE	56	.				
CASE	57	122.000	3.000	21.000	11.900	0.138
CASE	57	0.103				
CASE	58	120.100	3.000	8.000	15.700	.
CASE	58	.				
CASE	59	93.500	3.000	19.000	18.300	0.356
CASE	59	0.148				
CASE	60	119.100	3.000	17.400	19.800	.
CASE	60	.				
CASE	61	124.000	3.000	16.000	4.600	.
CASE	61	.				
CASE	62	75.200	3.000	19.000	15.100	.
CASE	62	.				
CASE	63	67.000	3.000	15.000	26.600	.
CASE	63	.				
CASE	64	119.300	3.000	10.500	20.300	.
CASE	64	.				
CASE	65	194.000	3.000	17.000	14.000	.
CASE	65	.				
CASE	66	207.500	3.000	20.000	8.500	.
CASE	66	.				
CASE	67	66.200	3.000	10.000	28.800	0.008
CASE	67	0.028				
CASE	68	64.700	3.000	18.000	16.700	0.394
CASE	68	0.002				
CASE	69	208.000	3.000	19.000	16.200	.
CASE	69	.				
CASE	70	208.900	3.000	23.000	23.300	.
CASE	70	.				
CASE	71	64.700	3.000	28.000	28.800	0.006
CASE	71	0.038				
CASE	72	67.000	3.000	34.000	16.700	.
CASE	72	.				
CASE	73	88.500	3.000	50.000	28.400	0.039
CASE	73	0.113				

2 CASES DELETED DUE TO MISSING DATA.
NUMBER OF CASES PROCESSED: 71

(1) = type of beach failure
1.000 = nonfailure
2.000 = microfailure
3.000 = macrofailure

(2) = angle above the failure

(3) = angle below the failure

(4) = percent silt above the failure

(5) = percent silt below the failure

Table-.2 MULTIPLE ANALYSIS OF COVARIANCE

Source	Wilks' F	Approx P	DF	Significance of Variables
Main Effect Failure Type	5.335	0.007	2.67	Upper Angle **
Covariate Distance	2.456	0.093	2.67	(Lower Angle*)

** P < 0.01

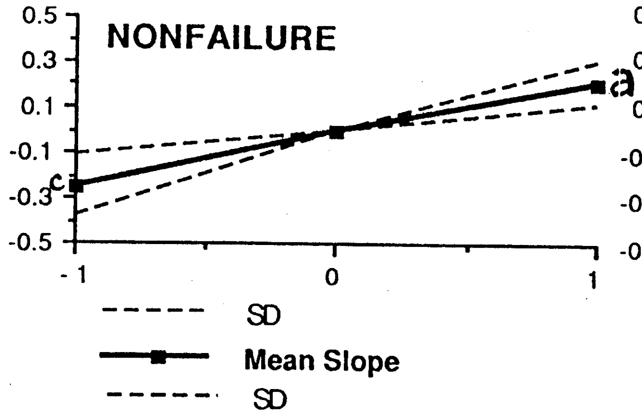
Percent silt was arcsine-square root transformed and analyzed separately. Neither upper nor lower angles were correlated significantly with transformed percent silt (P > .3 for both, DF=1,19-21). This result may have been attributed to the mixture of silt and sand laminae downslope, resulting in a more homogeneous mixture of silt and sand-sized particles, with no net change in percentage of silt.

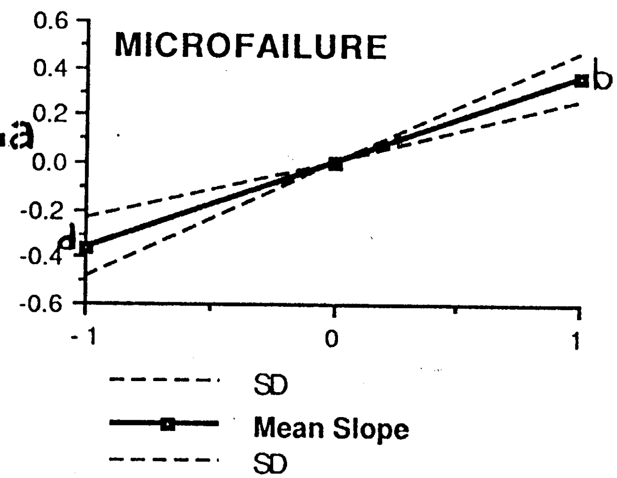
Statistical data from all three beach types surveyed showed that overall, beaches with microfailure showed a significantly steeper mean slope angle than either nonfailure or macrofailure on the upper slope. Submarine mean slope on beaches with nonfailure was significantly shallower than either microfailure or macrofailure (Table-.3).

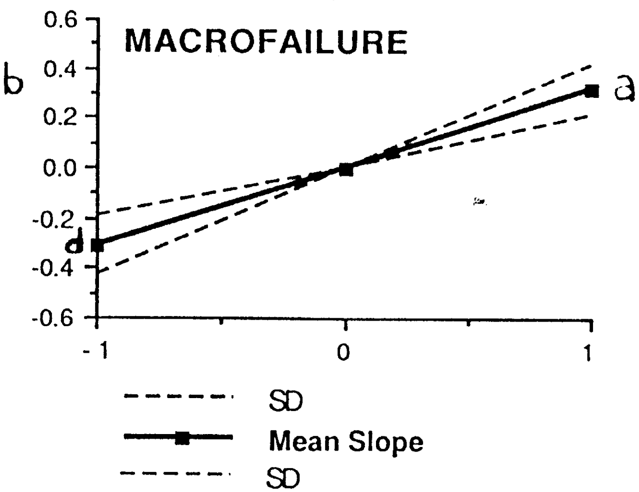
When beach trenches were dug on microfailing slopes, slippage planes were observed. These planes did not appear when macrofailure was present.

Table-.3 **STATISTICAL DATA FROM ALL THREE BEACH TYPES SURVEYED**

	Nonfailure	Microfailure	Macrofailure
Subaerial			
Angle Mean	12.05	21.53	18.47
SD	5.54	6.26	5.98
N	22	29	21
%Silt Mean	.079	.203	.136
SD	.107	.177	.170
N	5	10	7







	Nonfailure	Microfailure	Macrofailure
Submarine			
Angle Mean	14.64	21.46	18.17
SD	7.98	7.50	7.25
N	21	29	22
%Silt Mean	.049	.190	.063
SD	.052	.180	.058
N	6	10	7

b is significantly steeper than a
c is significantly shallower than d

DISCUSSION and CONCLUSION

Several factors may account for the failure of Grand Canyon beaches.

1. Slope is positively correlated with failure.

2. When stratigraphy alternating layers of silt and sand) is present the dip angles of nonfailure can increase.

3. If the slope deposit is homogeneous, failure can begin at less steep angles.

4. Sediment slippage planes exist between sand and silt laminae and may cause failure under saturated conditions.

All of these factors probably play a role in the failure of beaches. Slippage planes resulting from alternating silt and sand layers appear to interact most on microfailing beaches. Further study on this important mechanism should be considered. Clay expansion and contraction according to water availability may be correlated with slope failure but was not addressed in this paper. Seepage forces relating to rise and fall of ground water should also be considered for further study. Additional studies are planned by Avery and Beus (1990) and this report will contribute to that effort. Renovation of the mechanisms of seepage-force erosion will provide river and park managers with the information necessary to improve management of this system.

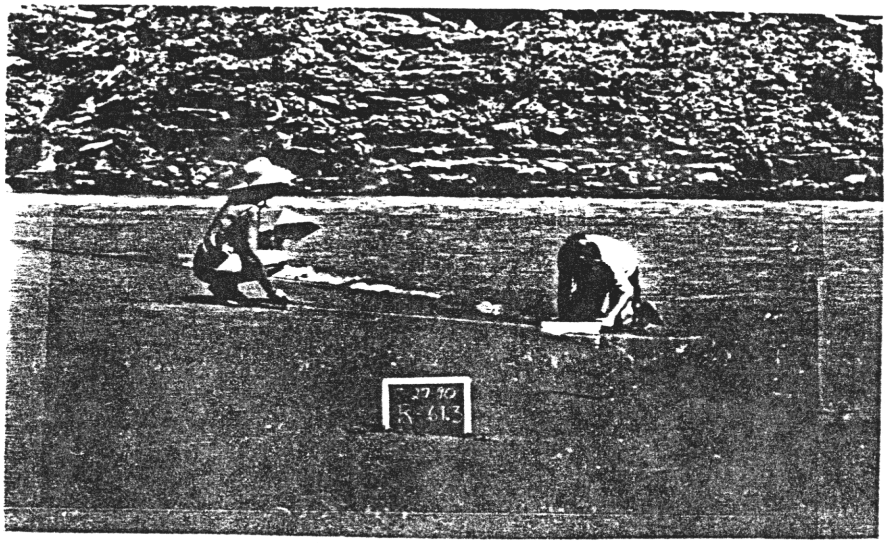


Figure 1 Nonfailure

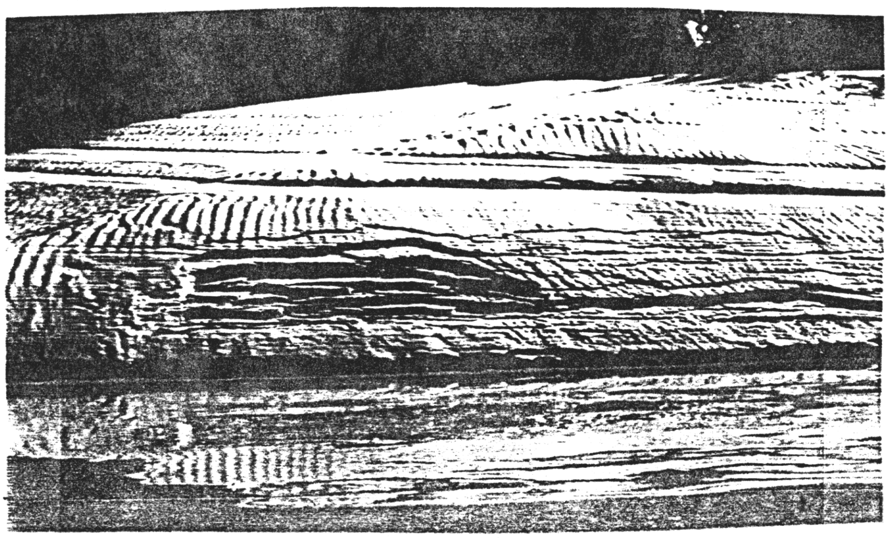


Figure 2 Microfailure

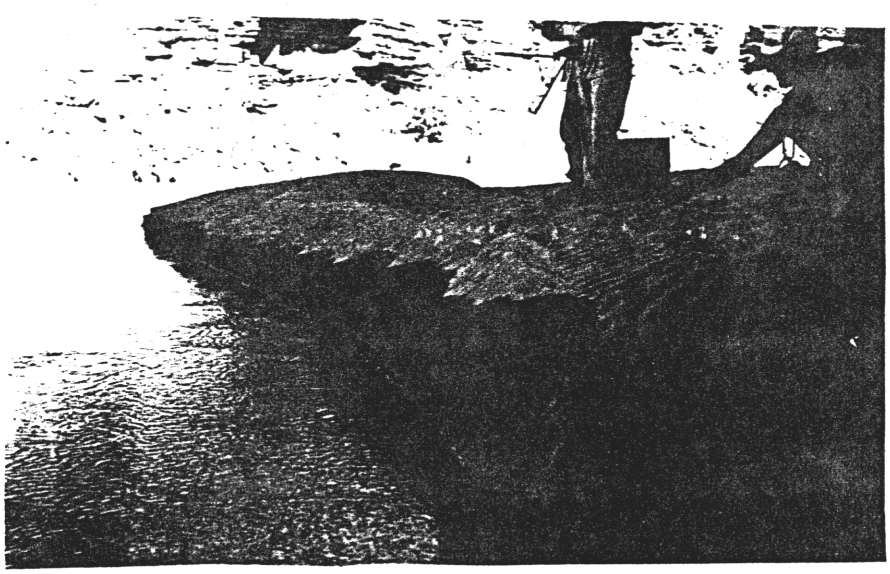


Figure 3 Macrofailure

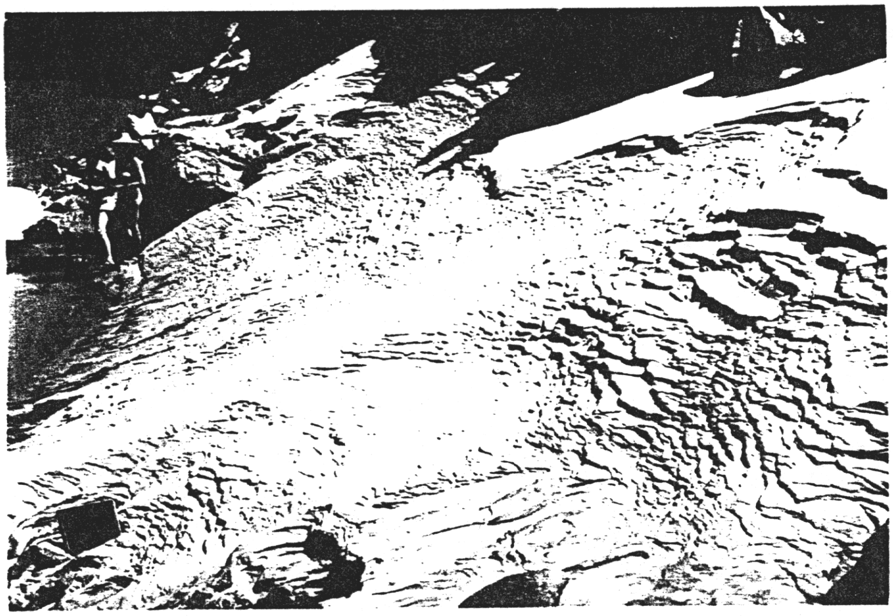


Figure 4 Microfailure on beach surface

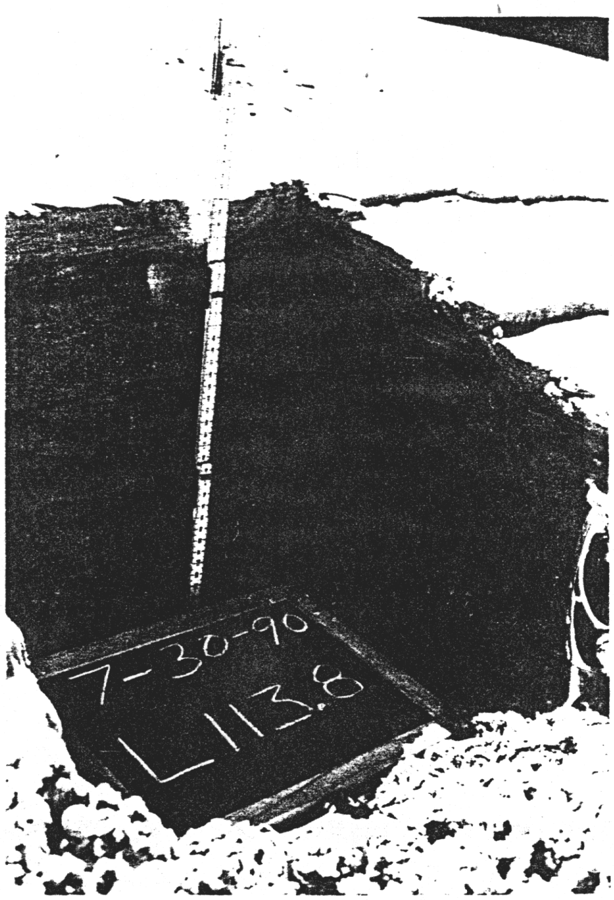


Figure 5 Trench dug below microfailure in figure 4 showing slippage planes between alternating silt and sand layers.

REFERENCES

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CHAPTER 4

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

MABLE LEW, AMY WELDEN

ABSTRACT

Researchers collected data concerning lizard distribution and density in the Colorado River corridor in Grand Canyon National Park. The habitat zone concept was used to collect data within three of Carothers et al. (1979) four zones. In analyzing the data from seventeen beaches, it was found that there was a significant difference between lizard species and lizard density by zone. A higher percentage of lizard species and density was found in Zone 4 which was comprised of a greater percentage of shrub and ground cover as well as insect richness.

INTRODUCTION

Researchers examined the distribution of lizards in the Grand Canyon and correlated lizard densities with the flora in three distinct zones along the Colorado River. Prior to fifteen years ago, herpetological research in the Grand Canyon had been limited resulting in a paucity of literature about canyon lizards. The information from this report and subsequent studies may contribute to the existing literature about lizard densities in the canyon. This information may be useful to park administrators assessing the impact of Glen Canyon Dam releases on lizard populations as they relate to the associated vegetation in the three zones.

We examined lizard distributions in three of Carothers et al. (1979) four habitat zones in the Colorado River corridor in Grand Canyon National Park. The specific objectives and hypotheses of the study were:

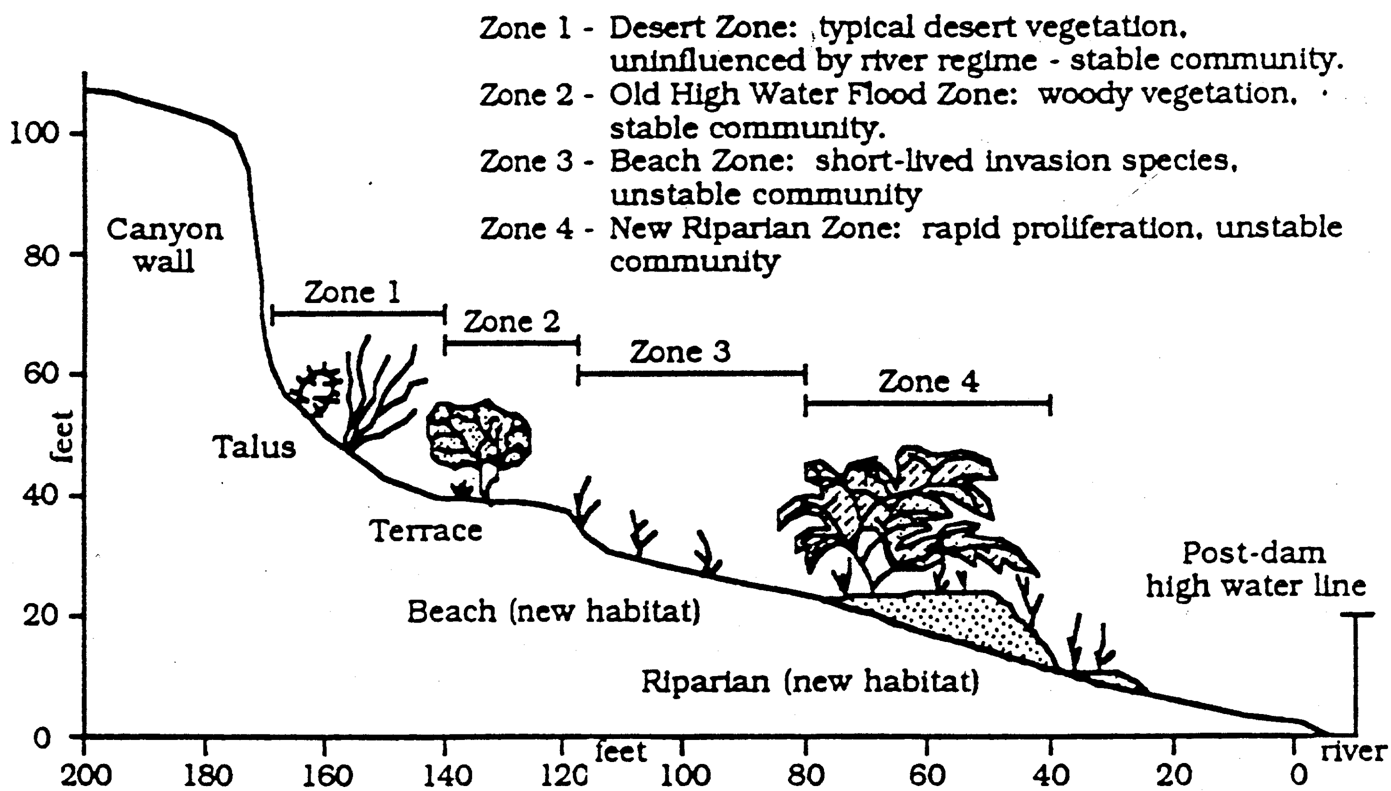
1. To identify and compare the number of lizard species found in each of the three zones.
2. To compare the lizard density per 500 square meters in each of the three zones.
3. To identify the relationship between lizard density and the following factors: temperatures, substrata or substratums, and plant characteristics.
4. To identify and correlate lizard species with plant species and substrate.

METHODS

When studying the distribution of lizards, it is appropriate to establish a basis for their distribution (Miller et al. 1982). Since the distribution of most species is confined to specific zones, the habitat zone concept was used to collect data. Although habitat zone distributions are fairly accurate, there are some drawbacks to this technique. For example, lizards would often overlap or cross zones and zone areas would often overlap and cross.

Three zones were identified using plant species and terraces. Zone 4, the New High Water Zone (NHWZ), was found near the water's edge and was marked by the presence of tamarix (Tamarix ramosissima), spiny aster (Aster spinosus), and camelthorn (Alhagi camelorum). Zone 2, the Old High Water Zone (OHWZ) was found on a terrace above the river and was inhabited by acacia (Acacia greggii), mesquite (Prosopis glandulosa), and fourwing salt bush (Atriplex canescens). The desert zone (Zone 1) which was typically located on a talus slope near canyon walls is characterized by brittlebush (Encelia farinosa), barrel cactus (Ferocactus acanthodes), and mormon tea (Ephedra spp.); Figure IV-1.

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



Seventeen beaches were sampled over a ten day period using the techniques presented below. The "Reptile Data Sheet" (Figure IV-2) was used to record all pertinent information. The name of the beach, river mile, date, and time of day were recorded. When possible, all three zones were sampled at each site. Due to the absence of some zones, primarily the desert zone, and the inaccessibility of some areas, this was not always feasible. When practicable, the same transect zone was observed at a different time of day. This explains the identical column on the Reptile Data Sheet. A quadrant parallel to the river was randomly selected and measured. Each study area measured 50 meters by 10 meters. The team members slowly walked the area and identified the number and species of lizards sighted in the 500 square meter plot. This was recorded along with the vegetation and substrate information. Every effort was made to walk each plot in approximately the same amount of time to provide consistency. This was generally done in 5 minutes. Once the lizard species and density were identified, the ambient and soil temperatures were taken and recorded. A temperature reading was taken after a three minute time period. The ambient temperature was taken in a shaded area. This procedure was repeated for the remaining zones.

Table IV-1 provides a brief description of the common lizards found in the Colorado River corridor. It is included as a reference for future researchers.

We used the following materials to collect data:

Clipboard with rubber bands
Sharpened pencils/sharpener
Note pad
Sandwich size ziploc bags
Soil thermometer (Celsius)
Ambient thermometer (Celsius)
50 meter tape
Reptile identification book
Scale (grams)
Reptile Data Sheet (1 per beach)
Fishing pole or insect net

Figure IV-2

REPTILE DATA SHEET

Date____________________
Beach name____________________
River mile____________________
Observer____________________

Key:
SB = Side-blotched
DS = Desert spiny
Whip = Northern whiptail
Tree = Tree lizard
DC = Desert collared
Chuck = Chuckwalla

NHWZ Time: _____ to _____
Temp: A_____ S_____
SB ____________________
DS ____________________
Whip ____________________
Tree ____________________
DC ____________________
Chuck ____________________
Vegetation:

Substrate:

Observations:

NHWZ Time: _____ to _____
Temp: A_____ S_____
SB ____________________
DS ____________________
Whip ____________________
Tree ____________________
DC ____________________
Chuck ____________________
Vegetation:

Substrate:

Observations:

===

OHWZ Time: _____ to _____
Temp: A_____ S_____
SB ____________________
DS ____________________
Whip ____________________
Tree ____________________
DC ____________________
Chuck ____________________
Vegetation:

Substrate:

Observations:

OHWZ Time: _____ to _____
Temp: A_____ S _____
SB ____________________
DS ____________________
Whip ____________________
Tree ____________________
DC ____________________
Chuck ____________________
Vegetation:

Substrate:

Observations

===

DESERT Time: ____ to ____
Temp: A___ S____
SB ____________________
DS ____________________
Whip ____________________
Tree ____________________
DC ____________________
Chuck ____________________
Vegetation:

Substrate:

Observations:

DESERT Time: ____ to _____
Temp: A____ S_____
SB ____________________
DS ____________________
Whip ____________________
Tree ____________________
DC ____________________
Chuck ____________________
Vegetation:

Substrate:

Observations:

Table IV-1 DESCRIPTION OF LIZARDS

Side-blotched Lizard (Uta stansburiana)

The side-blotched lizard is one of the most abundant lizards in the arid and semiarid regions of the western United States (Stebbins, 1966). This small (less than 10 centimeters) brownish lizard is characterized by an oval black or blue-black spot on its side. According to Pianka (1986), the side-blotched lizard is frequently found under shrubs, however Stebbins (1966) indicated a varied habitat which includes sand, rock, bushes or scattered trees.

Desert Spiny/Yellow-Backed Spiny Lizard (Sceloporus magister)

The desert spiny is a relatively large (9 to 30 centimeters) lizard with yellow-brown to grey-brown scales on its dorsal and lateral surfaces. It has an incomplete black collar and a banded tail (Miller et al. 1982). Tomko (1976) noted the highest densities of this lizard were in areas of Acacia, Tamarix, and Salix flora. It is arboreal and seeks shelter in crevices, under logs, and covered areas (Stebbins 1966). The spiny uses a "sit and wait" foraging technique, feasting on insects (Coleoptera, Diptera, Hymenoptera) and occasionally on lizards and vegetation (Tomko 1976). Stebbins (1966) issues a warning that the spiny lizard often bites when captured.

Northern Whiptail (Cnemidophorus tigris)

The Northern Whiptail is also known as the Western Whiptail. The whiptail is easily identified by the pale yellow, white or green longitudinal stripes on its ventral surface and its overall streamlined-snakelike appearance (Miller et al. 1982).

Tree Lizard (Urosaurus ornatus)

The tree lizard is slender with a long tail. The chevron-shaped markings on its dorsal side provide for easy identification. The adult male has a blue or blue-green belly and a blue or yellow throat patch. This lizard is usually found on dark vertical surfaces of rocks near water, not trees as his name suggests. When approached, the tree lizard will cock its head before retreating (Miller et al. 1982).

Desert Collared Lizard (Crotaphytus collaris baileyi)

The desert collared lizard is also known as the western collared lizard. It is relatively large and can reach 35 centimeters in length. It has two distinct black collars around its neck with the posterior band extending onto its forearms. The dorsal color is tan to brown, yellow, or green. Adult males often have bright green bodies or legs, with bright yellow on the head and feet. Their throats contain a blue-green or orange throat patch. Color and pattern variation occur relative to age, sex, and locale. They can also run on their hind legs using their tails for counterbalance (Miller et al. 1982).

Table IV-1 DESCRIPTION OF LIZARDS (Continued)

Chuckwalla (Sauromalus)

The chuckwalla is the second to the largest lizard in the Grand Canyon. They are flat and stocky with a blunt tipped tail. The young are banded with four or five dark brown body bands and three or four dark tail bands. Adult females resemble juveniles, but not as bright. Adult males are brown with gray or black speckles (Miller et al. 1982).

RESULTS

In analyzing the data from seventeen beaches, 105 lizards were recorded from July 25 to August 3, 1990. It was found that there was a significant difference between lizard species and lizard density by zone. Sixty-four percent of the lizards counted were observed in Zone 4. This was also the zone that contained the most canopy plant cover. Thirty-three percent of the total were sighted in Zone 2 (OHWZ). Only 2% of the lizards counted were found in Zone 1 (DESERT). This low percentage could be attributed to the paucity of available desert zones.

It was found that the side-blotched lizard was the most prevalent species making up 64% of the total lizards sighted. Whiptail was the next most frequently sighted species at 21%. The desert spiny consisted of 11% of the total count. The tree lizard comprised the lowest count at 4%. All four species were sighted in Zone 4 (NHWZ) and Zone 2 (OHWZ), but only the side-blotched was observed in Zone 3 (DESERT).

Three tree lizards were caught and each weighed 5 grams. The sole desert spiny that was caught weighed 35 grams and bit the researcher. Attempts were made to weigh other lizard species but they were too adept at running and hiding in ground cover.

Table IV-2 presents the raw data collected for the lizard study by zone and river mile. The type and count for each lizard sighted is presented along with ambient and soil temperatures of the zone in which they were found.

Lizard species richness and density by zone is presented in Figure IV-3. The raw data for this figure are presented in Table IV-3. Zone 1 which encompassed the desert area showed a significant difference in species richness and species density per 500 square meters. There were significantly fewer species (0.333/site) found in this zone as compared to Zone 2 (1.300/site) and Zone 4 (1.625/site) which showed no significance. The total number of lizards sighted in Zone 1 was also quite low.

A multiple analysis of covariance of data on the sites for which lizard substrate, vegetation, and temperature characteristics were recorded showed no significant effects of predictor variables on response variables (lizard species richness and density). Wilk's lambda approximate F values produced $p>0.1$ for all predictor variables. Lack of significance here was probably a result of the small sample size of this data set.

A multiple analysis of covariance was run on a larger data set (Table IV-4) that included predictors (mile, zone, and ambient temperature) and response variables (lizard species richness and density). Using a multiple analysis of covariance it was found that there was a significant variance between lizard species by zone and lizard density by zone. No significant difference was found in the predictors of mile and ambient temperature. However, it should be noted that the ambient temperature predictor did exhibit a near-significant trend with $p=.053$. The small sample size of this data set and missing temperature data contributed to this trend.

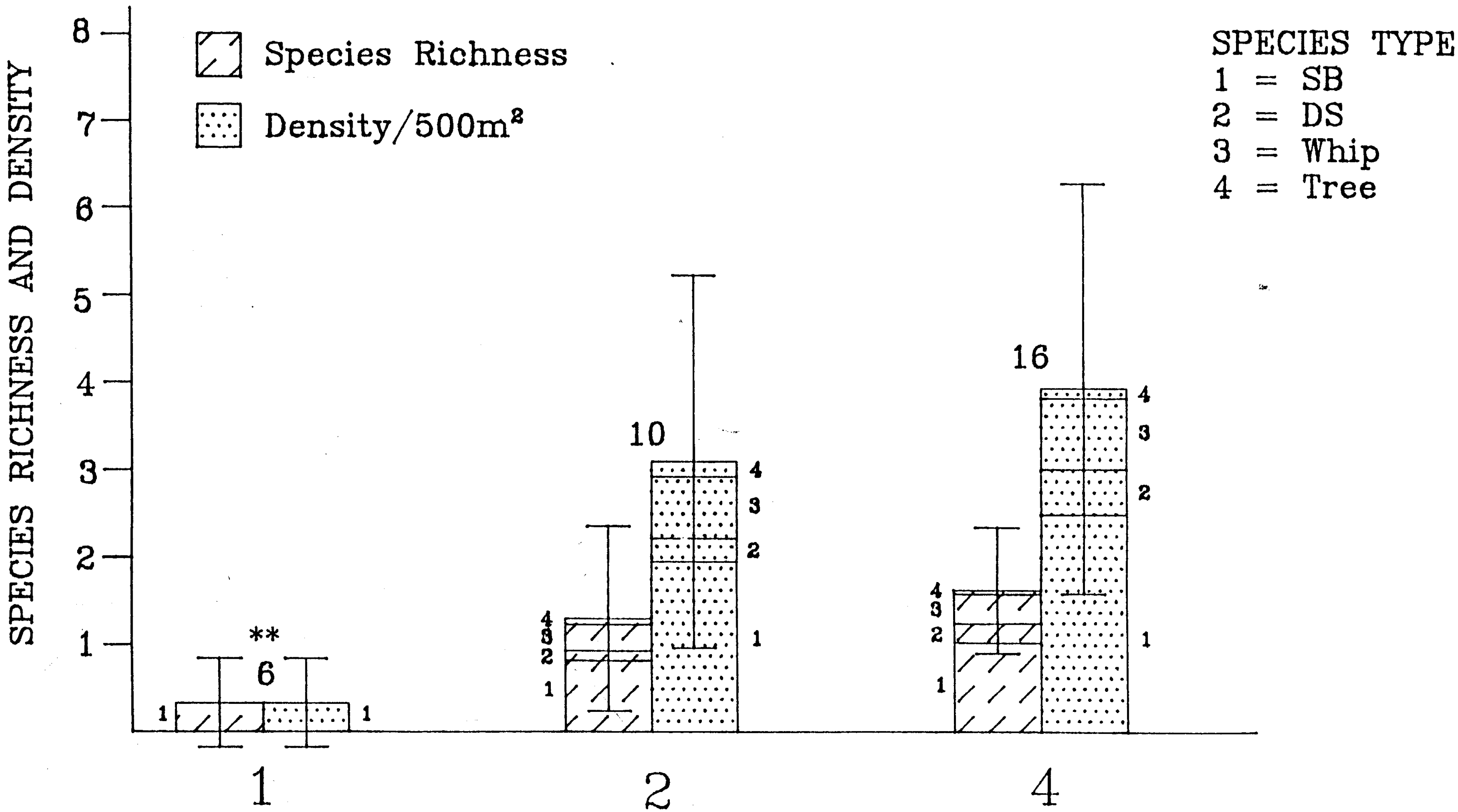
Table IV-2 Raw Data

		MILE	ZONE	LIZSPEC	LIZDENS	AMBTEMP
		SOILTEMP				
CASE	1	20.400	1.000	1.000	1.000	34.000
CASE	1	33.000				
CASE	2	20.400	1.000	2.000	1.000	34.000
CASE	2	33.000				
CASE	3	20.400	2.000	1.000	2.000	36.000
CASE	3	33.000				
CASE	4	34.700	1.000	1.000	2.000	39.500
CASE	4	42.700				
CASE	5	53.000	1.000	1.000	1.000	30.000
CASE	5	26.000				
CASE	6	53.000	1.000	3.000	4.000	30.000
CASE	6	26.000				
CASE	7	53.000	1.000	4.000	2.000	30.000
CASE	7	26.000				
CASE	8	53.000	2.000	1.000	4.000	35.000
CASE	8	26.000				
CASE	9	53.000	2.000	3.000	1.000	35.000
CASE	9	26.000				
CASE	10	53.000	2.000	4.000	2.000	35.000
CASE	10	26.000				
CASE	11	53.000	3.000	1.000	1.000	32.500
CASE	11	28.000				
CASE	12	62.500	1.000	1.000	2.000	37.800
CASE	12	42.000				
CASE	13	62.500	1.000	3.000	4.000	37.800
CASE	13	42.000				
CASE	14	62.500	2.000	0.000	0.000	39.400
CASE	14	46.000				
CASE	15	64.800	1.000	1.000	5.000	36.700
CASE	15	36.000				
CASE	16	64.800	2.000	1.000	3.000	35.600
CASE	16	35.000				
CASE	17	75.500	1.000	0.000	0.000	40.500
CASE	17	51.000				
CASE	18	93.200	1.000	2.000	1.000	43.400
CASE	18	57.000				
CASE	19	108.300	1.000	1.000	3.000	28.300
CASE	19	31.000				
CASE	20	108.300	1.000	3.000	1.000	28.300
CASE	20	31.000				
CASE	21	120.000	1.000	0.000	0.000	38.400
CASE	21	34.000				
CASE	22	120.000	1.000	1.000	4.000	32.300
CASE	22	30.000				
CASE	23	120.000	2.000	1.000	4.000	36.700
CASE	23	35.000				
CASE	24	122.000	1.000	1.000	4.000	.
CASE	24	.				
CASE	25	122.000	1.000	2.000	1.000	.
CASE	25	.				
CASE	26	122.000	2.000	3.000	4.000	35.600
CASE	26	26.000				

Table IV-2 Raw Data (continued)

CASE	27	122.000	3.000	0.000	0.000	.
CASE	27	.				
CASE	28	122.800	1.000	1.000	3.000	36.700
CASE	28	27.000				
CASE	29	122.800	1.000	3.000	1.000	36.700
CASE	29	27.000				
CASE	30	122.800	2.000	1.000	3.000	33.400
CASE	30	25.000				
CASE	31	122.800	3.000	0.000	0.000	36.100
CASE	31	21.000				
CASE	32	132.000	3.000	0.000	0.000	.
CASE	32	.				
CASE	33	136.600	1.000	1.000	3.000	37.800
CASE	33	34.000				
CASE	34	136.600	1.000	1.000	2.000	30.500
CASE	34	23.000				
CASE	35	136.600	2.000	1.000	2.000	37.800
CASE	35	33.000				
CASE	36	136.600	2.000	2.000	2.000	37.800
CASE	36	33.000				
CASE	37	136.000	2.000	3.000	3.000	33.400
CASE	37	27.000				
CASE	38	136.600	1.000	2.000	5.000	30.500
CASE	38	23.000				
CASE	39	136.600	2.000	1.000	2.000	33.400
CASE	39	27.000				
CASE	40	166.800	1.000	0.000	0.000	32.300
CASE	40	26.000				
CASE	41	166.800	1.000	1.000	1.000	32.300
CASE	41	26.000				
CASE	42	166.800	1.000	2.000	1.000	32.300
CASE	42	26.000				
CASE	43	166.800	2.000	1.000	1.000	32.300
CASE	43	28.000				
CASE	44	166.800	2.000	1.000	1.000	32.300
CASE	44	27.000				
CASE	45	166.800	2.000	2.000	1.000	32.300
CASE	45	28.000				
CASE	46	190.900	1.000	1.000	4.000	33.400
CASE	46	30.000				
CASE	47	190.900	1.000	3.000	1.000	33.400
CASE	47	30.000				
CASE	48	194.000	1.000	1.000	6.000	35.000
CASE	48	36.000				
CASE	49	194.000	1.000	3.000	3.000	35.000
CASE	49	36.000				
CASE	50	208.800	1.000	1.000	2.000	36.700
CASE	50	30.000				
CASE	51	208.800	2.000	0.000	0.000	34.500
CASE	51	28.000				
CASE	52	208.800	3.000	1.000	1.000	32.300
CASE	52	29.000				

FIGURE IV–3: Lizard Species Richness and Density as a Function of River Zone in the Grand Canyon



** = $p < .01$

Table IV-3 Summary Data

		MILE	ZONE	NOSPEC	LIZDENS	AMBTEMP
CASE	1	20.400	4.000	2.000	2.000	34.000
CASE	2	20.400	2.000	1.000	2.000	36.000
CASE	3	34.700	4.000	1.000	2.000	39.500
CASE	4	53.000	4.000	3.000	7.000	30.000
CASE	5	53.000	2.000	3.000	7.000	35.000
CASE	6	53.000	1.000	1.000	1.000	35.000
CASE	7	62.500	4.000	2.000	6.000	37.800
CASE	8	62.500	2.000	0.000	0.000	39.400
CASE	9	64.800	4.000	1.000	5.000	36.700
CASE	10	64.800	2.000	1.000	3.000	35.600
CASE	11	75.500	4.000	0.000	0.000	40.500
CASE	12	93.200	4.000	1.000	1.000	43.400
CASE	13	108.300	4.000	2.000	4.000	28.300
CASE	14	120.000	4.000	1.000	4.000	32.300
CASE	15	120.000	2.000	1.000	4.000	36.700
CASE	16	120.000	1.000	0.000	0.000	.
CASE	17	122.000	4.000	2.000	5.000	.
CASE	18	122.000	2.000	1.000	4.000	36.600
CASE	19	122.000	1.000	0.000	0.000	.
CASE	20	122.800	4.000	2.000	4.000	36.600
CASE	21	122.800	2.000	1.000	3.000	33.300
CASE	22	122.800	1.000	0.000	0.000	36.100
CASE	23	132.000	1.000	0.000	0.000	.
CASE	24	136.600	4.000	2.000	5.000	34.000
CASE	25	136.600	2.000	3.000	5.000	35.600
CASE	26	166.800	4.000	2.000	2.000	32.300
CASE	27	166.800	2.000	2.000	3.000	32.300
CASE	28	190.900	4.000	2.000	5.000	33.400
CASE	29	194.000	4.000	2.000	9.000	35.000
CASE	30	208.800	4.000	1.000	2.000	36.700
CASE	31	208.800	2.000	0.000	0.000	34.500
CASE	32	208.800	1.000	1.000	1.000	32.200

Table IV-4

MULTIPLE ANALYSIS OF COVARIANCE TABLE

SOURCE	WILK'S APPROX. F VALUE	p	DF	SIGNIF. VARS
MAIN EFFECT				
ZONE	4.710	0.017	2,28	S**,D**
COVARIATES MILE (ELEV)	0.088	0.916	2,28	NSD
AMBIENT TEMP	3.309	0.053	2,25	NSD

** p>.01

Other reptiles were sighted outside the study plots. Two Grand Canyon Pink Rattlesnakes were sighted at separate beaches. The first was seen in the evening at Nankoweap (mile 53.0). The second was sighted at Nevills (mile 75.5) in the morning. A striped whip snake was seen in the afternoon in the narrow canyon behind Blacktail (mile 120). At Pancho's Kitchen (mile 136.6) in the P.M., the California King Snake was sighted in Zone 2 (OHWZ) under an acacia. Chuckwallas were sighted at the Doll's House (mile 131), Pancho's Kitchen (mile 136.6), and Havasu Creek (mile 156.8).

DISCUSSION

In analyzing the data, it was found that fewer number of lizards were found in Zone 1 (Desert). This could be due to the small sample size. Zone 1 also had the lowest percentage of ground and shrub cover. Since lizards are poikilothermic, temperature is a factor in the identification of their location. Therefore, it would be to their advantage to have shrubs and ground cover nearby for shade. The substrate of Zone 1 was talus. The plants had a greater basal diameter. This means the lizards would have difficulty hiding from predators in the plant types characterized by this zone.

Zone 2 (OHWZ) contained 33% of the total population of lizards. The substrate was characterized as silty sand. The ground (58.2%) and shrub (54.7%) cover was slightly less than Zone 4. Zone 2 provided a suitable habitat for lizard populations.

There were increased concentrations of lizards in Zone 4 (NHWZ). By percentage, Zone 4 offered the greatest amount of ground (60.8%) and shrub (55.2%) cover. This would have been the area that would allow the greatest chance to regulate body temperature. Also, Zone 4 contained 87% of all insect species collected. Therefore, the lizards were in Zone 4 to utilize shade and food sources. The substrate of Zone 4 was sand. The basal diameter of the plants were small, which allowed the lizards to hide easily from predators.

All species were found in Zones 2 and 4. This may suggest that the substrate, ground and shrub cover, and food supply provided enough of a habitat range for all four species of lizards. Only the side-blotched lizard was found in Zone 1. This could be due to small sample size, the great amount of exposure to the elements, or the limited food supply.

No significant difference was found between lizard species and density and the beach mile or ambient temperature, although the latter approached statistical significance. This was attributed to the small sample size and missing temperature readings.

Data gathered in the lizard distribution and density study indicated that a higher percentage of lizard species and density are found in Zone 4. This would be the area most susceptible to flooding during water releases from Glen Canyon. This should be a concern, in that lizards, their source of shelter, and food might be destroyed during high water releases. Research should continue and records should be updated to determine if populations are being affected by the Glen Canyon Dam releases.

RECOMMENDATIONS

1. Researchers need to be at the same site for more than one day so comparisons can be made at different times of the day.

2. Other research teams need to stay out of the study area until the lizard team is able to get an accurate count. An announcement to this effect prior to departure for the river trip would alleviate much frustration.

3. The researchers need to record information concerning terrain and weather conditions.

4. Lizard and plant groups should coordinate specific beaches and procedures before the river trip.

5. Attempt to "fish" for lizards from the beginning in order to collect more data for a biomass study.

6. Prior to the river trip, current researchers should contact the previous team members for input and suggestions on how to utilize their time most effectively.

7. Researchers should be familiar with literature that helps them identify the lizards by sight as well as preferred habitat. Lizard specimens can be viewed at the biology museum on campus.

8. Data collected from 1990 should be used in conjunction with the data from 1991 to provide a more complete analysis.

9. Researchers need to schedule in time to "sit and watch" the different lizards to collect information about behavior; i.e., What are they eating? Do they drink water? Where are they most frequently seen?

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CHAPTER 5

GRAND CANYON RODENT POPULATIONS 1990

Jay L. Butler, Pamela S. Nyman and Michele B. Spurgiesz

ABSTRACT

The small mammal study examined the existance of nocturnal rodents in the old and new high water zones of the Grand Canyon Colorado River corridor. Data were gathered on mammalian community structure to document species compositional changes from prior years. Sixty eight traps were set each night with a 12% capture rate. A higher number of males than females were captured in the new high water zone. Nearly equal numbers of each sex were caught in the old flood zone. Three sites yielded little to no trap success and this was attributed to high ant densities on two of those beaches. This study supports prior findings that Peromyscus eremicus is the dominant resident mammal of the river corridor.

INTRODUCTION

This small mammal study examined the abundance and diversity of nocturnal rodents in the two most distinct beach zones, as described by Carothers (1976), along the Colorado River corridor of the Grand Canyon. The new high water zone (Zone 4), characterized by tamarisk and willow has actually been created by the fluctuating flows of the dam. The old high water zone (Zone 2) is no longer subject to floods, also as a result of the dam. This zone is dominated by acacia and mesquite (Figure 1).

Previous studies censused rodent communities since the completion of Glen Canyon Dam (Hoffmeister, 1971, Ruffner, 1975, 1976). The Bureau of Reclamation manages the dam to meet power demands. Consequently, daily fluctuations may range between 3,000 cubic feet/second (cfs) and 35,000 cfs (Ruffner, et al, 1978). Zone 2 was once inundated by spring floods which have been recorded as high as 300,000 cfs (Fenneman, 1931).

This study continued the anecdotal recording of density and diversity of species. In addition, we included an indication of gender predominance by zone and the interactive element of plant species, cover and variety. The project sought to determine if rodents would be found in greater abundance in the old, more established and stable high water zone (Zone 2) than in the fluctuating new riparian zone (Zone 4).

METHODS

At all camp sites during the 14 day river expedition, 34 traps were set in each zone at dusk. A transect was established in both zones and parallel traps at 5 meters distance were set. The Sherman live traps were baited with wild bird seed mixed with homogenized peanut butter at a ratio of 10:1. Traps were checked each morning and rodents caught were identified by species, then sexed and weighed. Each animal was released unharmed at its trap station.

Previous methods were similar with a yearly alteration of the type of bait used. Our average traps set were 68 while some years as many as 90 were set (Spears, F. and G. Spears, 1983). Since 1980, researchers have not marked rodents to indicate re-capture when the same site could be used consecutively.

RESULTS

Figures 2-4 show the number of captures for Zones 2 and 4. Figures 5-6 compare the different capture rates for males and females in the two capture areas. The 1990 results for total percentage of species recorded are summarized in a pie graph (Figure 7). A comparison of species captured for the years 1987, 1988, 1989 and 1990 are included in Figure 8.

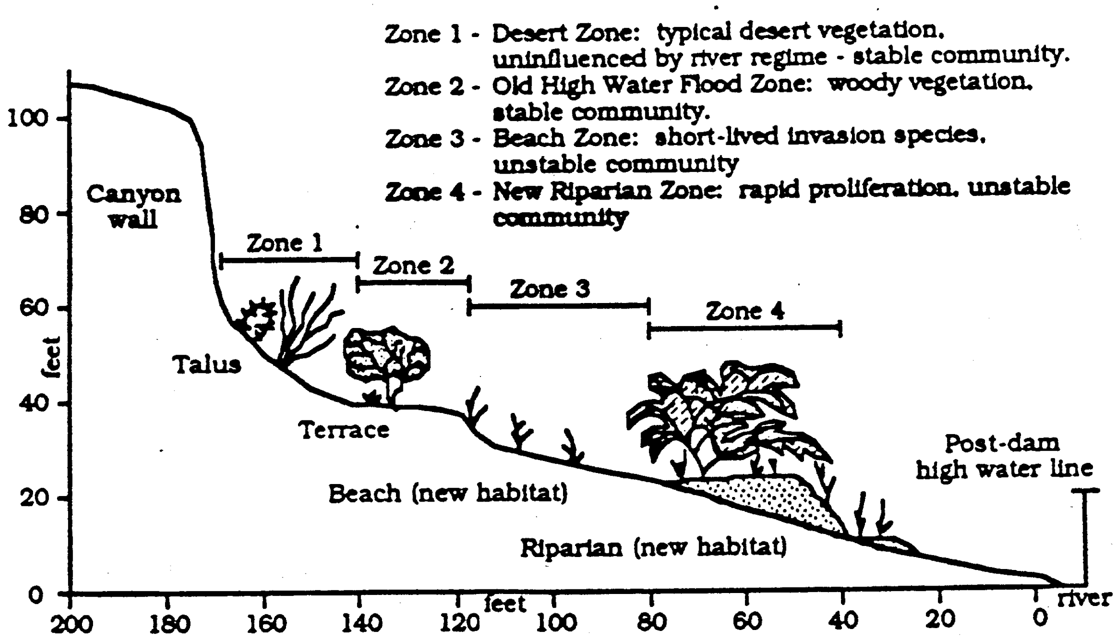
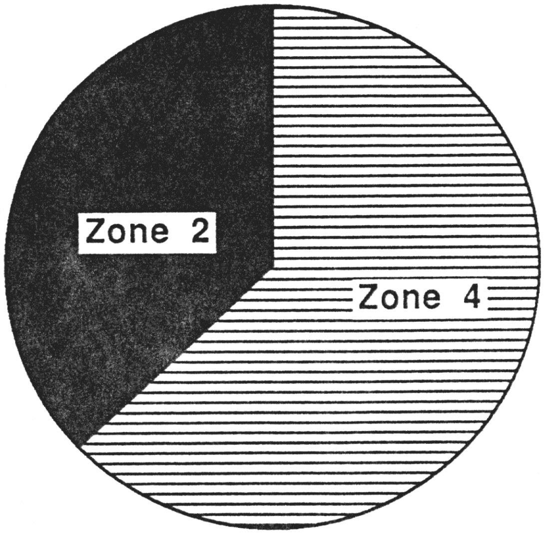
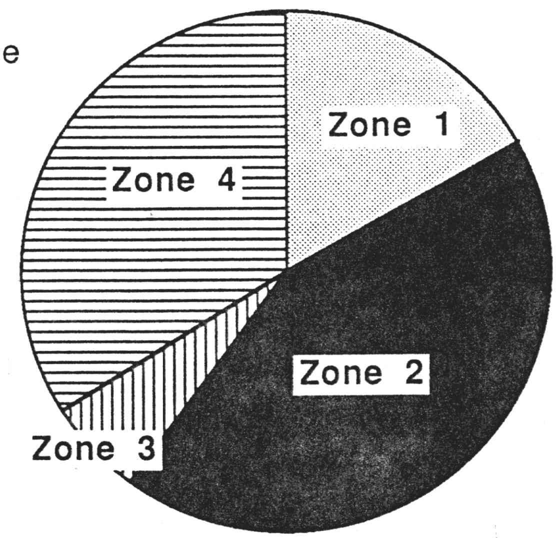


Figure V -1. Diagrammatic cross-section of vegetation zones in the Inner Gorge of the Colorado River in Grand Canyon after construction of Glen Canyon Dam (adapted from Carothers, et. al., 1979).



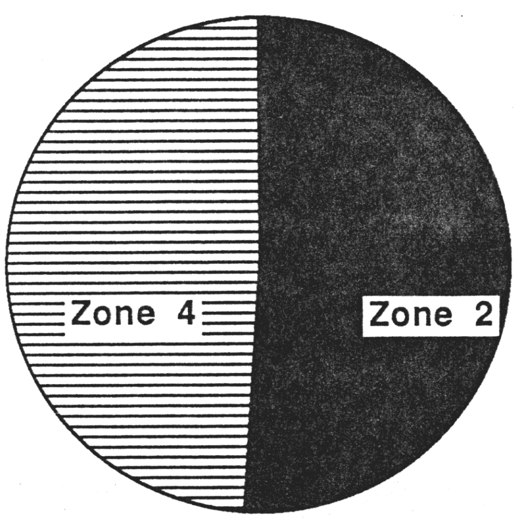
1982

Figure V-2. Percent of mammals by zone



1987

Figure V-3 Percent of mammals by zone



1990

Figure V-4. Percent of mammals by zone

	ZONES	% 1982	% 1987	% 1990
1	Zone 1	0	17	0
2	Zone 2	37	43	51
3	Zone 3	0	6	0
4	Zone 4	63	34	49

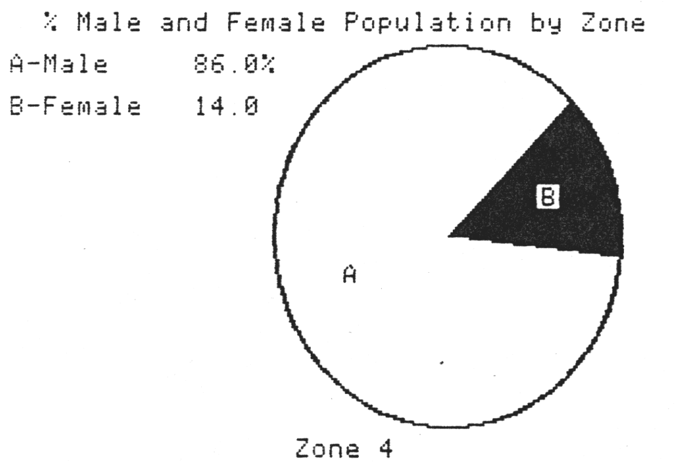


Figure II-5

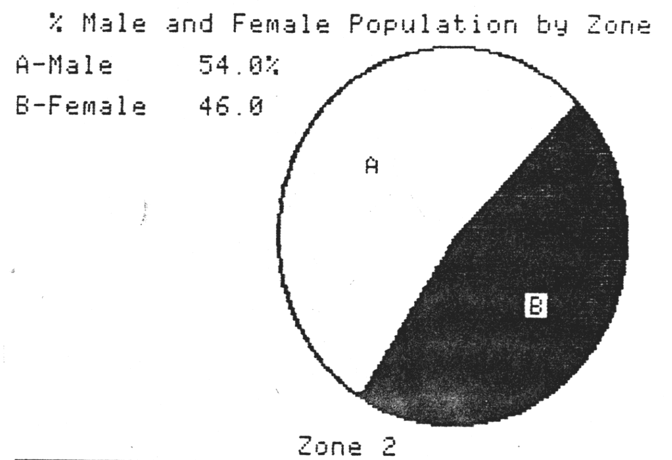


Figure II-6

Percent of each species for 1990

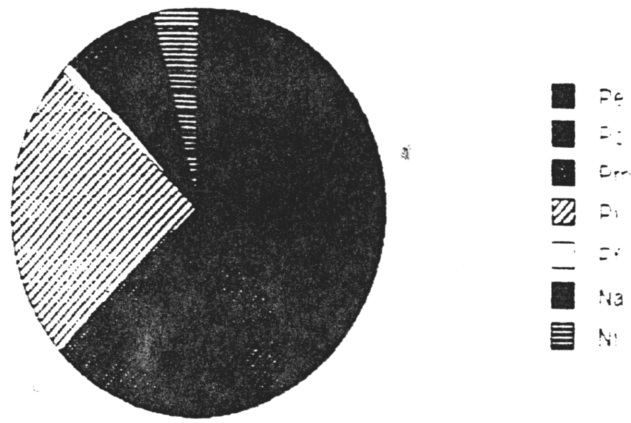


Figure V-7

	SPECIES	1990	1989	1988	1987
1	Pe	38.000	55.000	52.000	65.000
2	Pc	24.000	5.000	6.000	15.000
3	Pm	1.000	0.000	0.000	3.000
4	Pi	24.000	24.000	0.000	4.000
5	Pf	1.000	0.000	0.000	1.000
6	Na	8.000	6.000	4.000	2.000
7	Ni	4.000	6.000	3.000	2.000

Percent of species for 1987 through 1990

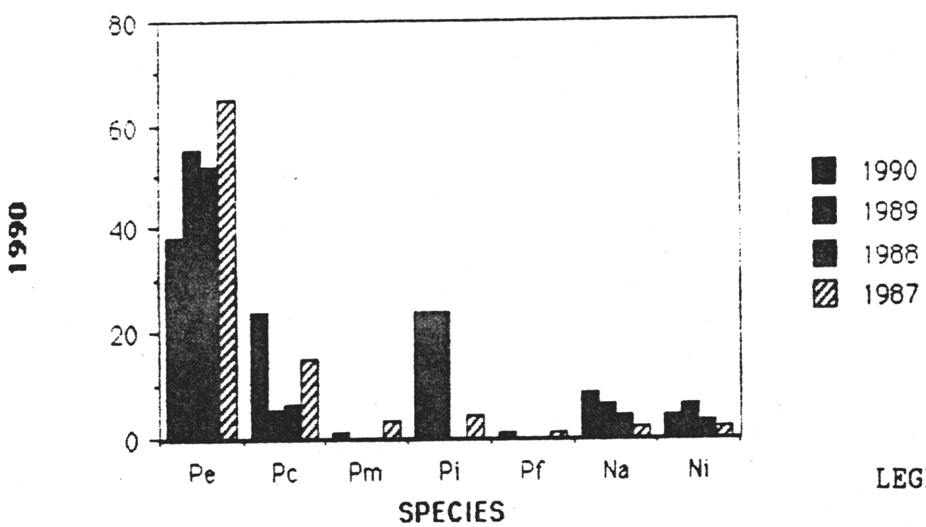


Figure V-8

LEGEND

Pe - Perognathus eremicus
Pc - Peromyscus crinitus
Pl - Perognathus intermedius
Pm - Peromyscus maniculatus
Pf - Perognathus formosus
Na - Neotoma albigula
Nl - Neotoma lepoda

DISCUSSION

The 1990 study caught 88 rodents at 10 study sites with a total of 680 trap nights. Our study shows approximately 12% trap success as compared with last year's 16% (Smith, 1989) success rate. This may have some correlation to beach erosion which other group studies have shown to be significant. The traps currently in use are not consistant in their spring action. This may also have affected capture rate.

Since the completion of Glen Canyon Dam, Zone 4 had been without environmental disturbance for 20 years and had the highest rodent density in the 1982 census (Trimble et. al., 1982). A major flood occurred in 1983 which scoured the new high water zone. Spears trapped these areas that summer and found only 18% of the rodents in the disturbed tamarisk transects. This was significantly less than the 63% trap success of 1982. The data for 1990, 7 years after the flood, suggest that small mammals are now using the old and new high water zones with equal frequency.

Females were consistantly caught in Zone 2 and seldom caught in Zone 4 (14% female to 86% male). Males were uniformly caught in both zones. This may indicate a difference in nesting and foraging territories.

At Nankoweap, the greatest number of wood rats (Neotom albigula) were caught. Signs of nesting were apparent in Zone 2.

According to beach mile data, the Inner Gorge yielded the least trap success. This was only exceeded by North Canyon, where no individuals have been caught for two years. Where ant infestations were high, rodent trap success was generally low.

Future studies should consider the ratio of male/females by zone and the evidence of lack of trap success in the above mentioned areas. Also recommended by this study team is careful consideration of bait and its possible environmental impact.

Traps need to be placed where they will not receive early morning sunlight and jeopardize captured animals. The establishment of permanent study sites which would be trapped on consecutive nights is suggested. Data gathered from marked rodents will reveal whether individuals are using both zones and give indications on territory size and shape. An effort to place a minimum of 50 traps per transect should be made.

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CHAPTER 6

COMPARATIVE WATER POTENTIAL IN RIPARIAN PLANT SPECIES OF THE GRAND CANYON NATIONAL PARK, ARIZONA

Edward M. Thompson and Lois D. Thompson

ABSTRACT

Water potential of ten riparian phreatophyte species were measured along the Colorado River corridor in Grand Canyon National Park. Two hundred fifty-three samples were tested using the Scholander pressure bomb. Measurements were made during pre-dawn and mid-day hours at two sites, and seven sites for pre-dawn. Of the ten species tested, considerable variation in water potential between species was observed. When up-river sites were compared to down-river sites, the new high water plants showed a more negative water potential down-river while the old high water plants remained the same. New high water zone species show less adaptation to water stress than old high water zone species.

INTRODUCTION

Besides Stevens' (1989) work on riparian plants, there is little research available that has been systematically carried out in the Grand Canyon. The distribution of riparian plant species in this system may relate to specific water potential characteristics, and their ability to deal with water stress in the post-dam fluvial environment. Rapid flooding and draw-down has been found to produce direct strain beyond the elastic tolerance limit of plants (Levitt 1980). This study was the first attempt to determine comparative water potentials for riparian plant species along the Colorado River corridor in the Grand Canyon National Park, Arizona.

LITERATURE REVIEW

Water Potential Gradient

An establishment of a water potential gradient (Ψ) was first accomplished by Scholander with his pressure bomb method, which provided a means of measuring tension in stems (Salisbury and Ross 1978). Scholander was able to show that the negative hydrostatic pressure in plants could be measured by placing a cut stem into the pressure bomb and applying pressure with nitrogen gas. As the stem is cut, the sap cavitates back into the stem. The pressure necessary to drive this sap back to the cut is measured as the plant's water potential, a negative value. Halophytes and xerophytes were found to have the strongest negative pressures while freshwater and forest plants have less negative pressures (Scholander 1965).

Plant water potential (Ψ) is used to express the energy status of water in plant cells and tissues. It consists of three component potentials: pressure potential Ψ_p: solute potential Ψ_s: and matric potential Ψ_m. Assuming that cell water changes are controlled by the vacuole, which occupies 80 to 90% of the total volume of mature parenchyma cells, the cell behaves like an osmometer. In these cells, changes in cell volume are responsible for developing Ψ_p. As water is lost from the cell, there is a decrease in cell turgor and Ψ_p approaches zero. The solute potential, Ψ_s, which always bears negative values, becomes increasingly negative as cells dehydrate. Thus when cell dehydration occurs, Ψ drops to more negative values. The matrix potential, negligible in parenchyma in cells which have 80-90% vacuole space, will also contribute to the overall decrease in Ψ as water content falls (Simpson 1981). Water potential is commonly measured in bars, where one bar is approximately equal to one atmosphere. Over the years, the accepted unit for water potential (Ψ) has changed from atmospheres, to bars, to pascals; the new internationally accepted unit of pressure. One pascal is relative to 1 x 10^{-5} bars (Levitt 1980). In this study, bars were used as the standard unit for Ψ .

Water Stress

Water stress may arise from an insufficient or excessive water activity in a plant's environment. In terrestrial plants, the former is caused by water deficit or drought and therefore is called water deficit stress or simply water stress. Water stress is commonly expressed as $S_d = -\Psi_e$ where S_d = the water (drought) stress and Ψ_e = the water potential of the environment. Since Ψ is always negative, water stress becomes a positive value (Levitt 1980).

Cells and tissues are regarded as water deficient when they are not at full turgor. In plants, water stress must be related to drought induced departures of physiological processes from the normal. Water balance of a tissue at a given time results from the balance between absorption and transpiration. As soil water is removed and soil water potential is falling to more negative values, plants must decrease their water potential to sustain the potential gradient for water absorption. At the same time, absorption becomes more difficult because of the great increase in soil resistance. Plant water potential thus becomes more negative with increasing soil dryness. At night, when transpiration ceases, daily water deficits are gradually eliminated and plant water potential eventually reaches equilibrium with soil water potential (Simpson 1981).

Water stress can bring about both primary and secondary injury to plants. Six different injuries; growth inhibition, starvation, toxin accumulation, biochemical lesions, ion efflux, and nutrient deficiency are identified. Plants have adapted different strategies to deal with water stress,primarily drought avoidance and drought tolerance (Levitt 1980). Drought avoiding plants are those which maintain a high plant water potential when exposed to extended periods of water stress. Drought tolerance refers to the ability of a plant to withstand water stress (Simpson 1981). The measurement of water potentials of the species in this study may reflect each species' ability to deal with water stress.

This study was designed to meet the following objectives related to water potentials of riparian vegetation.

Objective 1a: To compare the water potentials between ten species of riparian plants of the Colorado River corridor.

Objective 1b: To contrast water potentials of six species of riparian plants between mid-afternoon (3:00-5:00 P.M.) and early morning (3:00-5:00 A.M.).

Objective 2: To compare water potentials of five species of riparian plants common to the upper Grand Canyon and lower Grand Canyon, separated by river mile 100.

Objective 3: To compare water potentials of five species of riparian plants on seven beaches.

METHODS

Study sites were selected at seven beaches throughout the Grand Canyon, beginning at North Canyon (RM 20.5) and ending at Granite Park (RM 209.0). The sites were divided into upper canyon beaches (above RM 100) and lower canyon beaches (below RM 100) for sake of comparison. Two beaches were selected for comparisons of predawn and afternoon measurements, while all other measurements were strictly predawn. During this pre-dawn/dawn time frame, water potentials are at their highest levels while mid-day readings reflect minimum values (Simpson 1981). Three distinct zones were established for the study: the new high water zone (10,000-60,000 cfs), the old high water zone (60,000-150,000 cfs), and the desert (more than 150,000 cfs) (Carothers et al. 1979). Almost all samples were collected within the new and old high water zones.

Ten species of riparian vegetarian were selected based on availability and abundance at the selected campsites. Although each species was not necessarily found at each site, enough sampling was made to establish general trends in each species' water potential (Table VI-1). Individuals were randomly selected throughout the study site, gradually moving away from the river. Samples were cut from branches randomly selected on each plant in an attempt to minimize stem height effect.

At river mile 20.5, two tamarisks were sampled, one at the new high water and the other at the old high water zone. Samples on each plant were taken on different sides and heights. Data on Tamarix ramosissima indicated that height of the sample was not a significant factor in the plant in the new high water zone (Figure VI-1).

Graphs were produced using Lotus and statistical analyses using Systat.

RESULTS

A comparison of ten riparian plant species showed that there was a significant difference between the water potentials of each species and between pre-dawn and afternoon water potential (Figure VI-2). Statistical analyses of the raw data indicated differences between plant species ($p = .000$, $df = 1,248$), between pre-dawn and mid-day bars ($p = .000$, $df = 1,248$), and significant interaction between species and time of sampling ($p = .000$, $df = 1,248$). This interaction result was attributed to differences in the magnitude of responses between pre-dawn and mid-day samples between species. Distance from Glen Canyon Dam was statistically significant ($p = .000$, $df = 1,248$), indicating lower overall Ψ at lower elevations (Table VI-2).

In comparison of Ψ in the new high water zone and the old high water zone, T. ramosissima, T. sericea, and S. exiqua, in the hew high water zone, showed a decrease in water potential from up-river to down-river. The other two species, P. glandulosa and A. greggi, found in the old high water zone, showed water potentials that remained essentially the same across the elevational gradient (Figure VI-3).

A comparison of seven beaches and five species showed graphically the differences between the species and the trend for down-river new high water plants to be under more stress down-river. Again Ψ in the old high water zone plant species remained unchanged (Figure VI-4).

DISCUSSION

The examination of water potentials of ten riparian plant species exhibited a wide range of Ψ for phreatophytic species. The intraspecific variance for Ψ between A.M. and P.M. readings indicates the ability of a species to deal with drought stress, those with a larger range being more drought tolerant. Acacia greggii, a facultative phreatophyte found in the desert and old high water zone, exhibited high Ψ values for both A.M. and P.M., and also a range of 15.8 bars. Tamarix ramosissima and Tessaria sericeae, new high water plants, also exhibited wide ranges of 11.1 bars and 12.1 bars respectively. Conversely, Salix exigua, found in the new high water zone, showed the least negative, -8.6 bars, and a very narrow range of 5.6 bars for A.M. and P.M. This would indicate S. exigua does not have a great tolerance of water stress.

The evaluation of Ψ in plants found up-river and down-river revealed variability in new high water zone plants, Tessaria sericeae, Salix exigua, and Tamaria ramosissima; however, little change was observed in old high water zone plants Acacia greggii and Prosopis glandulosa. New high water zone plants which have only recently colonized the Colorado River corridor, may be more affected by abiotic factors of stage changes, substrate texture, elevation, and annual mean temperature than the established old high water zone plants. In each case, the up-river Ψ of new high water zone plants was less negative than down-river Ψ , indicating the down-river environment produces a higher water stress on those plants.

If colonization of less drought tolerant species such as Salix exigua is a biological goal for the Grand Canyon National Park, more research is needed to determine optimal flow regimes necessary to sustain S. exigua within its Ψ range. Water stress in this species may be a significant controlling variable. During this study, there was a controlled flow of 5,000 cfs for four days. Towards the end of this time, on Blacktail Beach, RM 120, S. exigua, showed its most negative water potential, -13.4 bars.

To better determine the influence of abiotic factors on up-river and down-river new high water zone plant species, readings on selected plants should be made every four hours over a twenty four hour period at up-river and down-river sites. Temperature and relative humidity should be monitored . Ideally, this study should be conducted four times within the year, once during each season. Suggested species to monitor are Tamarix ramosissima, Salix exigua, Tessaria sericeae, Acacia greggii, Prosopis glandulosa, and Brickellia longifolia. Celtis reticulata would also provide interesting data in this system.

CONCLUSION

In conclusion, plants found in the old high water zone show greater drought tolerance than most plants in the new high water zone. Water stress levels of new high water zone plants are less in the upper Grand Canyon region than in the lower canyon, while old high water plants remain virtually the same.

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Table VI-1. Water potential by river mile, species, and time.

		MILE	SPECIES	ID	TIME	WATER POTENTIAL
CASE	1	20.500	1.000	1.000	1.000	-10.500
CASE	2	20.500	1.000	1.000	1.000	-11.500
CASE	3	20.500	1.000	1.000	1.000	-9.500
CASE	4	20.500	1.000	1.000	1.000	-10.500
CASE	5	20.500	1.000	1.000	1.000	-10.500
CASE	6	20.500	1.000	1.000	1.000	-10.500
CASE	7	20.500	1.000	2.000	1.000	-19.500
CASE	8	20.500	1.000	2.000	1.000	-19.000
CASE	9	20.500	1.000	2.000	1.000	-23.000
CASE	10	20.500	1.000	2.000	1.000	-15.000
CASE	11	20.500	1.000	2.000	1.000	-18.000
CASE	12	20.500	1.000	2.000	1.000	-20.500
CASE	13	20.500	12.000	1.000	1.000	-5.500
CASE	14	20.500	12.000	2.000	1.000	-4.500
CASE	15	20.500	12.000	3.000	1.000	-6.500
CASE	16	20.500	12.000	4.000	1.000	-7.000
CASE	17	20.500	12.000	5.000	1.000	-8.500
CASE	18	20.500	12.000	6.000	1.000	-8.000
CASE	19	20.500	12.000	7.000	1.000	-6.500
CASE	20	20.500	12.000	8.000	1.000	-10.500
CASE	21	20.500	12.000	9.000	1.000	-8.000
CASE	22	53.000	1.000	1.000	1.000	-11.500
CASE	23	53.000	1.000	2.000	1.000	-9.000
CASE	24	53.000	1.000	3.000	1.000	-8.500
CASE	25	53.000	1.000	4.000	1.000	-13.500
CASE	26	53.000	1.000	5.000	1.000	-14.000
CASE	27	53.000	1.000	6.000	1.000	-15.000
CASE	28	53.000	2.000	1.000	1.000	-21.500
CASE	29	53.000	2.000	2.000	1.000	-15.000
CASE	30	53.000	2.000	3.000	1.000	-24.500
CASE	31	53.000	2.000	4.000	1.000	-21.500
CASE	32	53.000	2.000	5.000	1.000	-27.500
CASE	33	53.000	2.000	6.000	1.000	-26.500
CASE	34	53.000	2.000	7.000	1.000	-23.000
CASE	35	53.000	2.000	8.000	1.000	-33.500
CASE	36	53.000	2.000	9.000	1.000	-20.000
CASE	37	53.000	3.000	1.000	1.000	-16.500
CASE	38	53.000	3.000	1.000	1.000	-10.000
CASE	39	53.000	3.000	2.000	1.000	-21.000
CASE	40	53.000	3.000	2.000	1.000	-13.500
CASE	41	53.000	3.000	3.000	1.000	-11.500
CASE	42	53.000	3.000	3.000	1.000	-17.500
CASE	43	53.000	3.000	4.000	1.000	-13.500
CASE	44	53.000	3.000	4.000	1.000	-19.000
CASE	45	53.000	3.000	5.000	1.000	-13.500
CASE	46	53.000	3.000	6.000	1.000	-14.000
CASE	47	53.000	3.000	7.000	1.000	-21.000
CASE	48	53.000	3.000	8.000	1.000	-22.500
CASE	49	53.000	4.000	1.000	1.000	-12.500
CASE	50	53.000	4.000	2.000	1.000	-14.500
CASE	51	53.000	4.000	3.000	1.000	-15.000
CASE	52	53.000	4.000	4.000	1.000	-9.500
CASE	53	53.000	4.000	5.000	1.000	-12.000

CASE	54	53.000	4.000	6.000	1.000	-14.000
CASE	55	53.000	4.000	7.000	1.000	-12.000
CASE	56	53.000	4.000	8.000	1.000	-16.500
CASE	57	53.000	4.000	9.000	1.000	-15.000
CASE	58	53.000	5.000	1.000	1.000	-8.000
CASE	59	53.000	5.000	2.000	1.000	-7.500
CASE	60	53.000	5.000	3.000	1.000	-7.500
CASE	61	53.000	5.000	4.000	1.000	-6.000
CASE	62	53.000	5.000	5.000	1.000	-6.500
CASE	63	53.000	5.000	6.000	1.000	-6.500
CASE	64	53.000	5.000	7.000	1.000	-5.500
CASE	65	53.000	5.000	8.000	1.000	-7.000
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CASE	67	53.000	5.000	10.000	1.000	-6.000
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CASE	69	53.000	5.000	12.000	1.000	-7.500
CASE	70	53.000	5.000	13.000	1.000	-12.000
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CASE	73	53.000	8.000	2.000	1.000	-8.000
CASE	74	53.000	8.000	3.000	1.000	-10.000
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CASE	78	53.000	8.000	7.000	1.000	-12.000
CASE	79	53.000	8.000	8.000	1.000	-12.000
CASE	80	64.800	1.000	1.000	1.000	-15.000
CASE	81	64.800	1.000	1.000	2.000	-28.500
CASE	82	64.800	1.000	2.000	1.000	-13.000
CASE	83	64.800	1.000	2.000	1.000	-13.000
CASE	84	64.800	1.000	2.000	2.000	-32.500
CASE	85	64.800	1.000	3.000	1.000	-22.500
CASE	86	64.800	1.000	3.000	2.000	-29.500
CASE	87	64.800	1.000	4.000	1.000	-18.000
CASE	88	64.800	1.000	4.000	2.000	-22.500
CASE	89	64.800	1.000	5.000	1.000	-17.500
CASE	90	64.800	1.000	5.000	2.000	-34.500
CASE	91	64.800	1.000	6.000	1.000	-18.000
CASE	92	64.800	1.000	6.000	1.000	-18.000
CASE	93	64.800	1.000	6.000	2.000	-31.000
CASE	94	64.800	1.000	7.000	1.000	-21.000
CASE	95	64.800	1.000	7.000	2.000	-30.000
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CASE	115	81.100	3.000	2.000	1.000	-19.500
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CASE	118	81.100	3.000	5.000	1.000	-23.000
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CASE	120	81.100	3.000	7.000	1.000	-15.000
CASE	121	81.100	12.000	1.000	1.000	-12.000
CASE	122	81.100	12.000	2.000	1.000	-12.000
CASE	123	81.100	12.000	3.000	1.000	-18.000
CASE	124	81.100	12.000	4.000	1.000	-19.500
CASE	125	81.100	12.000	5.000	1.000	-13.000
CASE	126	81.100	12.000	6.000	1.000	-10.500
CASE	127	81.100	12.000	7.000	1.000	-19.000
CASE	128	120.000	1.000	1.000	1.000	-19.000
CASE	129	120.000	1.000	2.000	1.000	-16.000
CASE	130	120.000	1.000	3.000	1.000	-18.000
CASE	131	120.000	1.000	4.000	1.000	-15.500
CASE	132	120.000	1.000	5.000	1.000	-18.000
CASE	133	120.000	1.000	6.000	1.000	-19.500
CASE	134	120.000	1.000	7.000	1.000	-20.500
CASE	135	120.000	1.000	8.000	1.000	-20.500
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CASE	137	120.000	5.000	1.000	1.000	-8.000
CASE	138	120.000	5.000	2.000	1.000	-17.500
CASE	139	120.000	5.000	3.000	1.000	-18.000
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CASE	176	166.500	4.000	5.000	1.000	-15.500
CASE	177	166.500	4.000	5.000	2.000	-20.500
CASE	178	166.500	4.000	6.000	1.000	-16.500
CASE	179	166.500	4.000	6.000	2.000	-21.500
CASE	180	166.500	5.000	1.000	1.000	-8.000
CASE	181	166.500	5.000	1.000	1.000	-9.000
CASE	182	166.500	5.000	1.000	2.000	-10.000
CASE	183	166.500	5.000	2.000	1.000	-5.000
CASE	184	166.500	5.000	2.000	1.000	-7.000
CASE	185	166.500	5.000	2.000	2.000	-11.500
CASE	186	166.500	5.000	3.000	1.000	-8.500
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CASE	206	166.500	10.000	2.000	2.000	-18.000
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CASE	215	209.000	1.000	1.000	1.000	-10.500
CASE	216	209.000	1.000	2.000	1.000	-19.500
CASE	217	209.000	1.000	3.000	1.000	-12.000
CASE	218	209.000	1.000	4.000	1.000	-20.500

CASE	219	209.000	1.000	5.000	1.000	-26.000
CASE	220	209.000	1.000	6.000	1.000	-18.000
CASE	221	209.000	2.000	1.000	1.000	-24.000
CASE	222	209.000	2.000	2.000	1.000	-33.500
CASE	223	209.000	2.000	3.000	1.000	-16.000
CASE	224	209.000	2.000	4.000	1.000	-23.000
CASE	225	209.000	2.000	5.000	1.000	-23.500
CASE	226	209.000	2.000	6.000	1.000	-20.000
CASE	227	209.000	3.000	1.000	1.000	-18.500
CASE	228	209.000	3.000	2.000	1.000	-13.000
CASE	229	209.000	3.000	3.000	1.000	-14.000
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CASE	238	209.000	4.000	6.000	1.000	-21.000
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CASE	248	209.000	94.000	1.000	1.000	-6.000
CASE	249	209.000	94.000	2.000	1.000	-9.500
CASE	250	209.000	94.000	3.000	1.000	-6.500
CASE	251	209.000	94.000	4.000	1.000	-2.500
CASE	252	209.000	94.000	5.000	1.000	-7.000
CASE	253	209.000	94.000	6.000	1.000	-8.000

Species Code Number	Scientific name	Common name
1	<u>Tamarix ramosissima</u>	Tamarisk
2	<u>Prosopis glandulosa</u>	Mesquite
3	<u>Acacia greggii</u>	Cat-claw
4	<u>Tessaria sericeae</u>	Arrowweed
5	<u>Salix exigua</u>	Coyote willow
6	<u>Salix gooddingsii</u>	Goodings willow
8	<u>Baccharis salicifolia</u>	Seep willow
10	<u>Baccharis sarothroides</u>	Desert broom
12	<u>Brickellia longifolia</u>	Brickellia
94	<u>Alhagi camelorum</u>	Camelthorn

Table VI-2: Two-factor analysis of covariance of plant water potential (-bars) as a function of plant species (10 species) and pre-dawn vs. mid-day time, with distance from Lees Ferry (elevation) as a covariate.

ANALYSIS OF COVARIANCE TABLE

Source	F	P	DF
Main effects			
Species	15.996	0.000	1,248
Time (A.M. vs P.M.)	78.756	0.000	1,248
Interaction Effect			
Species x time	20.560	0.000	1,248
Covariate			
Mile	8.042	0.005	1,248

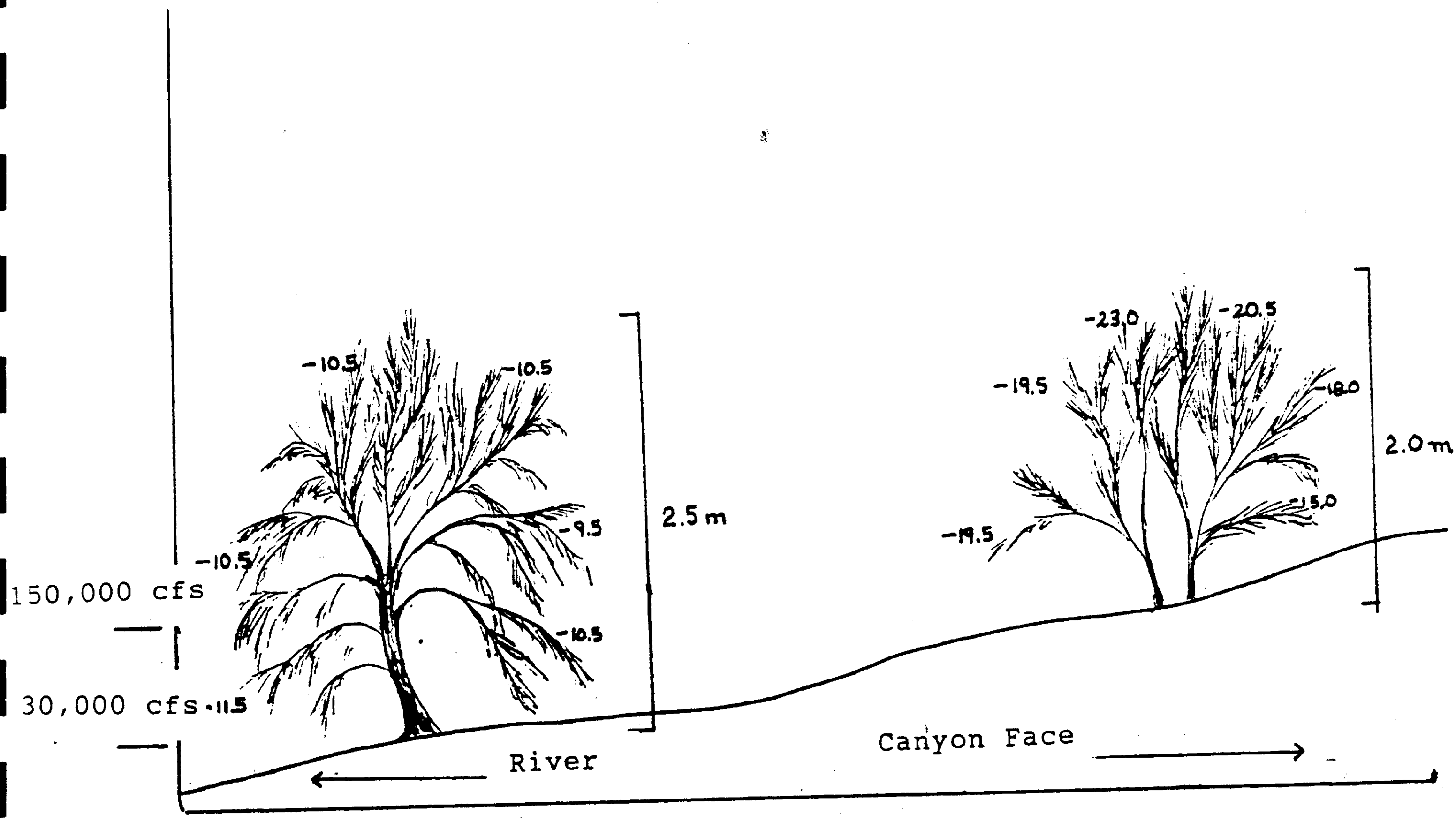


Figure VI-1. Water potential readings (bars) on _Tamarix ramosissima_ at North Canyon (RM 20.5) showing variance within two individuals.

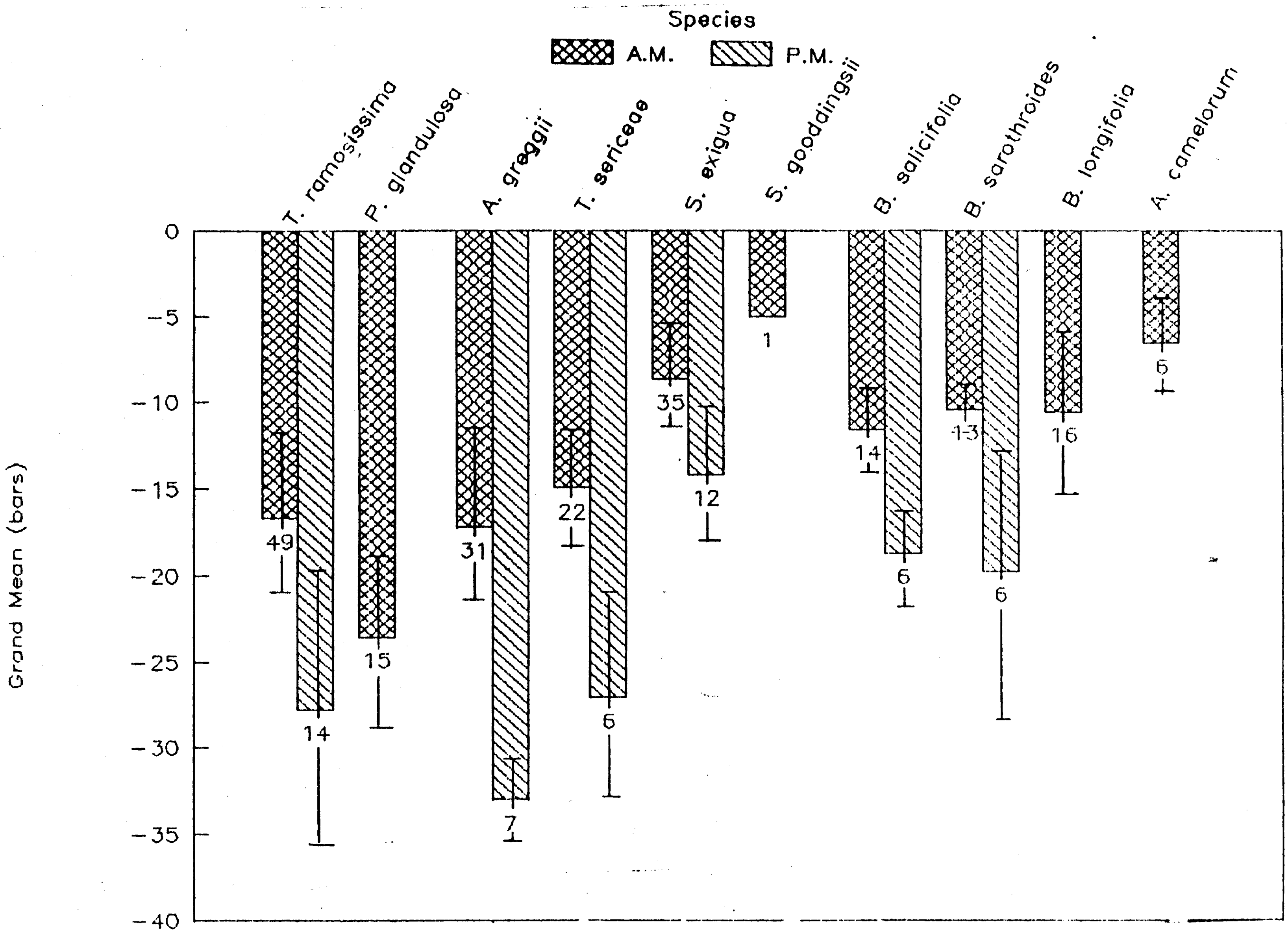


Figure VI-2. Grand mean water potentials for 10 species of riparian plants showing AM/PM contrasts.

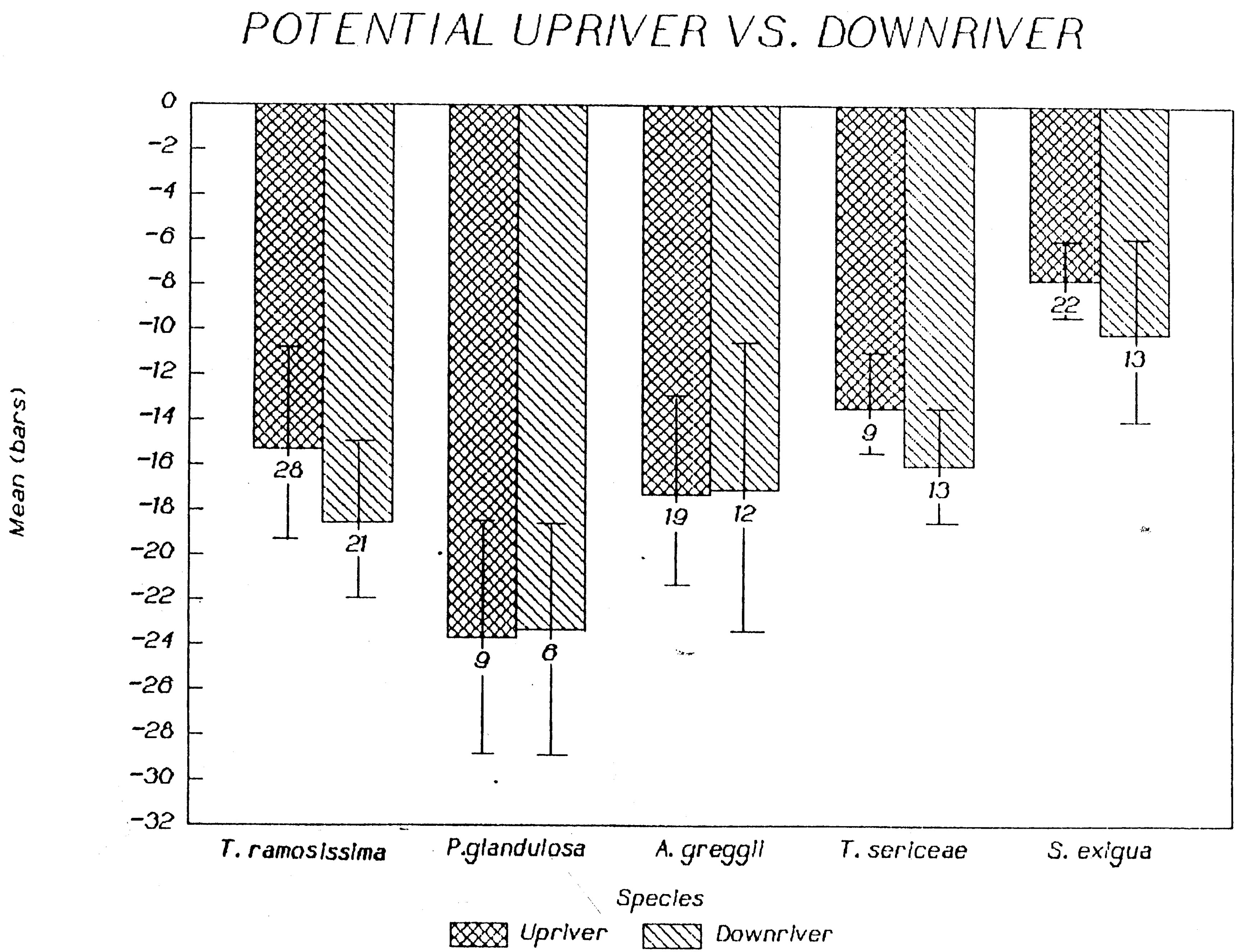


Figure VI-3. Mean water potential of five riparian plant species contrasting upriver with downriver.

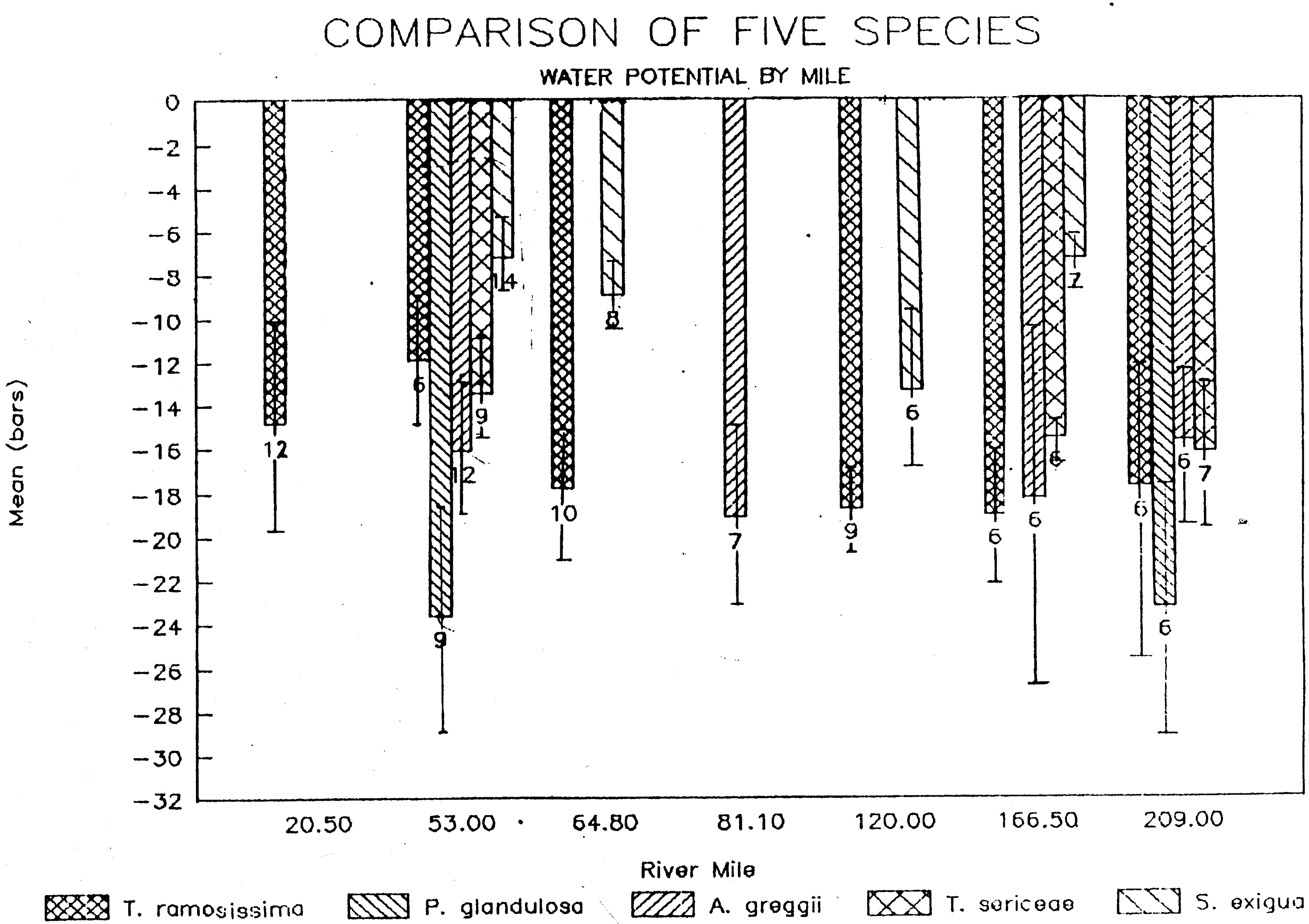


Figure VI-4. Mean water potential of five riparian plant species showing variance between beach sites located throughout the Grand Canyon.

Appendix

Figure A-1. Acacia greggi

Figure A-2. Tamarix ramosissima

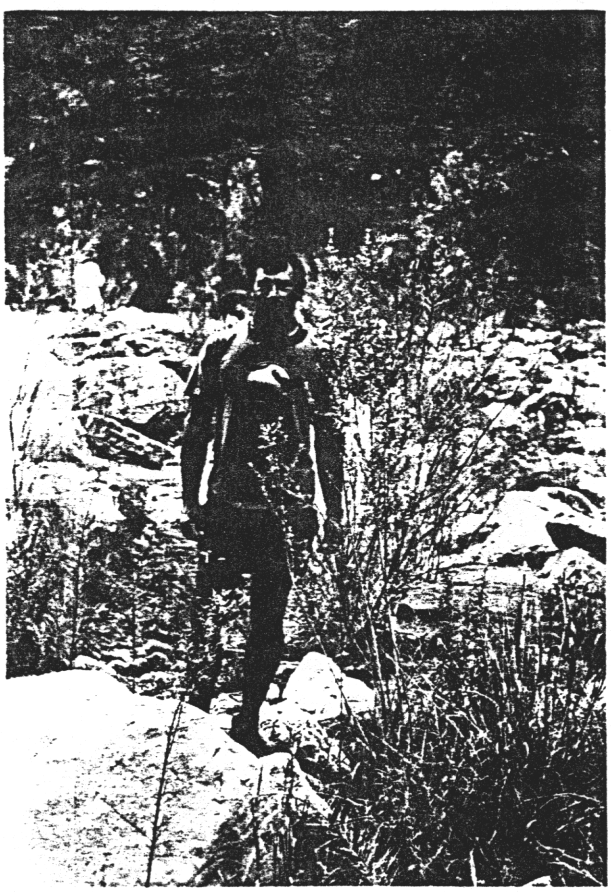
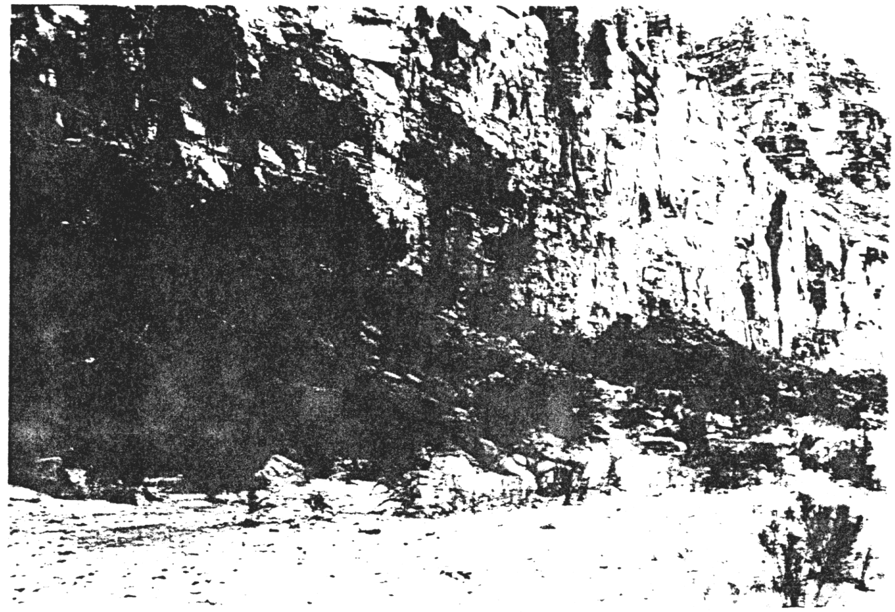


Figure A-3. Tessaria sericeae

Old High Water Zone



New High Water Zone

Figure A-4. National Canyon (RM 166.5) showing the old high water zone and alluvial deposits in the new high water zone.

MATERIALS

10 single edge razor blades
1 air thermometer
1 small barometer
3 metric tape measures
3 head lamps
3 hand lenses
2 large flashlights and 1 extra battery
12 "AA" batteries
3 clipboards (non-coated)
2 bulbs for head lamps and flashlights
2 Scholander cylinders, 70 Bars
2 small nitrogen gas cylinder
1 industrial size nitrogen and w/regulator and hose
connections to transfer gas into small nitrogen tanks
full at 2200 lbs., need permit and truck to transfer
1 crescent wrench
teflon pipe tape
petroleum jelly
chamois (for cleaning)
duct tape
vinyl tarp
canvas tarp
1 pack of gal. ziplock
2 doz. Q-tips
1 small flat screwdriver
1 plier
20 data sheets
3 pencils
1 sharpener
1 box of Kleenex

DATA SHEET

Site________________ R.M._________ Time________________

Date______________________________ Temperature________

Collectors Ed, Lois______________ Bar. Pressure______

Experimental Objective:______________________________

Species Name	Species I.D. #	Individual I.D.	Basal Diam (cm)	Disturbance Zone	Water Pot.(bars)	Comments

CHAPTER 7

RIPARIAN PLANT COMMUNITY STRUCTURE IN THE GRAND CANYON

Roger Smith, David Bennett, and Lawrence E. Stevens

ABSTRACT

This study involved examination of the plant community structure along the riparian corridor of the Colorado River through Grand Canyon. Sites along the river were sampled in four zones parallel to the water's edge. Species richness, basal diameter coverage, and substrate type were examined for each zone. The results suggest that moisture gradient, dam-controlled water flow levels, flooding disturbance, and associated substrate changes are factors which affect the plant community structure and on-going succession.

INTRODUCTION

Although riparian habitat in Arizona comprises only 0.04% of the landscape, riparian habitat supports more than 50% of the state's plant and animal species. In addition to supporting significant species richness, riparian habitats are favored for recreation. Despite their biological and recreational worth, approximately 90% of the riparian habitat in the Southwest has been eliminated by grazing, development and mismanagement. Construction of Glen Canyon Dam above the Grand Canyon accidentally created the largest continuous riparian habitat in the Southwest. The structure of that plant community was the subject of study.

Several authors studied the river corridor flora intensively. Carothers et al. (1979) identified four zones along the river. Zone I was the area farthest from the river, characterized by desert vegetation. Zone II was the Old High Water Zone, representing the highest level of flooding prior to the construction of Glen Canyon Dam. Zone III was poorly vegetated and "back beach" area lying just below the Old High Water Line II. Zone IV was the New High Water Zone, which is established by the current high water level as determined by the controlled flows released from Glen Canyon Dam.

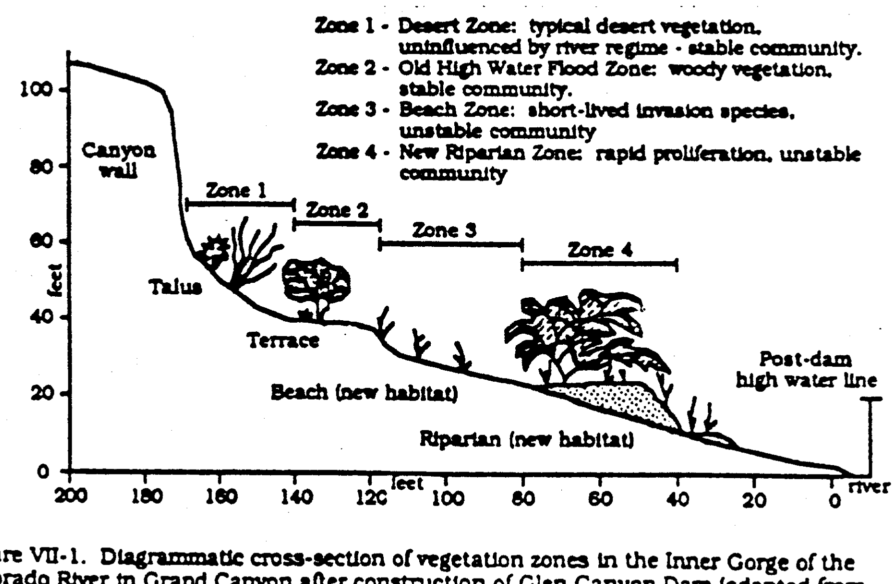


Figure VII-1. Diagrammatic cross-section of vegetation zones in the Inner Gorge of the Colorado River in Grand Canyon after construction of Glen Canyon Dam (adapted from Carothers, et. al., 1979).

In a subsequent study, Stevens (1989) used small plot sizes (2m x 3m) to census vegetation throughout the river corridor. He found that plant species richness was significantly lower in Zone IV than in Zones III, II and, to a lesser extent, Zone I.

This study attempted to characterize plant communities found along the Colorado River corridor in Grand Canyon using a larger quadrat size (10m x 50m). This study was conducted to relate plant community structure to variables of disturbance, moisture gradient and substrate texture. It furthermore provided data on substrate texture, ground cover and shrub cover for concurrent lizard and mammal studies. This research is an effort to improve our understanding, and perhaps aid National Park Service management, of this fluvial ecosystem.

METHODS

The system of data collection deemed most appropriate for this study was sampling 10m x 50m quadrats in zones I, II, and IV along the river, with limited sampling of Zone III. Quadrats lay parallel to the river in each of the major zones present at each area studied. Randomness of quadrats was established by pacing steps equal to readout on a digital watch which was stopped upon random command. Number of individuals and basal diameters of each stem for each plant species were measured and recorded within quadrats. The substrate was then characterized by the method used by Stevens (1989). Mean basal area for each species for each zone site was calculated. The percent total vegetation cover of the zone as well as percent coverage comprised by each species was calculated from basal diameter information.

RESULTS

We encountered a wide variety of phreatophytic and xerophytic species on the plots examined (Table VII-1, Table VII-2).

Table VII - 1: Plant species encountered on plots in the Colorado River corridor, Grand Canyon National Park.

NUMBER	SPECIES
1	Tamarix ramosissima
2	Prosopis glandulosa
3	Acacia greggii
4	Tessaria sericea
5	Salix exigua
6	New High Water Zone
7	Phragmites australis
8	Baccharis salicifolia
9	Baccharis emoryi
10	Baccharis sarothroides
11	Baccharis brachyphylla
12	Brickellia longifolia
13	Populus fremontii
14	Celtis reticulata
15	Aster spinosus
16	Artemesia ludoviciana
17	Opuntia basilaris
18	Gutierezzia sarothrae
19	Ephedra nevadensis
20	Stephanomeria pauciflora
21	Dyssodia pentachaeta
22	Euphorbia sp.
23	Brickellia atractyloides
24	Atriplex canescens. male
25	Gutierezzia microcephala
26	Lepidium fremontii
27	Eriogonum inflatum
28	Galium stellatum
29	Tiquilia latior
30	Machaeranthera sp.
31	Eriogonum sp.
32	Stanleya pinnata
33	Encelia farinosa
34	Sphaeralcea sp.
35	Haplopappus acredinius

36	Nicotiana trigonophylla
37	Echinocactus polycephalus
38	Atriplex canescens female
39	Unknown Asteraceae No. 1
40	Datura meteloides
41	Equisetum sp.
42	Chaenactis sp.
43	Porophyllum gracile
44	Apocynum sp.
45	Echinocereus sp.
46	Opuntia phaecantha
47	Thamnausma montana
48	Mammillaria tetrancistra
49	Cassia sp.
50	Unknown Asteraceae No. 2
51	Unknown Climbing Dicot
52	Opuntia chlorotica
53	Sarcostemma cynanchoides
54	Condalya sp.
55	Xylorhiza tortifolia
56	Hedeoma sp.
58	Nolina microcarpa
59	Unknown Fern No. 1
60	Lycium andersonii
61	Ferocactus acanthodes
62	Pleurocoronis pluriseta
63	Unknown Brickellia No. 1
65	Agave utahensis
66	Primula sp.
68	Dichoria sp.
69	Unknown Cruciferae No.
70	Unknown Dicot. No. 2
71	Unknown Boraginaceae No. 1
72	Erigeron sp. No. 1
74	Unknown Dicot. No. 3
75	Eriogonum sp. No. 2
76	Sarcobatus vermiculatus
77	Allionia incarnata
78	Larrea tridentata
79	Opuntia acanthaster
80	Phoradendron californicum
81	Yucca baccata
82	Opuntia erinaceae
83	Psorothamnus sp.
94	Alhagi camelorum

Table VII-2: Field data collected on quadrats in this study.

CASE	MILE	ZONE	SPECIES	TOTDEN	TOTBA
1	20.400	4.000	15.000	20.000	78634.488
2	20.400	4.000	16.000	16.000	140.496
3	20.400	4.000	1.000	95.000	2106.015
4	20.400	4.000	9.000	36.000	306.343
5	20.400	4.000	12.000	4.000	56.745
6	20.400	4.000	25.000	10.000	166.842
7	20.400	4.000	17.000	2.000	76.969
8	20.400	4.000	19.000	1.000	3.142
9	20.400	4.000	20.000	1.000	314.160
10	53.000	4.000	11.000	5.000	6.434
11	53.000	4.000	5.000	4.000	26.421
12	53.000	4.000	4.000	26.000	22.841
13	64.500	4.000	1.000	134.000	324.227
14	64.500	4.000	4.000	88.000	33.866
15	64.500	4.000	12.000	8.000	207.738
16	64.500	4.000	34.000	22.000	2.458
17	64.500	4.000	35.000	16.000	182.655
18	64.500	4.000	15.000	11.000	53.996
19	64.500	4.000	36.000	1.000	0.785
20	64.500	4.000	5.000	27.000	36.865
21	64.500	4.000	39.000	4.000	4.909
22	64.500	4.000	21.000	10.000	7.698
23	64.500	4.000	30.000	1.000	0.196
24	64.500	4.000	9.000	1.000	28.274
25	64.500	4.000	18.000	11.000	100.401
26	64.500	4.000	40.000	3.000	4.618
27	64.500	4.000	20.000	9.000	75.940
28	64.500	4.000	16.000	14.000	549.832
29	64.500	4.000	41.000	1.000	0.071
30	64.500	4.000	42.000	1.000	12.566
31	64.500	4.000	44.000	32.000	5.089
32	64.500	4.000	43.000	1.000	3.142
33	120.000	4.000	18.000	33.000	111.992
34	120.000	4.000	40.000	3.000	18.473
35	120.000	4.000	43.000	11.000	4.455
36	120.000	4.000	35.000	16.000	48.705
37	120.000	4.000	16.000	17.000	196.388
38	120.000	4.000	5.000	8.000	7.952
39	120.000	4.000	21.000	35.000	242.706
40	120.000	4.000	1.000	15.000	692.449
41	120.000	4.000	15.000	13.000	69.021
42	120.000	4.000	8.000	1.000	12.566
43	120.000	4.000	94.000	563.000	110.545
44	120.000	4.000	12.000	5.000	56.706
45	120.000	4.000	20.000	5.000	90.478
46	137.000	4.000	1.000	79.000	3140.028
47	137.000	4.000	9.000	3.000	18.035
48	137.000	4.000	8.000	3.000	26.179
49	137.000	4.000	12.000	10.000	2.124
50	137.000	4.000	35.000	1.000	3.142
51	137.000	4.000	32.000	1.000	19.635
52	137.000	4.000	16.000	3.000	12.828
53	137.000	4.000	18.000	2.000	7.952

54	137.000	4.000	3.000	4.000	1.227
55	137.000	4.000	20.000	2.000	1.272
56	137.000	4.000	41.000	2.000	2.655
57	166.000	4.000	12.000	6.000	4.253
58	166.000	4.000	63.000	16.000	1174.244
59	166.000	4.000	18.000	6.000	60.507
60	166.000	4.000	9.000	1.000	12.566
61	166.000	4.000	16.000	2.000	25.133
62	166.000	4.000	56.000	6.000	10.603
63	166.000	4.000	48.000	1.000	113.098
64	166.000	4.000	3.000	21.000	17.288
65	166.000	4.000	32.000	1.000	0.785
66	166.000	4.000	43.000	23.000	24.161
67	166.000	4.000	41.000	500.000	98.175
68	166.000	4.000	10.000	68.000	2196.592
69	166.000	4.000	33.000	1.000	0.785
70	166.000	4.000	1.000	56.000	3244.773
71	166.000	4.000	28.000	1.000	0.785
72	166.000	4.000	15.000	13.000	90069.585
73	166.000	4.000	35.000	2.000	56.549
74	166.000	4.000	53.000	9.000	1.467
75	166.000	4.000	54.000	2.000	39.270
76	166.000	3.000	53.000	1.000	3.142
77	166.000	3.000	66.000	26.000	25.437
78	166.000	3.000	16.000	7.000	291.831
79	166.000	3.000	12.000	16.000	1024.948
80	166.000	3.000	36.000	1.000	0.785
81	166.000	3.000	42.000	4.000	25.072
82	166.000	3.000	18.000	7.000	42.664
83	166.000	3.000	68.000	2.000	1.571
84	166.000	3.000	8.000	3.000	58.905
85	166.000	3.000	69.000	2.000	402.125
86	166.000	3.000	65.000	1.000	0.785
87	166.000	3.000	10.000	115.000	217.444
88	166.000	3.000	70.000	1.000	1.767
89	166.000	3.000	71.000	4.000	330.064
90	166.000	3.000	72.000	2.000	56.549
91	166.000	3.000	21.000	3.000	190.852
92	166.000	3.000	56.000	2.000	3.534
93	166.000	3.000	74.000	1.000	12.566
94	166.000	3.000	3.000	2.000	0.141
95	166.000	3.000	32.000	3.000	4.189
96	166.000	3.000	20.000	1.000	3.142
97	166.000	3.000	34.000	11.000	31.484
98	166.000	3.000	62.000	3.000	12.828
99	166.000	3.000	1.000	167.000	279.776
100	209.000	4.000	4.000	1074.000	539.853
101	209.000	4.000	46.000	1.000	176.715
102	209.000	4.000	1.000	24.000	86.792
103	209.000	4.000	10.000	16.000	1661.906
104	209.000	4.000	76.000	1.000	4.909
105	209.000	4.000	35.000	70.000	409.295
106	209.000	4.000	78.000	3.000	67.020
107	209.000	4.000	94.000	12.000	4596.212
108	209.000	4.000	3.000	5.000	203.576

109	209.000	4.000	7.000	1.000	7.069
110	209.000	4.000	17.000	2.000	3.534
111	209.000	4.000	46.000	1.000	12.566
112	20.400	2.000	19.000	22.000	1727.880
113	20.400	2.000	22.000	77.000	2462.866
114	20.400	2.000	17.000	73.000	7120.134
115	20.400	2.000	30.000	9.000	38.484
116	20.400	2.000	29.000	18.000	341.752
117	20.400	2.000	28.000	19.000	22.247
118	20.400	2.000	21.000	13.000	5.226
119	20.400	2.000	16.000	2.000	19.242
120	20.400	2.000	25.000	11.000	223.910
121	20.400	2.000	27.000	1.000	0.785
122	20.400	2.000	23.000	2.000	56.549
123	20.400	2.000	31.000	1.000	0.196
124	20.400	2.000	12.000	1.000	78.540
125	20.400	2.000	32.000	1.000	19.635
126	53.000	2.000	24.000	51.000	1923.323
127	53.000	2.000	38.000	45.000	1549.915
128	53.000	2.000	2.000	91.000	7987.250
129	53.000	2.000	3.000	1.000	28.274
130	53.000	2.000	26.000	14.000	229.783
131	53.000	2.000	33.000	1.000	176.715
132	64.500	2.000	24.000	27.000	84.823
133	64.500	2.000	38.000	21.000	148.441
134	64.500	2.000	33.000	23.000	158.828
135	64.500	2.000	19.000	6.000	33.511
136	64.500	2.000	37.000	2.000	226.195
137	64.500	2.000	17.000	4.000	4596.357
138	64.500	2.000	2.000	46.000	2426.727
139	109.000	2.000	35.000	1.000	3.142
140	109.000	2.000	39.000	8.000	952.518
141	109.000	2.000	3.000	22.000	694.729
142	109.000	2.000	28.000	1.000	3.142
143	109.000	2.000	18.000	1.000	0.785
144	109.000	2.000	45.000	5.000	98.175
145	109.000	2.000	19.000	66.000	3519.055
146	109.000	2.000	33.000	100.000	2529.430
147	109.000	2.000	46.000	6.000	110.085
148	109.000	2.000	52.000	1.000	50.266
149	109.000	2.000	47.000	3.000	84.823
150	109.000	2.000	48.000	10.000	273.398
151	109.000	2.000	49.000	4.000	12.883
152	109.000	2.000	50.000	2.000	19.242
153	109.000	2.000	51.000	1.000	12.566
154	120.000	2.000	33.000	61.000	2782.780
155	120.000	2.000	3.000	23.000	1167.437
156	120.000	2.000	43.000	26.000	16.680
157	120.000	2.000	18.000	91.000	300.828
158	120.000	2.000	46.000	1.000	7.069
159	120.000	2.000	35.000	20.000	501.439
160	120.000	2.000	20.000	1.000	0.785
161	120.000	2.000	53.000	6.000	7.363
162	120.000	2.000	46.000	1.000	38.485
163	120.000	2.000	54.000	2.000	6.283

164	120.000	2.000	21.000	3.000	4.403
165	120.000	2.000	19.000	4.000	188.692
166	120.000	2.000	28.000	2.000	4.811
167	137.000	2.000	11.000	96.000	2745.465
168	137.000	2.000	18.000	81.000	93.312
169	137.000	2.000	58.000	12.000	622.184
170	137.000	2.000	12.000	9.000	226.983
171	137.000	2.000	32.000	7.000	10.557
172	137.000	2.000	55.000	5.000	24.544
173	137.000	2.000	35.000	1.000	3.142
174	137.000	2.000	3.000	5.000	5.468
175	137.000	2.000	19.000	3.000	67.020
176	137.000	2.000	43.000	1.000	0.283
177	166.500	2.000	60.000	52.000	861.301
178	166.500	2.000	3.000	36.000	1888.302
179	166.500	2.000	48.000	4.000	56.745
180	166.500	2.000	19.000	22.000	315.441
181	166.500	2.000	59.000	2.000	35.441
182	166.500	2.000	55.000	144.000	540.843
183	166.500	2.000	33.000	11.000	138.230
184	166.500	2.000	65.000	5.000	377.149
185	166.500	2.000	61.000	20.000	3701.158
186	166.500	2.000	10.000	3.000	75.661
187	166.500	2.000	54.000	2.000	66.366
188	166.500	2.000	18.000	8.000	5.821
189	166.500	2.000	53.000	2.000	0.664
190	166.500	2.000	62.000	27.000	443.676
191	166.500	2.000	45.000	3.000	2412.749
192	166.500	2.000	30.000	6.000	2.421
193	166.500	2.000	34.000	3.000	3.207
194	166.500	2.000	63.000	11.000	101.482
195	166.500	2.000	75.000	3.000	205.250
196	209.000	2.000	76.000	8.000	88.358
197	209.000	2.000	2.000	27.000	6898.954
198	209.000	2.000	3.000	17.000	621.662
199	209.000	2.000	77.000	1.000	0.785
200	209.000	2.000	78.000	1.000	490.875
201	209.000	2.000	79.000	1.000	78.540
202	209.000	2.000	80.000	10.000	70.686
203	209.000	2.000	54.000	3.000	16.756
204	53.000	1.000	33.000	143.000	6136.261
205	53.000	1.000	21.000	4.000	1.539
206	53.000	1.000	37.000	10.000	3365.360
207	53.000	1.000	48.000	1.000	7.069
208	53.000	1.000	19.000	74.000	2611.092
209	53.000	1.000	45.000	23.000	1118.727
210	53.000	1.000	28.000	2.000	1.571
211	53.000	1.000	82.000	23.000	1463.200
212	53.000	1.000	60.000	3.000	44.244
213	53.000	1.000	24.000	5.000	98.175
214	53.000	1.000	38.000	5.000	114.511
215	53.000	1.000	81.000	2.000	4751.670
216	53.000	1.000	30.000	2.000	19.242
217	53.000	1.000	18.000	25.000	75.430
218	53.000	1.000	2.000	1.000	28.274

219	209.000	1.000	78.000	12.000	1414.309
220	209.000	1.000	2.000	7.000	2391.645
221	209.000	1.000	83.000	1.000	7.069
222	209.000	1.000	76.000	24.000	98.996
223	209.000	1.000	79.000	9.000	821.095
224	209.000	1.000	77.000	4.000	1.227

FIGURE VII-2

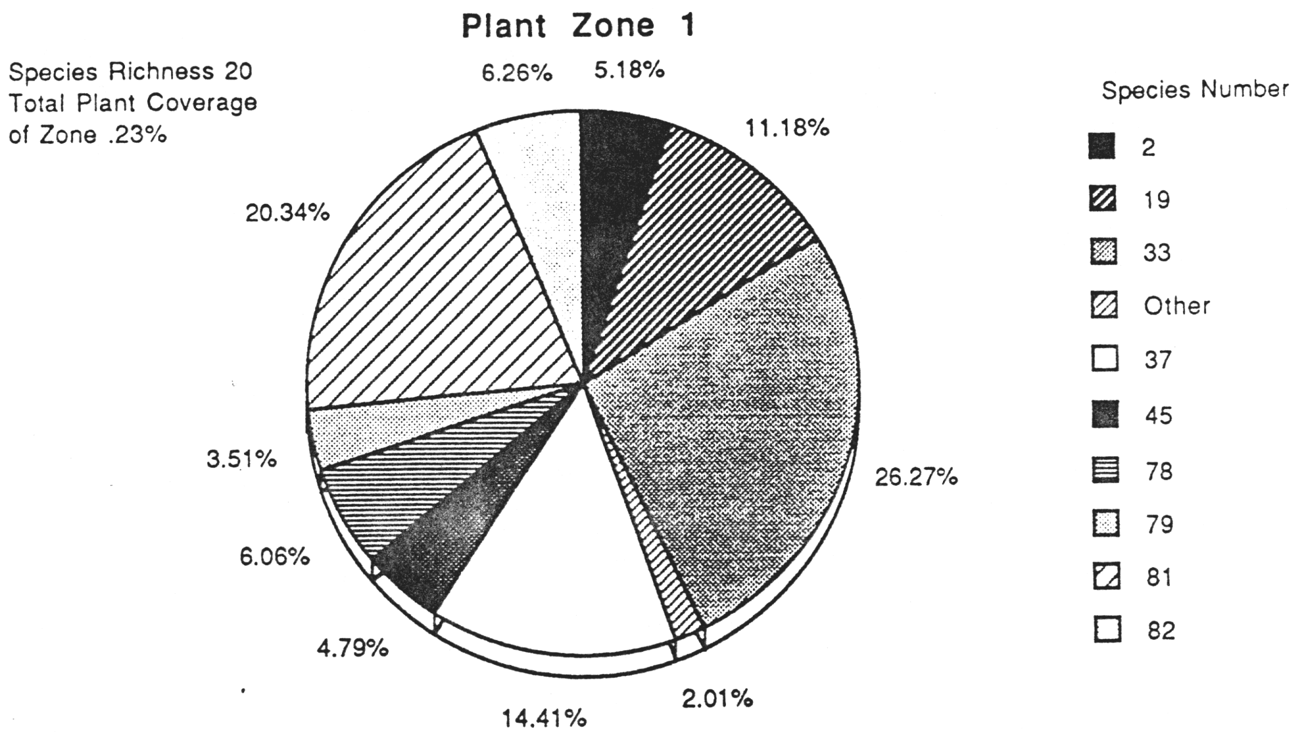


FIGURE VII-3

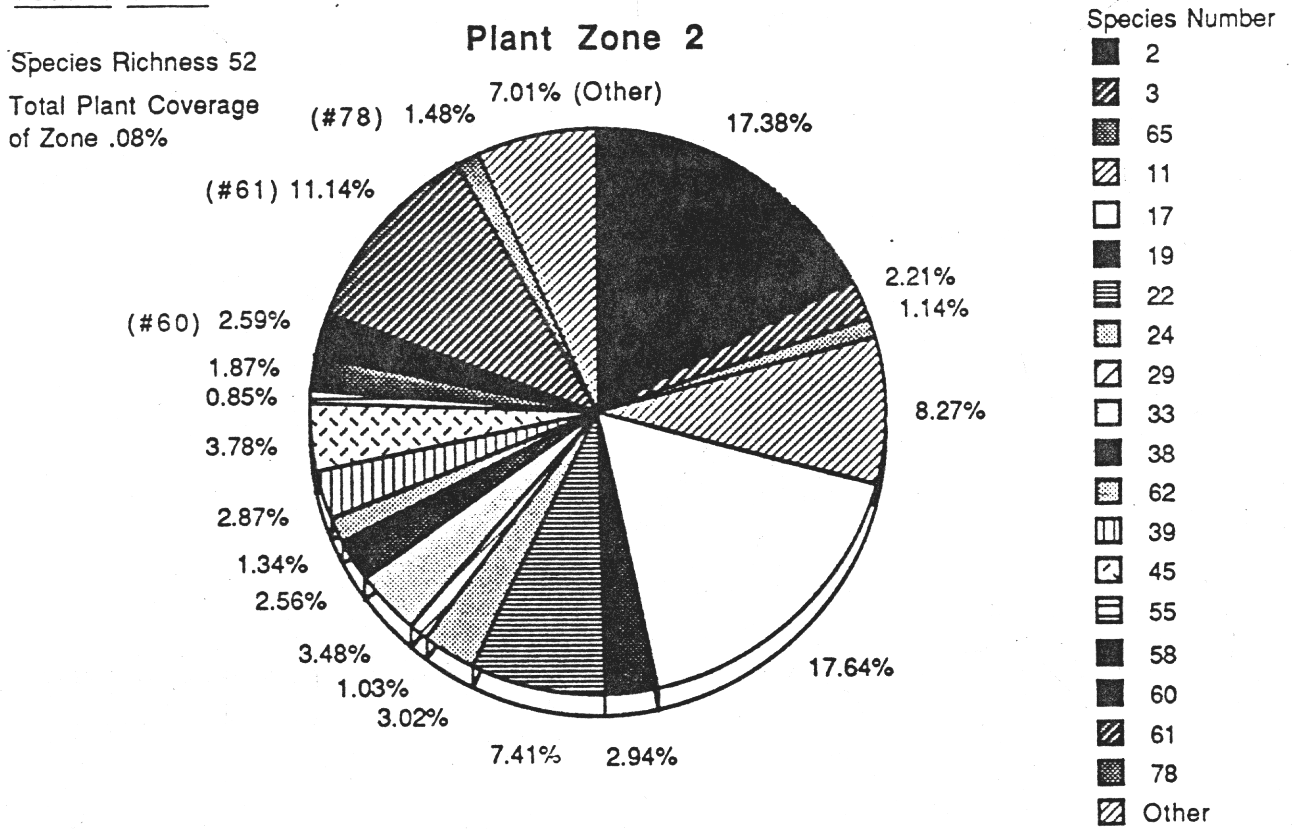


FIGURE VII-4

Species Richness 24
Total Plant Coverage
of Zone .06%

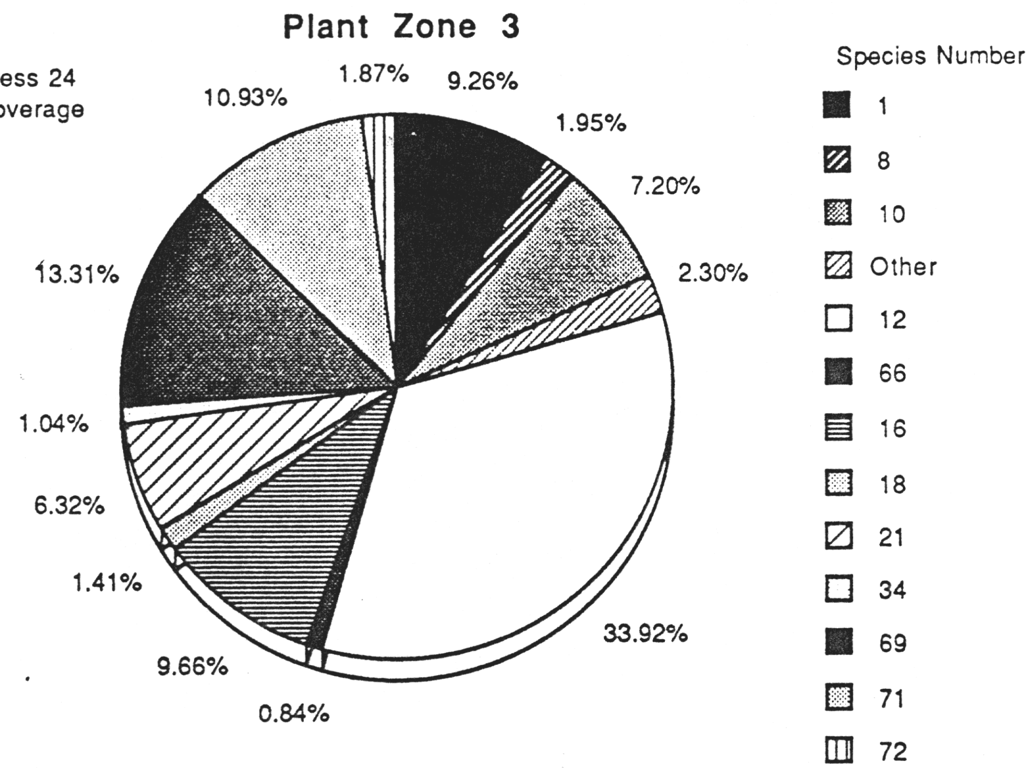
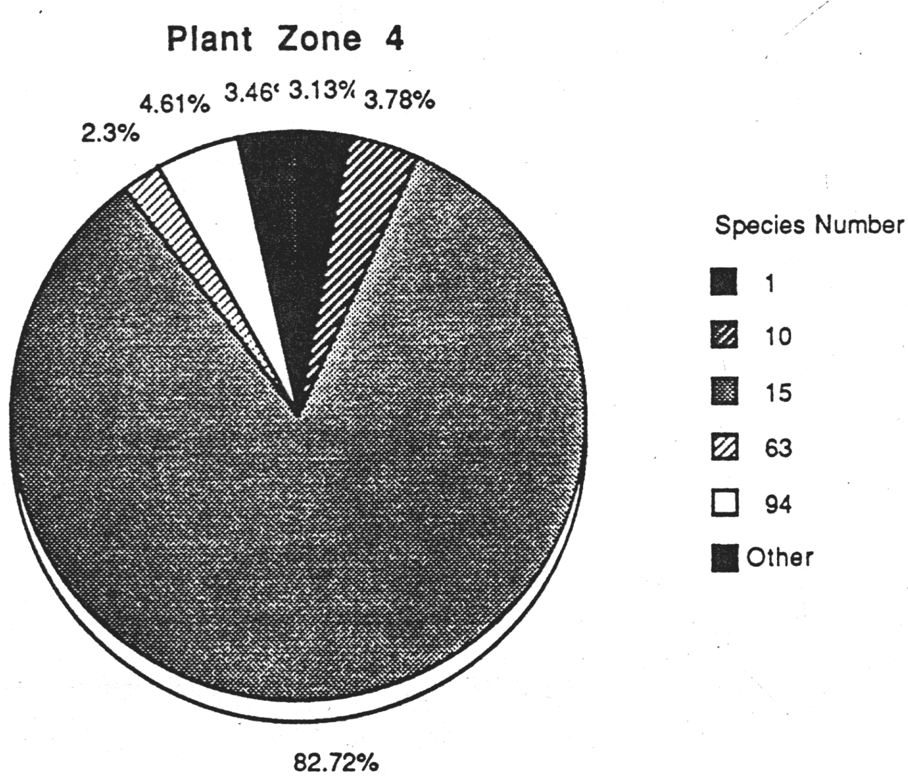


FIGURE VII-5

Species Richness 39
Total Plant Coverage
of Zone .15%



Substrate grain size, standard deviation of substrate grain size, ground cover (duff or grass) and shrub cover (all species) was found to vary between zones (Table VII-3). Substrate grain size varied little, from 3.3 (sandy) in the new high water Zone IV to 4.0 (rocky gravel) in the desert Zone I. Variability of grain size decreased towards the river from the desert, indicating distinctly more silt/sand along the river. The percent ground cover (duff or grass) and shrub cover (all species) increased towards the river from the desert.

Table VII-3: Mean values for substrate grain size, standard deviation of substrate grain size, ground cover (duff or grass) and shrub cover (all species) in four flood zones along the Colorado River in Grand Canyon National Park.

ZONE	MEAN SPECIES RICHNESS (sd)	SUBSTRATE (sd)	PERCENT GROUND COVER	PERCENT SHRUB COVER
I	15.0 (-----)	4.00 (1.026)	23.1	25.6
II	12.1 (5.273)	3.40 (0.864)	58.2	54.7
III	30.0 (-----)	3.37 (1.140)	30.2	25.6
IV	13.0 (6.325)	3.30 (0.649)	60.8	55.2

Characterization of Zones:

Zone I

Results: The sheer canyon walls functionally precluded the desert zone at many beaches. Therefore, only two sample sites were used to represent these results. Zone I was characterized by Encelia and Yucca as the dominant plants. Major contributor species were Echinocactus polycephalus and Ephedra nevadensis (Figure VII-2). The species richness observed was 20, and the total plant coverage, (as determined by basal area), of the zone was .23%. The substrate is characterized by rocky gravel and medium-sized cobble with fairly even distribution (Table VII-3). The general plant coverage of the zone was a pattern of evenly-distributed individuals of the dominant and major contributor species. Some of the cactus species, such as Echinocereus, were found in close association with the canopy of shrubby species like Ephedra and Encelia.

Zone II

Results: The Old High Water Zone was sampled at eight different sites. The data indicated that Opuntia basilaris and Prosopis glandulosa were the dominant species of the zone in terms of basal area coverage. The major contributor plants were Ferocactus, Baccharis brachyphylla and Euphorbia (Figure VII-3). There were a large number of minor contributing species as evidenced by the recorded species richness of 52 for the zone. The total plant coverage of the zone was .08%. The substrate in Zone II was sandy with gravel and some cobble (Table VIII-3). The pattern of plant coverage was variable, with large patches or belts of Prosopis in dense clumps. In the areas between the canopy of Prosopis, shrubs such as Atriplex, Euphorbia, and Baccharis were fairly evenly distributed. Smaller ground cover species and cactus were often found in association with the margins of larger plant canopies.

Zone III
Results: The following results were based on one sample in the alluvial zone. Dominant plants in Zone III were Brickellia, Boraginaceae and Cruciferae, with Brickellia being by far the most abundant of these three. Contributor species of note were Baccharis sarothroides, Tamarix, and Artemesia. Densities of other species were low. Species richness for Zone III was 24, with a total plant coverage of .06%. Species tended to be grouped regionally with uniform stem size within groupings. Overall distribution of species was fairly uniform. The substrate in Zone III was highly variable with pockets of sand and gravel plus cobbles of varying size (Table VI-3).

Zone IV
Results: Researchers sampled even quadrats in Zone IV, the New High Water Zone. This one was characterized by overwhelming dominance of one species, Aster spinosus. Contributor species were Baccharis, Tamarix, Alhagi and unknown Brickellia No. 1. There were 34 other species comprising only 3.46% of the total. The Aster tended to be somewhat clumped and favored sandy, low-lying areas as a habitat. Overall distribution of all species, however, appeared to be somewhat uniform. Species richness of the zone was 39, with a total plant coverage of .15%. The substrate in Zone IV was almost exclusively composed of sand (Table VII-3).

DISCUSSION

This study attempted to relate the observed plant community structure to the variables of moisture availability, disturbance, and nature of the substrate. The pattern of mean species richness was noted to decrease going from desert to Old High Water Zone, (OHWZ), and then increased dramatically in the Alluvial Zone (see Table VII-3). The desert zone experiences the least flooding disturbance, and may have reached a more stable community structure where most niches have been filled. In contrast, the OHWZ has experienced occasional disturbance such as the flood of 1983, which displaced established species. The alluvial zone had a more intermittent exposure to flooding disturbance, which created a complex of factors affecting species richness. One factor is that such disturbance removes vegetation which creates open habitat areas for other species to colonize. Additionally, the variability of substrate carried across the alluvial fan created a wide range of niches, allowing for establishment of widely varied species. These results suggest prediction that the largest number of species should be found where ecological disturbance is intermediate in intensity; however, data on competitive exclusion in the zone are lacking (Stevens, 1989). Further confirmation of this trend is the dramatic decrease in the species richness in the New High Water Zone, (NHWZ). Frequent flooding disturbance of the NHWZ precludes establishment of many species, but encourages colonization by opportunistic plants, especially those with clonal growth forms. This contributes to high stem numbers, but low species representation.

Moisture availability would be expected to decrease as one moves away from the river. The trend in percent ground shrub cover largely follows the same pattern. This is due, in part, to the fact that a great deal of the ground cover is composed of herbaceous annual plants, which establish quickly in high moisture environments. Therefore, the annuals grow well in the NHWZ, but not in Zone III which has less ground moisture. This is a possible explanation for the lack of ground cover in this periodically disturbed zone. The ground cover in the OHWZ and desert zones may be less affected by annual plants, since this cover is represented more by the stable plant community in place (Table VII-3).

The mean species richness of Zone III was significantly higher than the other three zones (Table VII-3). In addition to the previously discussed reference predicting this trend in the zone of intermediate disturbance, it is possible that some additional factors operate there. It may be possible that the occasional disturbance flows across the alluvium bring new nutrient-rich sediments from the side canyons. This would be in contrast to the NHWZ where deposition of new sediments has all but ceased since the dam's installation. Further, the fluctuating river flows may remove existing nutrient-rich sediment layers through erosion. On the other edge of the river corridor, the desert and OHWZ may have lost significant amounts of the original soil nutrients through absorption by the longer-standing plant communities there.

The data shows a trend of diminishing total plant coverage of the zone from the desert through the OHWZ and back beach zones (Figs. VII-1 through 2). Since these data use a measure of the basal diameter of the individuals, the large basal-growth forms of the desert zone plants such as Yucca and the cacti register highest. In the OHWZ and the back beach zone, plants had a much smaller basal diameter, and often a larger canopy growth form. This results in a lower basal diameter coverage, but a gross appearance of a more heavily vegetated area. The trend reverses between the NHWZ and the other zones, likely a function of the increased stem numbers of the clonal species such as Aster, Equisetum, and Tessaria.

It is significant to note that of the 9000 square meters sampled in this study, not a single first season Tamarix seedling was recorded. Tamarix seed germination is dependent upon the availability of moist, silty substrate, and they have short-lived seeds (Stevens, 1989). The current regime of controlled flow releases do not favor these conditions. It appears that native clonal species such as Aster and Salix have the ability to invade open habitat areas, translocating between stems the needed resources that may be in short supply. In this respect, such species may in fact be replacing the exotic Tamarix through succession.

The management plan at Grand Canyon National Park must ultimately be based in an understanding of how it affects park resources, such as riparian systems along the Colorado River. The few number of sites censused during this study exhibited high variability within zones, and adequate description of this dynamic system must include repeated censuses of a large number of study plots with equal representation in all zones and some understanding of riparian vegetation in tributaries. Further study is recommended to more accurately characterize these plant communities, as well as to document the successional changes which may occur in the future. The study also has significance to other studies which rely on an understanding of plant communities, such as investigations of invertebrate and vertebrate distributions. Standardization of data recording methods through the use of an efficiently organized data sheet, as well as a larger number of researchers would increase the effectiveness of the study.

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Chapter 8

LEVEL OF RADIOACTIVE URANIUM IN COLORADO RIVER SEDIMENTS

Bryan Bates, Stephen Martin, Michael Stock

Introduction

At present, very little geochemical data has been obtained on the background level of radioactive uranium in the Colorado River system in Grand Canyon National Park (Taylor, C.O., Vasquez, K., and J. Shannon, 1989). The obtained data could provide a useful baseline data set which future sampling of sediments can be compared to and to determine the impact of development on the marginal areas of the Grand Canyon and Colorado River corridor.

In Grand Canyon National Park, sedimentary rocks may have higher-than-normal levels of radioactive uranium since uraniferous breccia pipes are common in this region of Arizona. The level of radioactive uranium tends to increase as the percentage of silica increases in the rock, and tends to be higher in low temperature igneous rocks. The breccia pipes supply a natural uranium source for the Colorado River sediments. An alternative source of uranium could be man-made through surface spill, mining activity, or other surface disruptive activity of the natural uranium ores.

The hypothesis is that the levels of radioactive uranium in the Colorado River sediments are within a normal range as expected for sediments sourced from locally uraniferous sedimentary rocks and low temperature igneous rocks.

Objective

1. Run a follow-up reconnaissance sediment geochemical survey (previous survey 1989), and resample old beach sites near stream tributaries in the Grand Canyon-Colorado River system;
2. Analyze river sediment samples, and measure the concentration of radioactive uranium and thorium using gamma ray spectrometric techniques; and
3. Determine the background levels of radioactive uranium and thorium in sediments to be used in future geochemical studies.

Method

A. Sediment Geochemical Survey

The sample area included the Colorado River corridor in Grand Canyon National park on a 225 mile route between Lees Ferry and Diamond Creek. Samples of river sediment (consisting predominantly of clay and silt) were taken near the water/sand interface at selected beach sites. One kilogram mass samples of sediments were collected in whirlpak bags using a garden trowel, and labeled by location with a permanent marker. Color photographs of the sample sites done in the 1989 survey were used in order to resample the same locations in addition to new locations.

B. Sample Preparation

The samples were oven-dried at approximately 60 degrees Celsius for 24 hours at the NAU geology rock laboratory. One hundred grams of each sample were separated. The samples were mechanically sieved for phi size using an automatic shaking apparatus. Then the percentages of sand, silt, and clay were determined for each of the samples. The remaining fraction of each sample was stored for one month in sealed plastic containers allowing parent and daughter products in the radioactive series of uranium and thorium to be equilibrated.

C. Gamma Ray Spectrometric Analysis

The samples were analyzed for radioactive uranium and thorium using in-house passive gamma ray techniques at the NAU laboratories. Natural radioactive gamma ray spectra were measured for each sample using a shielded activated NaI crystal, photomultiplier tube and pulse analyzer. The spectra were then compared with the spectra from reference samples of known concentrations of uranium and thorium. The concentrations of uranium and thorium in the samples were computed from the relative sizes of their energy peaks relative to the reference samples.

The results are reported in ppm for uranium and thorium. The elemental analyses were evaluated both in terms of absolute abundance and concentration ratio of uranium and thorium. Results are summarized in Tables 1 and 2. and Figure 8-1.

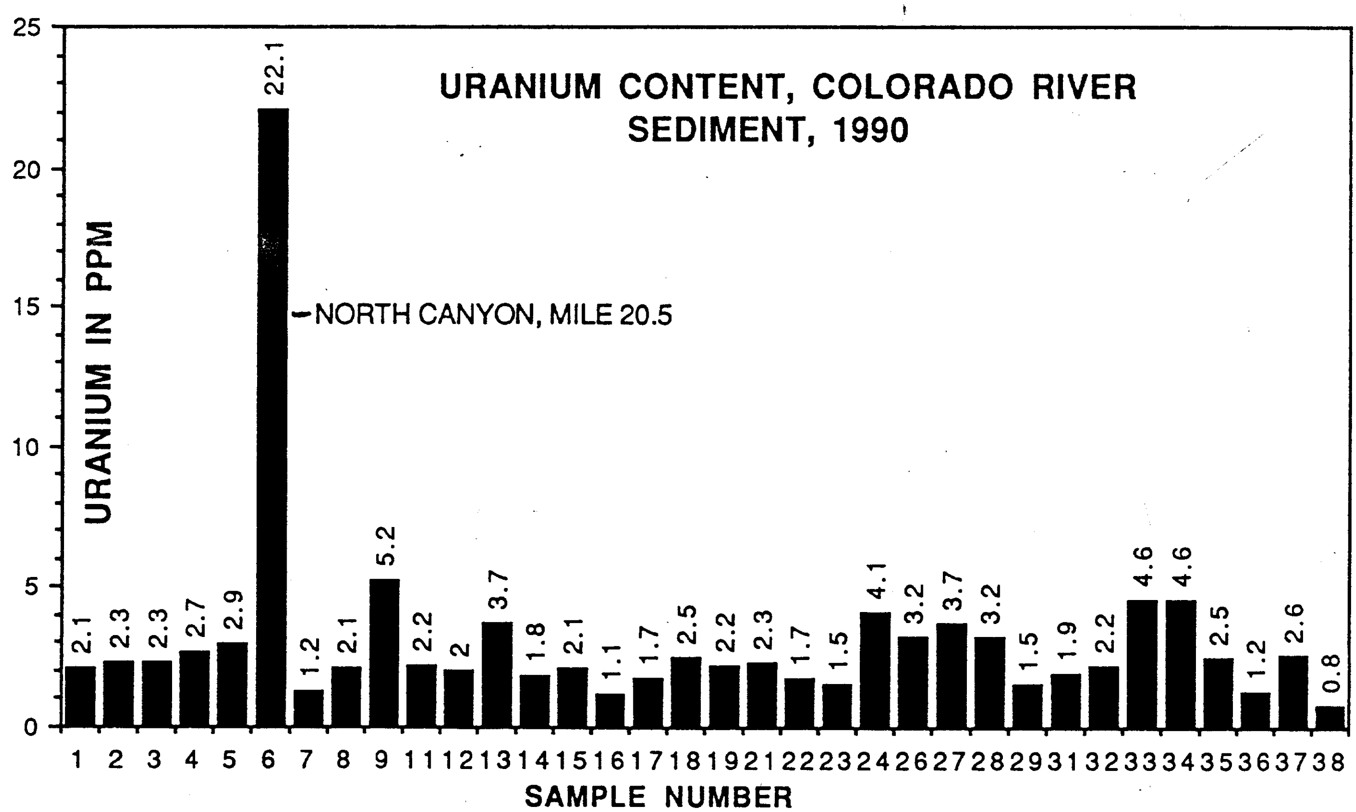

Figure 8-1: Graph of Uranium content.

Table 1. Radioactivity Data From 1990 Colorado River Sample Study

Sample Number	U ppm	Th ppm	K %	Locality
90-CR-01	2.1	4.2	1.2	Above Lees Ferry
90-Cr-02	2.3	4.9	1.5	Below Lees Ferry
90-CR-03	2.3	3.8	1.6	Kanab Creek
90-CR-04	2.7	8.4	1.1	Mile 122
90-CR-05	2.9	8.3	1.9	Shinumo Canyon
90-CR-06	22.1	92.7	0.7	North Canyon
90-CR-07	1.2	2.4	1.0	Awatubi Canyon
90-CR-08	2.1	5.1	1.6	Mile 122
90-CR-09	5.2	2.9	1.0	Granite Rapid Beach
90-CR-11	2.2	5.2	1.4	Silver Grotto
90-CR-12	2.0	5.2	1.3	Bass Campsite
90-CR-13	3.7	8.9	1.7	Little Colorado River
90-CR-14	1.8	0.0	2.6	Little Colorado River
90-CR-15	2.1	5.0	1.5	Little Colorado River
90-CR-16	1.1	2.5	0.8	Jackass Canyon
90-CR-17	1.7	3.3	1.0	Havasu Creek
90-CR-18	2.5	5.6	1.8	Blacktail Creek
90-CR-19	2.2	5.9	2.2	Mile 194 L in Creek bed
90-CR-21	2.3	5.5	2.4	Mile 194 L beach
90-CR-22	1.7	3.5	1.4	Granite Park Mile 209
90-CR-23	1.5	3.2	0.9	Shinumo Creek mile 108
90-CR-24	4.1	10.5	1.8	Little Colorado River
90-CR-26	3.2	5.4	1.7	Kanab Creek
90-CR-27	3.7	11.1	1.9	Forster Canyon
90-CR-28	3.2	4.2	1.8	National Canyon
90-CR-29	1.5	2.4	1.3	Middle National Canyon
90-CR-31	1.9	4.2	1.7	Colorado River beach
90-CR-32	2.2	5.4	1.9	Colorado River beach
90-CR-33	4.6	10.1	2.2	Colorado River above Kanab
90-CR-34	4.6	9.8	2.1	Middle Kanab
90-CR-35	2.5	4.5	1.9	Lower National Canyon
90-CR-36	1.2	1.7	0.7	Lower National Canyon
90-CR-37	2.6	5.5	1.8	Middle National Canyon
90-CR-38	0.8	1.4	1.0	Middle National Canyon

D. Conclusions

Sediment samples in the 1990 Colorado River Study are all within the typical range of normal sediments with respect to their U, Th and K contents, with the exception of sample number 90-CR-06 from North Canyon. High uranium and thorium contents in this sample indicate significant enrichment in these elements. As both uranium and thorium are high, the source of this enrichment is likely to be a natural magmatic (high temperature) process. Uranium ores are formed by low-temperature hydrothermal processes which typically enrich uranium, but do not enrich thorium. thus, although the cause of the enrichment in this sample warrants further study, there is no indication that contamination from a uranium core has occurred in the canyon, caused by natural or other processes. Other samples show minor enrichment of uranium over thorium (Th/U < ~4) and depletion of potassium (K%/Uppm < ~1), but these ratios are typical of water transported sediments.

Table 2: Samples: Percentage of Clay, Silt, and Sand in the Samples

Location	Mile	Percent Clay/Silt/Sand
Lees Ferry 1	0	2.9/2.3/94.8
Lees Ferry 2	0	5.0/2.6/92.4
Badger	8	3.1/3.4/93.5
Shinumo Wash	29	3.7/3.3/92.9
Silver Grotto	29	30.3/10/57.7
U. Nankoweap	52	1.8/0.3/97.9
L. Nankoweap	53	
Awatubi	58.1	0.8/1.2/98
Little Colorado R. 1	61.1	23.7/15.4/60.9
Little Colorado R. 2	61.1	56.8/12.7/30.5
Little Colorado R. 3	61.1	19.8/6.5/73.7
Granite Park	93.2	51/9.3/39.7
Lower Bass	108.3	8.0/5.5/86.5
Elves Chasm	116.5	56.1/13/56.1
Blacktail	120.1	10.7/21.1/68.2
122 Mile	122.0	13.4/4.9/18.4
Forster	122.8	27.2/4.2/68.6
Middle Kanab #1	143.5	20.5/6.8/72.7
Middle Kanab #2	143.5	80.2/4.0/15.8
Havasu	156.9	14.6/10.8/74.6
Upper National	166.5	11.3/15.2/73.5
Middle National 2	166.5	26.5/17/56.5
Lower National 3	166.5	.9/2.3/96.8
194 Mile #1	194	38.1/13.1/48.8
194 Mile #2	194	60.5/14.8/2

CHAPTER 9

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

Bruce Bridenbecker and Allen Stewart

ABSTRACT

The sedimentary structures observed during this study include: 1) laminar bedding; 2) cross-bedding; 3) undulatory, straight crested, lingoid, and rhomboid ripple marks; 4) climbing ripple marks; 5) megaripples; 6) convolute bedding; 7) flaser bedding; 8) lenticular bedding; 9) microfaulting; and 10) microslumping.

Among these, the first eight are current bedforms and indicate that these sedimentary structures are a result of fluctuating water and sediment input levels.

The final two structures are related to beach failure. Microfaulting and microslumping occur as a result of desolution of sediment caused by fluctuating water levels.

INTRODUCTION

Beach deposits on the Colorado River in the Grand Canyon are undergoing phenomenal changes as a result of water fluctuations associated with Glen Canyon Dam. Examination of the sedimentary structures in the beaches and bars that form along the river corridor provides information on their depositional history. It also provides information on beach failure that has been associated with the water fluctuations.

Sedimentary structures that were observed in the beaches and bars of the Colorado River in the Grand Canyon are formed as a result of flow patterns associated with eddies. Debris fans, that have formed at the mouth of side canyons, serve as a mechanism that constrict the river channel. The point at which the river channel begins to expand is where eddies occur, resulting in the eventual formation of three types of beach/bar deposits (Schmidt and Graf, 1987; figure IX-1).

Laminar bedding, cross-bedding, convolute bedding, ripple marks, climbing ripples, megaripples, flaser bedding, and lenticular bedding were the structures observed in nonfailed beach/bar deposits. These were also observed in failed beaches with the inclusion of microfaults and microslumps. One of the unique features of this study was the identification of the microstructures associated with failed beaches which illuminates another factor in the evolution of beach/bar deposits of the Colorado River in the Grand Canyon.

METHODS

Study Sites:

Beach		Structures
Mile 19.8		Crossbeds, laminar beds, ripple marks, and organic layers
Mile 20	North Canyon	Laminar beds with organic layers
Mile 29	Shinumo	Laminar beds, organic layers, climbing ripples, and crossbeds
Mile 33.5	Nautiloid	Laminar beds
Mile 53	Nankoweap	Convoluted beds, clay layers, organic layer, ripple marks, and laminar beds.
Mile 64	Carbon Canyon	Climbing ripples, megaripples, convoluted beds, crossbeds, laminar beds, organic beds.
Mile 81.1	Grapevine	Convoluted beds, climbing ripples, and fine interbedded clay layers
Mile 113.8		Interbedded clays, crossbeds, laminar beds, convoluted beds, microfaulting, and microslumping.
Mile 120.1	Blacktail	Laminar beds, convoluted beds, and crossbeds.
Mile 122		Massive beds, crossbeds, and fine interbedded clay layers
Mile 124		Numerous clay layers, and cross-beds with both types of beach failure (macro and micro)

Beach	Structures
Mile 166.4 National	Crossbeds, convoluted beds, organic layers, laminar beds, massive beds, and climbing ripples

Equipment:

1. Shovel	5. Machete	9. Ruler
2. Cheesecloth	6. Scissors	10. T-pins
3. Paint Brush	7. Latex Acrylic	11. Acrylic Spray
4. Coffee Can	8. Brunton Compass	

Methodology:

1. Erosional features were examined at sites where trenches were not dug.
2. Trenches were dug at right angles and parallel to each beach.
3. Strike and dip of each study site were recorded.
4. Each study site was photographed in black and white format for research purposes.
5. Sketches were made of structures.
6. At chosen sites, latex peels were made, using the following format:
   a. The sand was sprayed with clear acrylic where the peel was to be made.
   b. Cheesecloth was cut 20 cm longer than the depth of the cut, spread, and anchored with the t-pins.
   c. Another coat of acrylic spray was applied to the cheesecloth.
   d. Several coats of acrylic latex were applied with a brush.
   e. After several hours, when the acrylic was dry enough; the peel was removed and stored.

RESULTS AND DISCUSSION

Data were collected from July 25 through August 4, 1990 on the Colorado River. During this time period 12 beaches were studied which included the digging of eight L-shaped trenches. Three of these trenches were dug so as to investigate the structures associated with failing beaches. Five latex peels were made on two of the trenches at National Beach (Mile 166.4). These trenches, peels, and erosional surfaces resulted in exposure of well defined sedimentary structures.

<u>Sedimentary Structures</u>

The types of sedimentary structures that were observed included: 1) Laminar bedding; 2) Crossbedding; 3) Ripple marks; 4) Climbing ripple marks; 5) Megaripples; 6) Convolute Bedding; 7) Flaser bedding; 8) Lenticular Bedding; 9) Microfaulting; and 10) Microslumping.

Much of the laminar bedding along the Colorado River is similar to the rhythmites described by Reineck and Singh (1975) and is a result of water level fluctuations coupled with differential sedimentary load from major tributaries (figure IX-2). This type of bedding consists of thin interbedded sands and clays. Each of these beds are called lamina. Lamina are relatively uniform in nature, have small aerial extent, and form in short periods of time. Each lamina forms under essentially constant physical conditions with constant delivery of the same material. Groups of lamina stack on top of each other with each one representing some minor fluctuations in rather constant physical conditions (Reineck and Singh, 1975).

Crossbeds as seen on the beaches during this study, are mostly a result of deposition from migrating small-current and wave ripples. They consist of inclined dipping beds, bounded by subhorizontal surfaces and are indicative of traction current deposits (Selley, 1975; figure IX-3).

Ripple marks are produced as a result of the interaction of waves or currents on a sediments surface. Most of the ripple marks seen in planar view were undulatory and are interpreted to be associated with gentle to medium traction currents. Other types of ripples observed in the field included straight crested, lingoid, and rhomboid (figures IX-4, 5, 6, 7). The straight crested ripples are interpreted as low energy forming and occur as a result of receding water levels. Lingoid ripples are discontinuous and broken with forward closures. This type of ripple has formed as a result of stronger currents and is a result of shallow, medium velocity currents. Rhomboid ripples develop under a very thin layer of water and are produced by washovers on the landward side of bars. In the study area these formed during times of receding water and the flow regimes associated with this phenomena (Reineck and Singh, 1975).

Climbing ripples are formed from the migration and simultaneous upward growth of ripples produced by either currents or waves (figure IX-8). Both in-phase and in-drift types were observed indicating a slight but regular, progressive increase in current velocity with a decrease in depth. The environment of deposition is periodic rapid accumulation of sediment (Reineck and Singh, 1975).

Megaripples were observed at Carbon Canyon (Mile 64) on an eddy-center deposit. These form as a result of receding water and a high flow regime. This will be discussed below in more detail.

Convoluted bedding is widespread in the study area and is produced by differential liquefication of a sedimentation unit often resulting from deformation of ripple marks (figure IX-9). The cause of this soft sediment deformation has been linked to the expulsion of water from the sediments and in some instances overloading of the sediments after desolution occurs (Reineck and Singh, 1975).

Flaser and lenticular bedding were also observed in the study area (figures IX-10, 11). For the purpose of this paper they will be lumped together. Both of these form as a result of discontinuous ripple trains and sand lenses. The major difference is that lenticular beds are isolated in both the vertical and horizontal direction whereas flaser beds are usually isolated in only the vertical sense. Formation is a result of ripple trains being differentially eroded and infilled by subsequent deposits (Reineck and Singh, 1975).

Microfaulting and microslumping were observed at Mile 113.8 and are directly related to beach failure (figures IX-12, 13). These will be discussed below in more detail.

Beach Sites

The majority of the beaches where data were collected can be classified as separation deposits. The study area at Carbon Canyon (Mile 64) is an eddy-center deposit, and the beach at Mile 113.8 is associated with beach failure. The following discussion will be limited to three beaches. Carbon Canyon and Mile 113.8 are discussed because they are special cases. National Beach (Mile 166.4) is included because of the extensive trenching and latex peels that were collected there and because it is atypical of separation deposits.

National Beach

The trenches and location of National Beach indicate that this is a typical separation deposit as described by Schmidt and Graf (1987). It forms in the mantle downstream portion of a debris fan and extends into the river channel. This type of beach is thought to originally form in secondary eddies and low velocity portions of the separation zone environment. It almost is never associated with the main recirculating eddy. The bar will begin to develop and migrate shoreward until it attaches to a nearby debris fan. In this case the fan is associated with National Canyon (Schmidt and Graf, 1987).

Figure IX-14 is a photograph of the bedding in a trench with a compass bearing of N55W. The following is a description of the layers from the bottom to the top of the trench. At the bottom of the trench is a thick clay-rich layer. This was deposited by either the retreat of a large scale flooding event, slow retreat of sediment rich waters, or some combination of the two. Above the clay layer is a laminar bedded clay/sand sequence. These were deposited by fluctuating water levels during periods of high sediment input. The next sequence is a massive sand layer caused by a large scale flooding event and deposited in one setting. Upward from the massive sand is another laminar bedded clay/sand sequence. Above this is another massive sand that grades upward into a laminar bedded sequence. On top of the laminar beds is an organic layer made up of small twigs, bits of leafy material, and other similar particles. This is similar to what is seen on the beach today during the occurrence of high water. The next sequence is a series of massive sands with the uppermost layer being a laminar bedded sequence. Strike and dip measurements indicate that the direction of flow at the time of deposition was S10W. This is not much different than the present flow direction of S40W.

<u>Carbon Canyon</u>

Carbon Canyon was examined during a period of low water flow. As a result of this data were gathered on an eddy-center deposit. Schmidt and Graf (1987) describe these as sandy deposits found at the center of most eddies. Sediment is deposited in the center of eddies due to the low flow regime found there.

Figure IX-15 is a photograph of the bedding in a trench with a compass bearing of N80W. The following is a description of the layers from the bottom to the top of the trench. At the bottom of the trench is a series of laminar bedded clays/silts. This was deposited during a time of high sediment load and receding waters. On top of the laminar beds were a series of in-phase grading to in-drift climbing ripples. This is indicative of a slight but regular, progressive increase in current velocity and decreasing depth. Moving upward, a sequence of convolute bedding occurs caused by the removal of water from the sediments resulting in the deformation of ripple marks. The uppermost layer consists of ripple marks.

In planar view the uppermost layer of ripple marks are superimposed upon sets of megaripples (figure IX-16). These have a wavelength of 90 cm and a strike of N90E. They are almost perpendicular to the lingoid ripples which have a strike of N10E. The presence of megaripples is a result of coarser sands carried at higher flow regimes than the superimposed active small ripples (Reineck and Singh, 1975).

In analyzing this sedimentary sequence a strong resemblance to a channel bar deposit was noted. This probably occurs as a result of the drastic change in the flow rates of the Colorado River combined with high seasonal influxes of sediment.

Beach at Mile 113.8

Figure IX-17 is a photograph of a failed beach at Mile 113.8. This beach is unique in that it is on the up-river side of a small, steeply dipping debris fan. It is very similar to the upper pool deposit described by Schmidt and Graf (1987). Massive microfailure is taking place at the beach and was the focal point of a trench dug on a compass bearing of N44E which is perpendicular to the beach front.

Bedding planes were highly contorted as a result of beach failure. Significant features were encountered in spite of the deformation. Figure IX-12 shows microfaulting corresponding with surfacial failure zones and leaving air pockets in the substrata. Figure IX-13 shows a microslump that appears to have glided along a clay layer. Figure IX-18 is an S-shaped structure that appears to have formed as a result of microslumping in overlying beds. These types of features were observed at various places along the trench.

The following interpretation of beach failure for this particular beach is based upon the above mentioned observations. When flow levels are high, water fills the pore space in the beach up to the river level. As water level drops the water drains out of the pore space along the clay layers, which are relatively impermeable. As this happens the sands , which are heavy due to moisture, begin to slide down the now lubricated clay layers. When enough weight is involved, the underlying clay layer will rupture allowing water to flow into a lower sand layer. This sand layer is already gliding down another clay layer which compounds the process. As this process gains momentum the whole beach will eventually slide into the river. It appears that as each of the microfault planes migrate to the river that they become candidates for macrofailure surfaces.

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TABLE IX-1 COMPASS READINGS AT STUDY SITES

Beach		Compass Reading	Type of exposure
19.8		S85E	Erosional Feature
20	North Canyon	N85W	Erosional Feature
29	Shinumo	S40E strike S50W dip	L-trench
33.5	Nautiloid	N30E	Erosional Feature
53	Nankoweap	N60E strike S30E dip	L-trench
64	Carbon Canyon	N10E strike N80W dip	L-trench
81.1	Grapevine	N80W	Erosional Feature
113.8		N44E strike S46E dip	L-trench
120.1	Blacktail	N45W	Erosional Feature
122		N60E strike N25W dip	L-trench
124		N45E strike N35W dip	L-trench
166.4	National	N35E strike N55W dip	L-trench (A)
		N50W strike S40W dip	L-trench (B)

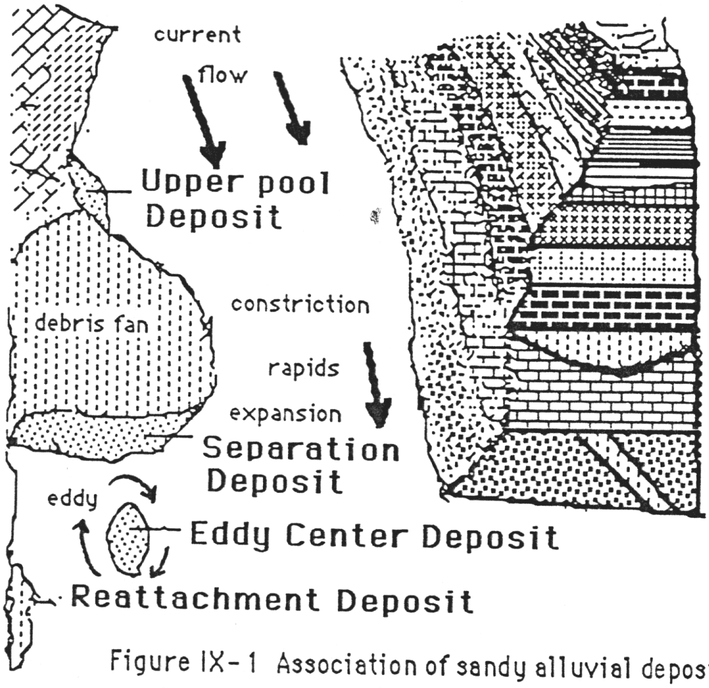


Figure IX-1 Association of sandy alluvial deposits with debris fans and rapids: The debris fans constrict the river to form rapids. Then the river widens, which produces eddies. Sand is deposited in the slower areas of the river. After Schmidt and Graf, 1988.

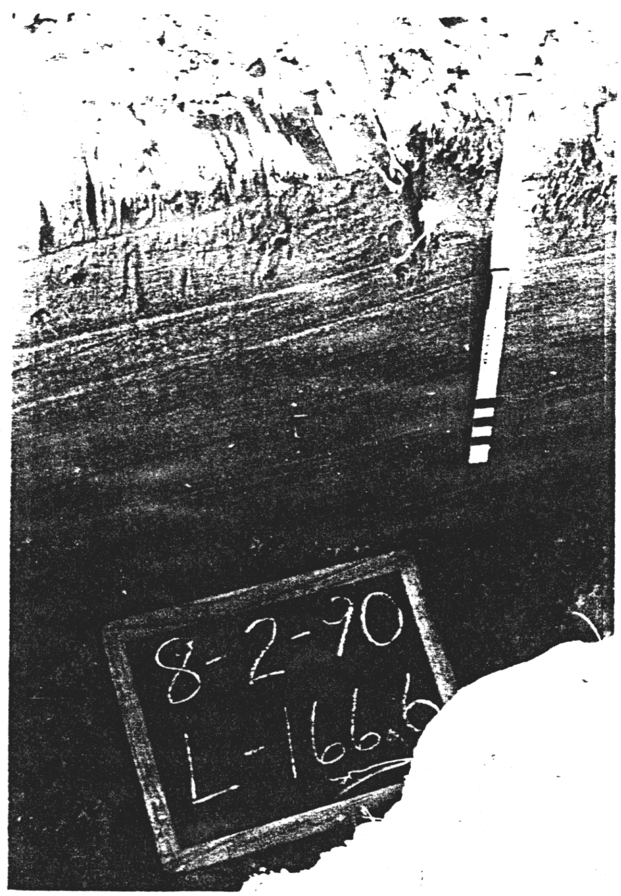


Figure IX-2 Laminar bedding (cm scale)

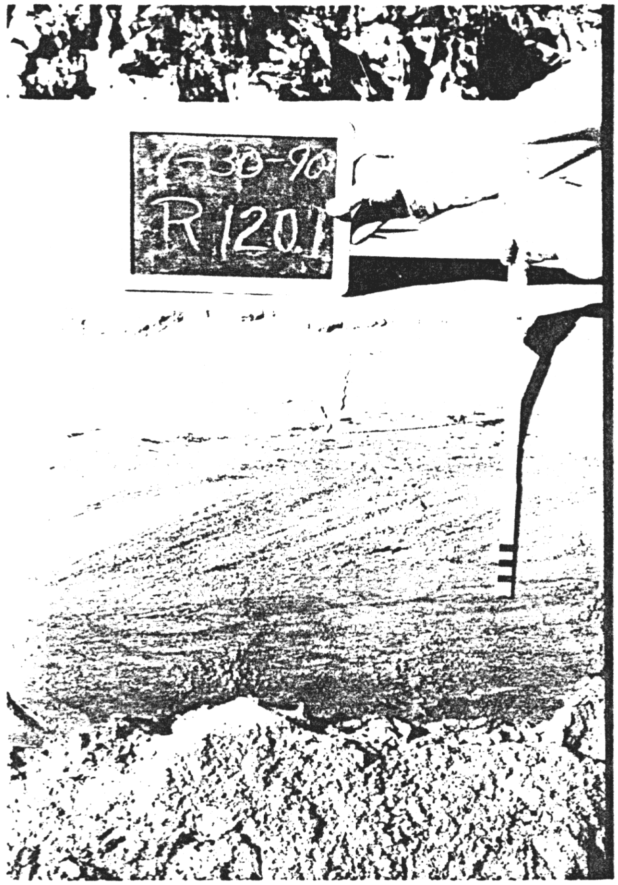


Figure IX-3 Crossbedding (cm scale)

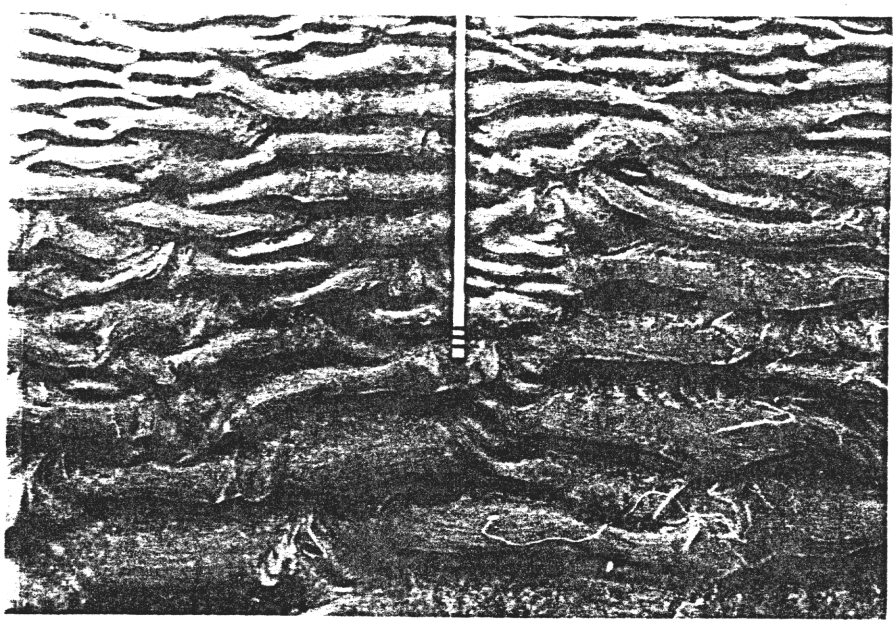


Figure IX-4 Undulatory ripples (cm scale)

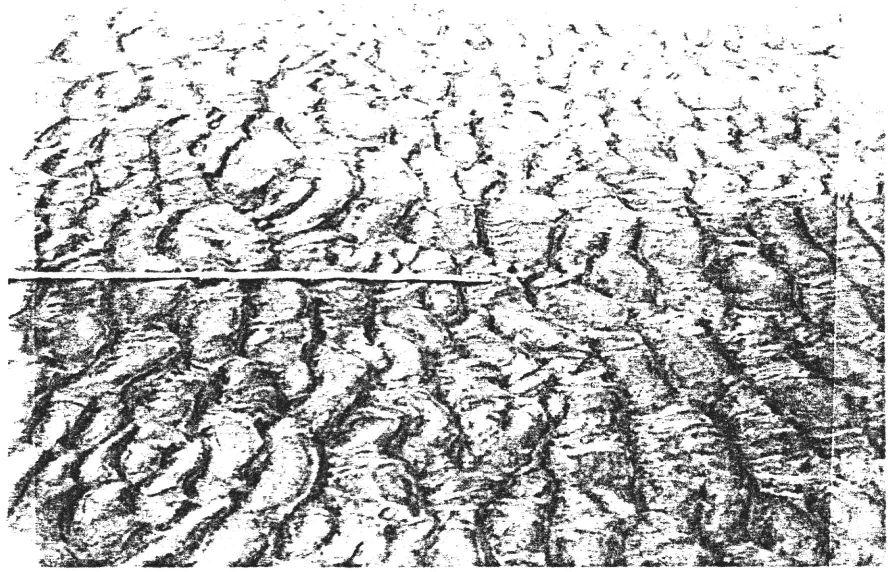
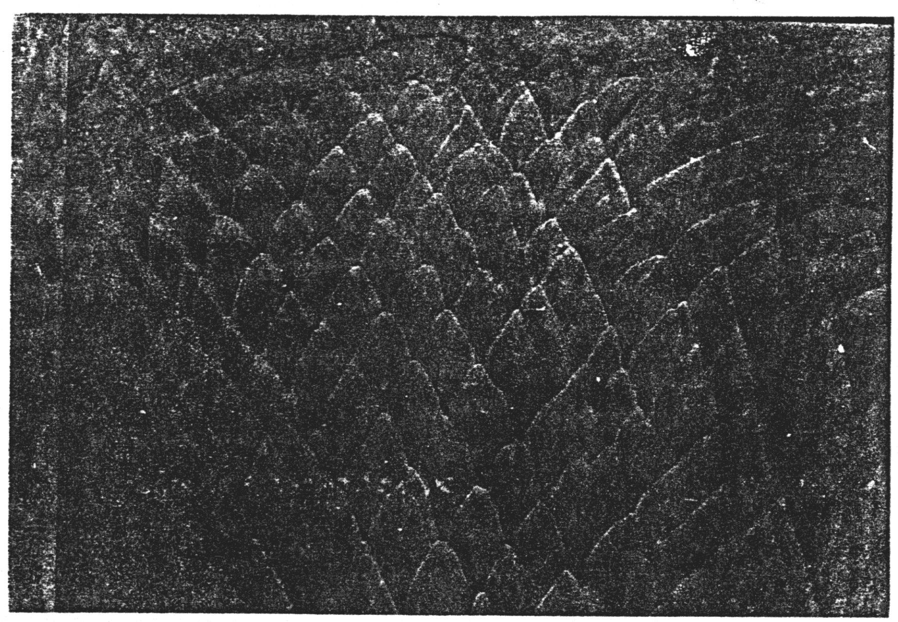
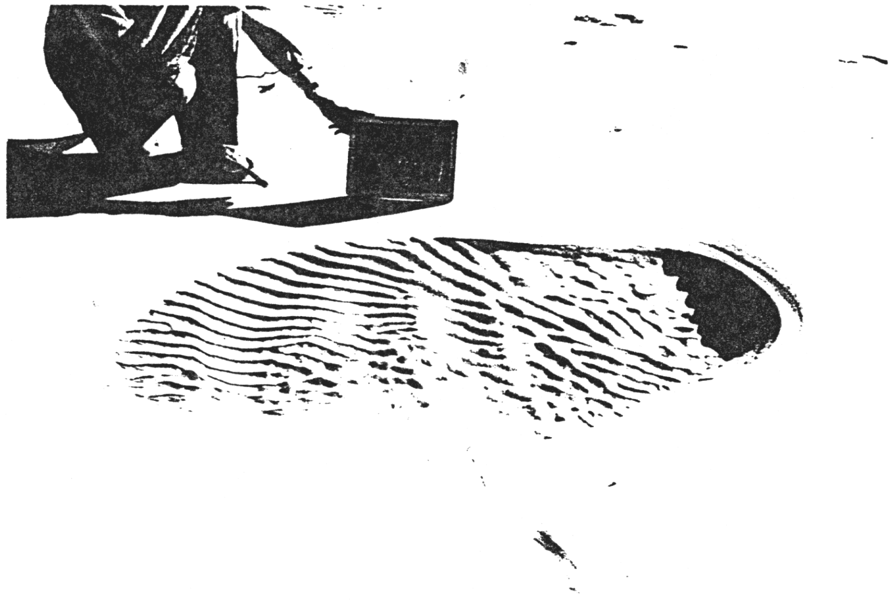


Figure IX-5 Lingoid ripples (cm scale)



Fiqure IX-6 Rhomboid ripples



Fiqure IX-7 Straiqht ripples

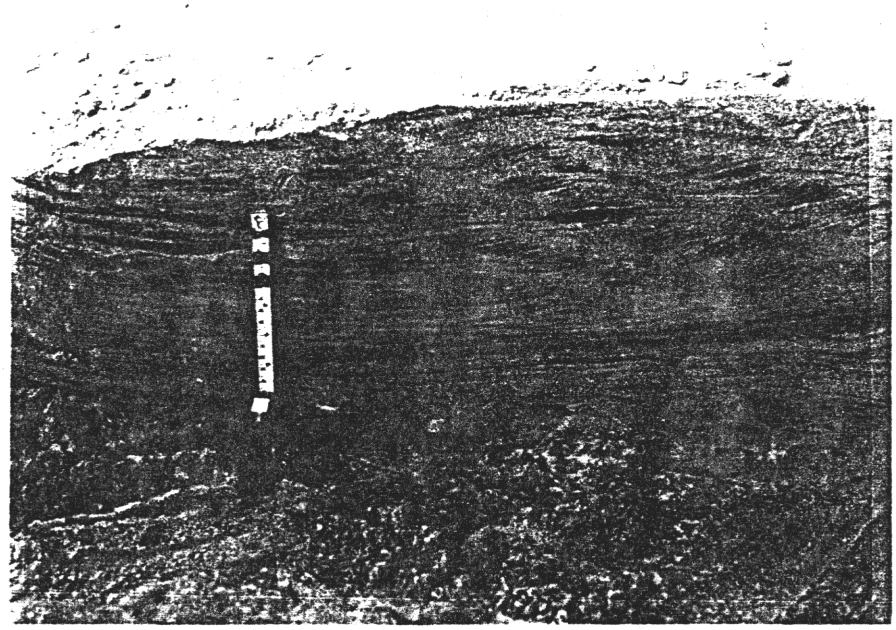


Figure IX-8 Climbing ripples (cm scale)

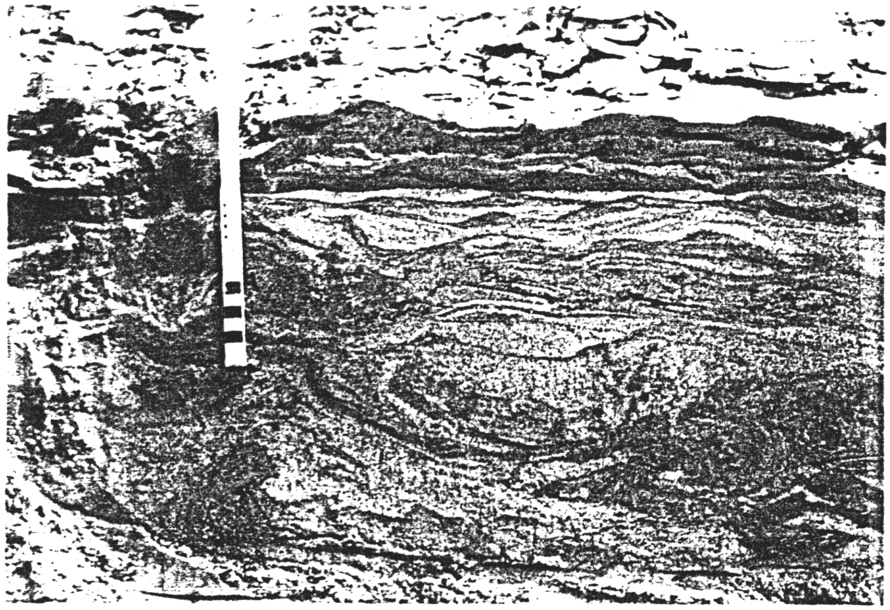


Figure IX-9 Convoluted bedding (cm scale)

Figure IX-10 Flaser bedding (cm scale)

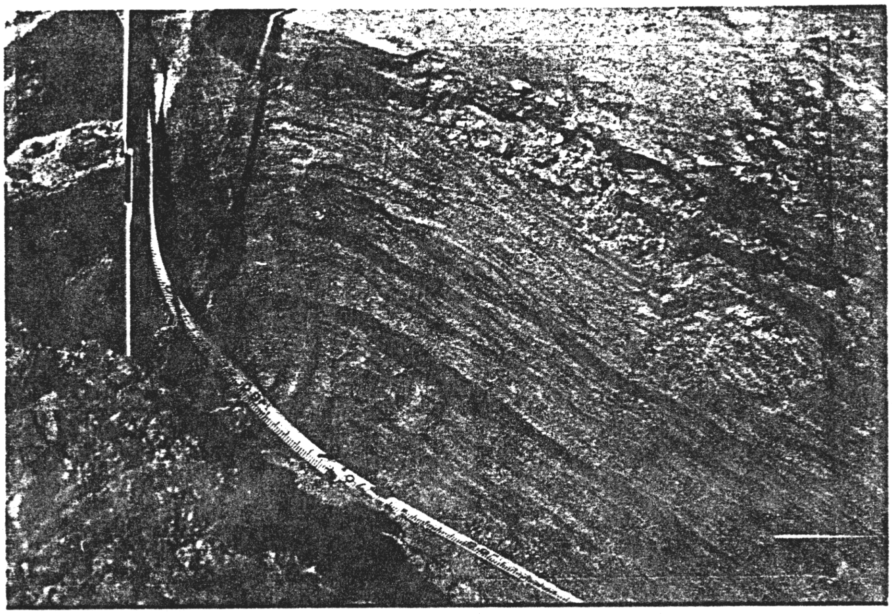


Figure IX-11 Lenticular bedding

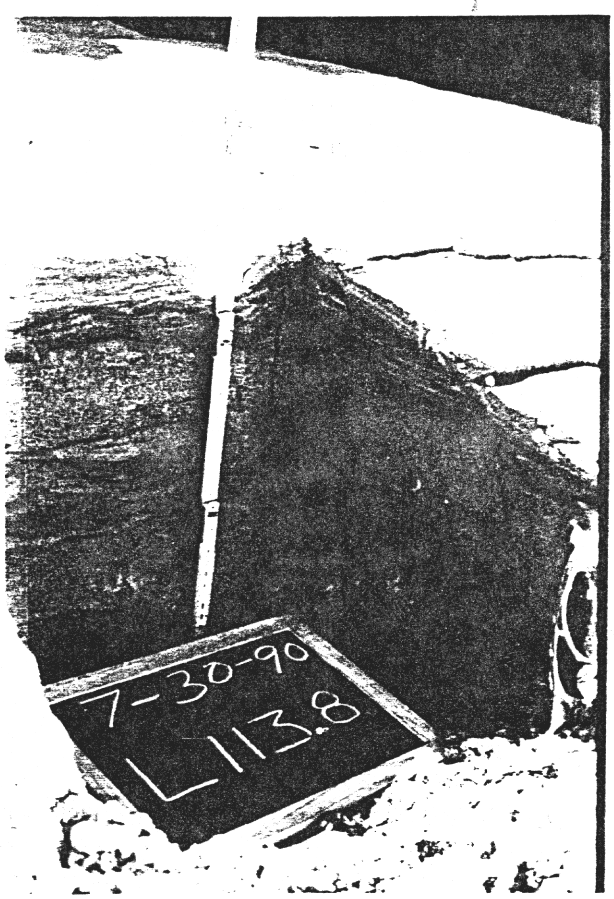


Figure IX-12 Microfaulting

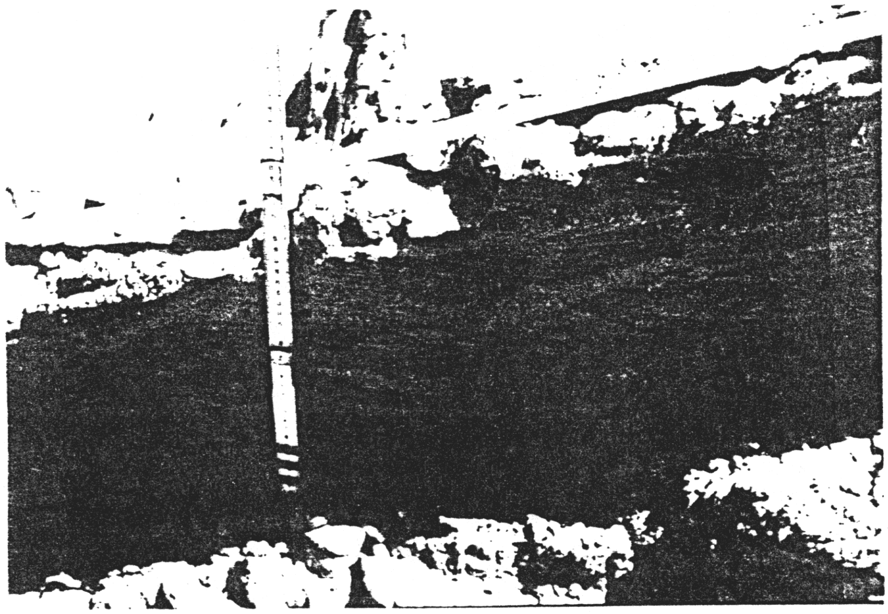


Figure IX-13 Microslumping

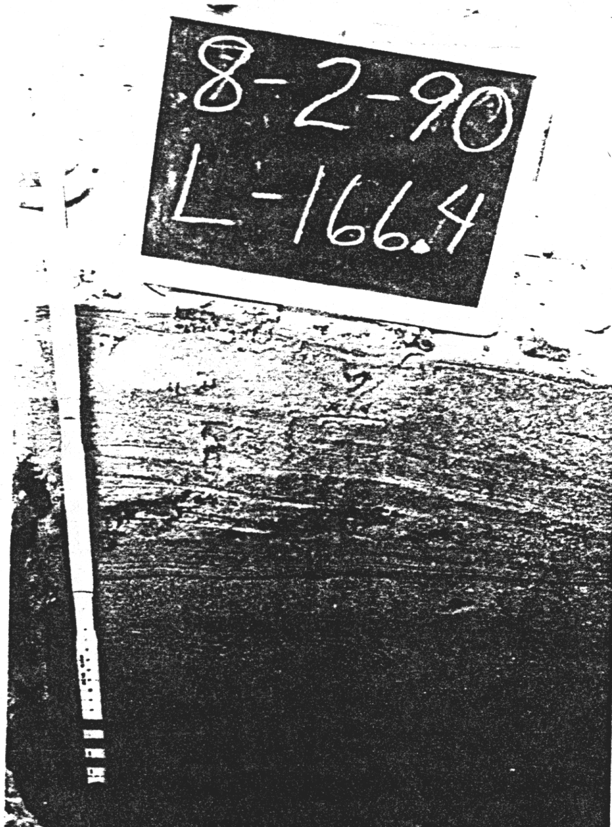


Figure IX-14 National beach trench

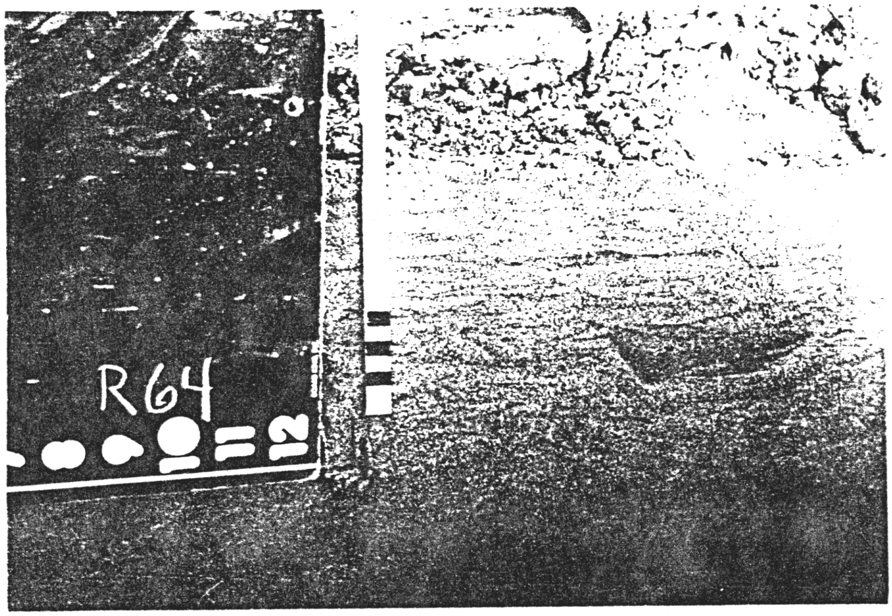


Figure IX-15 Carbon Canyon trench

Figure IX-16 Megaripples

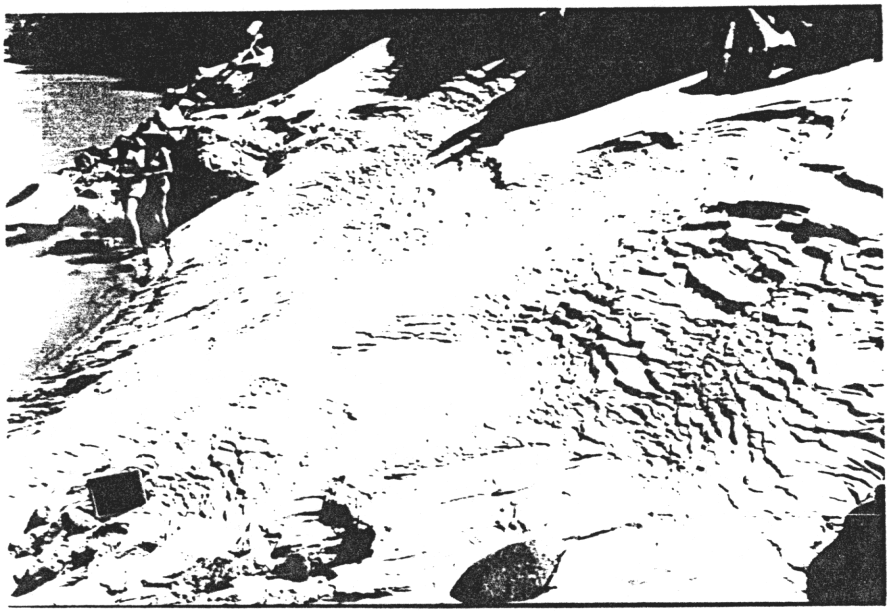


Figure IX-17 Trench site, Mile 113.8, microfailing on beach.

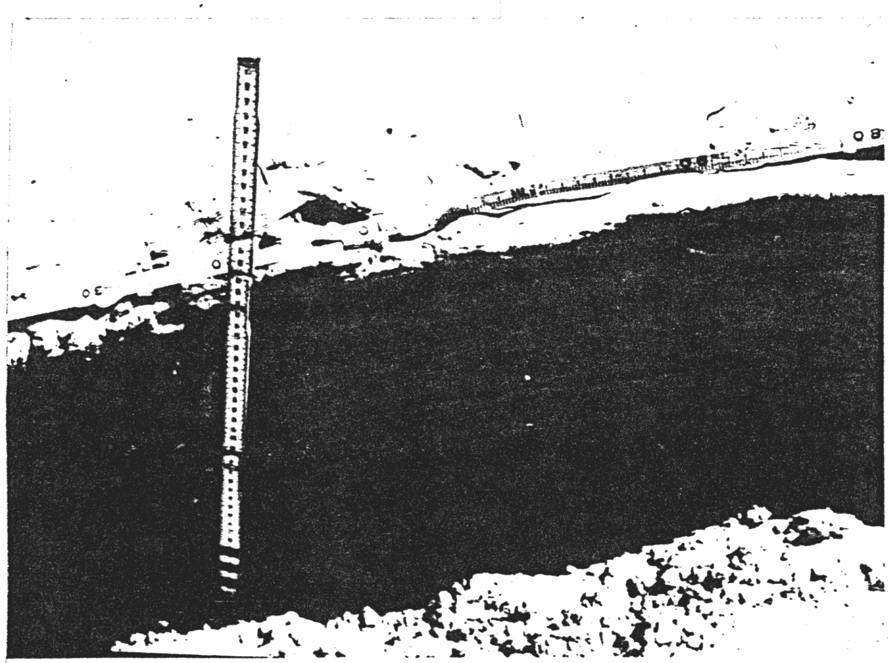


Figure IX-18 S-folds at Mile 113.8

CHAPTER 10

INVERTEBRATE SPECIES ASSOCIATED WITH VARIOUS VEGETATION AND HABITAT TYPES IN THE COLORADO RIVER CORRIDOR, GRAND CANYON NATIONAL PARK

William M. Curtis and Michael J. Stock

ABSTRACT

Invertebrates (insects) were collected quantitatively and qualitatively at eighteen sites in Grand Canyon National Park in July and August, 1990. Collecting was carried out to survey and compare species richness and density within two vegetative zones along the Colorado River corridor. Ninety-seven species from fifty-seven families were collected and/or observed. Both species richness and diversity were found to be significantly higher in the New High Water Zone than in the Old High Water Zone. Collecting in the Desert Zone was limited, but the diversity appears to be lowest there.

INTRODUCTION

A study was conducted from July 25 to August 4, 1990 to determine the diversity and density of insects on Colorado River beaches in the Grand Canyon National Park. Samples were taken from selected plant types representative of two of the four vegetative zones found along the river corridor (selected zones were the New High Water Zone, [NHWZ] and the Old High Water Zone [OHWZ]). In addition spot checking, aquatic sampling, and night collecting with ultraviolet light were conducted.

These insects play an integral role in the various food chains that exist along the river corridor. Given that the corridor's vegetation has changed as a result of the Glen Canyon Dam's water release regime, it can be expected that the diversity and density of insects has also changed. The types and numbers of insects that are encountered by hikers and river-runners also makes this insect study of value to management efforts by the Grand Canyon National Park staff.

The primary purpose of this study is to establish base-line data that could be available for future studies.

METHODS AND MATERIALS

Diurnal collections were conducted with sweep nets. At eleven beach sites collectors conducted fifty one-meter sweeps of eight selected plant species (one-meter sweep consists of one back and forth motion of a net in a plant's foliage, with a distance one-meter across). The eight plants consisted of two Old High Water Zone species: Prosopis glandulosa and Acacia greggii, and six New High Water Zone species: Tamarix ramosissima, Baccharis salicifolia, Baccharis sarothroides, Tessaria sericea, Salix exigua, and Brickellia longifolia. Most of the identification and counting was carried out in the laboratory where dissecting scopes were available. The diversity and total density of herbivorous species, predatory species, and incidental species in each of these eight plants was then determined using the Systat computer program. This was done for each beach site sample.

Additional night collections and diurnal spot check collections were conducted to determine other species present. Night collections were accomplished using an ultraviolet black light (powered by a 12 volt car battery) which was suspended against a white background, in an open space in either the old or new high water zone. Collecting sessions were of one-half hour duration shortly after sunset. The diurnal spot checks were done by netting and hand collection of insects found on sandy beaches, in pools and streams, on marsh vegetation, on humans and trapped mammals, and on the following plant species: Populus fremontii, Datura meteloides, Brickellia longifolia, Salix exiqua, Celtis reticulata, Phragmites australis, and Stephanomeria pauciflora.

All samples were collected or dispatched in ethyl acetate killing jars, and stored in a variety of vials, jars, envelopes, and whirl-paks; ninety percent ethyl alcohol was the preserving agent. The prepared collection will be stored at the Museum of Northern Arizona, Flagstaff, Arizona.

RESULTS AND DISCUSSION

Identification and quantification of collected specimens occurred in the lab after the conclusion of the research expedition. Results from the fifty sweeps received the most consideration because they permit a quantifiable comparison of insect diversities and densities in the old and new high water zones. The spot check and night collection data further reveal the diversity of insect species present along the river corridor, but not their densities. The results of this 1990 study are presented in Table 10-1 and in Figures 10-1 and 10-2.

Data in the graphs reveals a greater diversity and density in the New High Water Zone vegetation than in the Old High Water Zone. This is in accordance with 1982 and 1983 study findings (Byars, 1982, 1983). All NHWZ plant types featured larger number of insect species than did the OHWZ plants, with the exception of Baccharis sarothroides. The same holds true for insect densities. Spot and black light samples reinforced these findings with a greater diversity found in the NHWZ whenever sampling was conducted. Out of ninety-seven species, eighty-four (86.5%) were in the NHWZ and thirteen (13.8%) were found in the OHWZ (Table 10-1).

Relative diversity in the sweep samples from individual vegetation types showed less dramatic differences. All NHWZ species contained higher diversity than OHWZ species with the exception of Baccharis sarothroides. This species was only sampled once due to its appearance in the latter part of the study. This, combined with the type of foliage associated with it, could account for the low diversity encountered in this species. In the OHWZ, Prosopis glandulosa (2 cases) supported a mean of 5.0 total species (2 herbivores and 3 predators), and Acacia greggii (3 cases) supported 4.33 mean species (3.33 herbivores and 1.0 predators). Of the NHWZ species, Baccharis salicifolia (1 case) supported 17 species mean total (5 herbivores, 9 predators, and 3 incidental), Salix exigua (2 cases) supported 9.5 total mean species (2.5 herbivores, 3.5 predators and 3.5 incidental), Tessaria sericea (4 cases) supported 8.5 mean total species (3 herbivores, 3.5 predators, 2 incidental), Tamarix ramosissima (5 cases) supported 7.4 species mean total (1.8 herbivores, 3.4 predators, 2.2 incidental), Brickellia longifolia (2 cases) supported 7.5 species mean total (3.5 herbivores, 3.5 predators, .5 incidentals), and Baccharis sarothroides (1 case) supported 3 species mean total (2 herbivores, 1 predator) (Figure 10-1).

Baccharis salicifolia and Tessaria sericea contained the highest diversity and Baccharis sarothroides, Acacia greggii and Prosopis glandulosa had the lowest.

Density of invertebrates generally followed the same trends, with highest density found among NHWZ vegetation types and lowest in the OHWZ types (Figure 10-2). In most cases the majority of organisms were herbivores. The exceptions were Tessaria sericea which produced large numbers of spiders and Salix exigua which contained large numbers of incidental organisms.

The most abundant herbivores in the NHWZ are Cicindellidae, Aphidae, Tingiidae, Lygaeidae, and Cicadidae. Dominant predator species are Reduviidae and spider species. Incidental species are predominantly Simulidae and Chironomidae.

In the OHWZ, herbivores are Curculionidae and Meloidae. Predator species include Reduviidae and Formicidae.

CONCLUSIONS

Both species diversity and density were found to be highest in vegetation types from the NHWZ. Diversity is highest in Baccharis salicifolia and Salix exigua. Density is highest in Baccharis salicifolia, Tamarix ramosissima and Salix exigua. Exploitation of OHWZ types seems to be very limited at this time of year. This seems to correspond with findings by the reptile study team (Chapter 4).

Three first-recorded sightings were made during this study. A Mantispidae, several Dinothrombium mites, and Haliplidae in the Colorado River were recorded.

REFERENCES CITED

Byars, B., 1983. Insect density and diversity on Colorado River beaches, p. 44-76. In Colorado River Investigations I, Northern Arizona University/Museum of Northern Arizona Class Report, S.S. Beus and S. Carothers (Eds.).

Byars, B., 1984. Insect diversity and density on Colorado River beaches, p. 132-136. In Colorado River Investigations II, Northern Arizona University/Museum of Northern Arizona Class Report, S.S. Beus and S. Carothers (Eds.).

Figure 10-1.

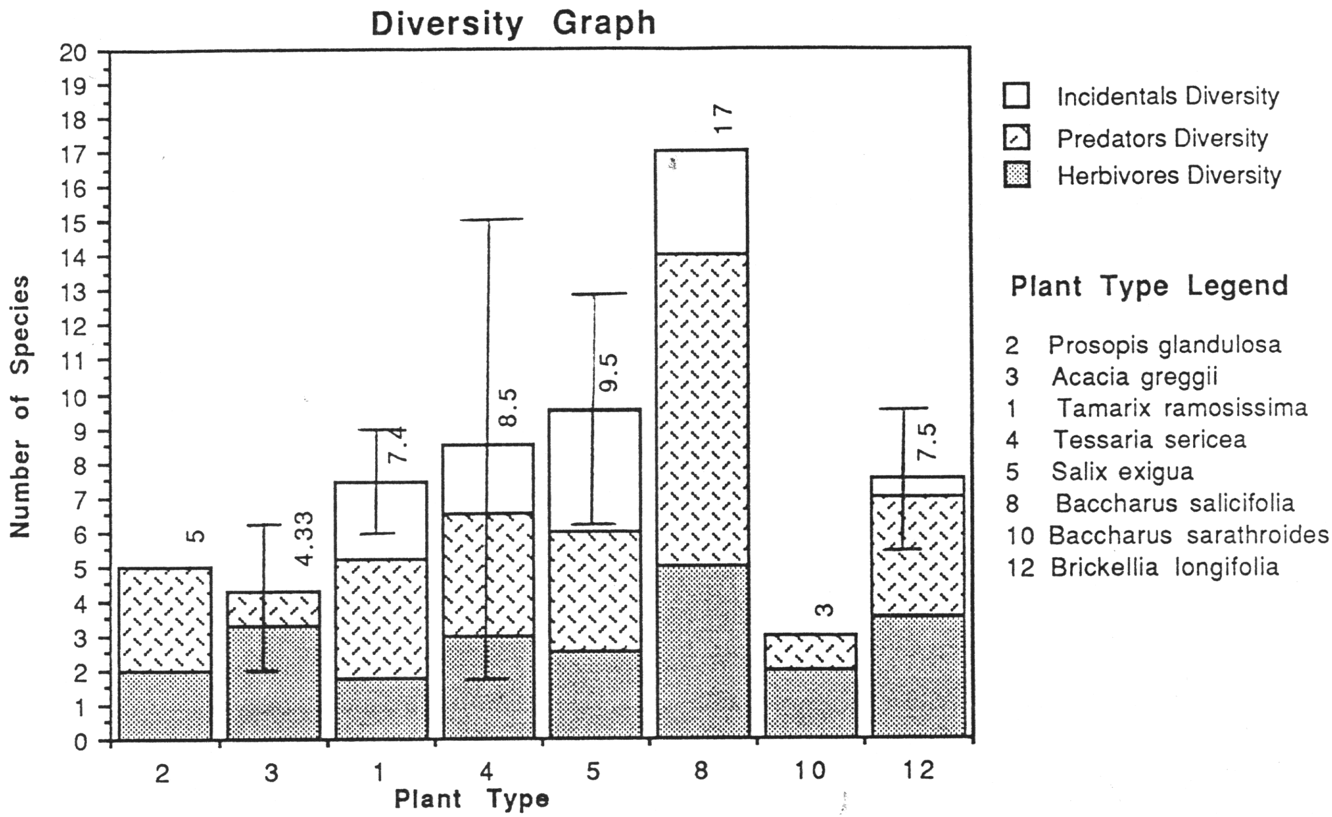


Figure 10-2.

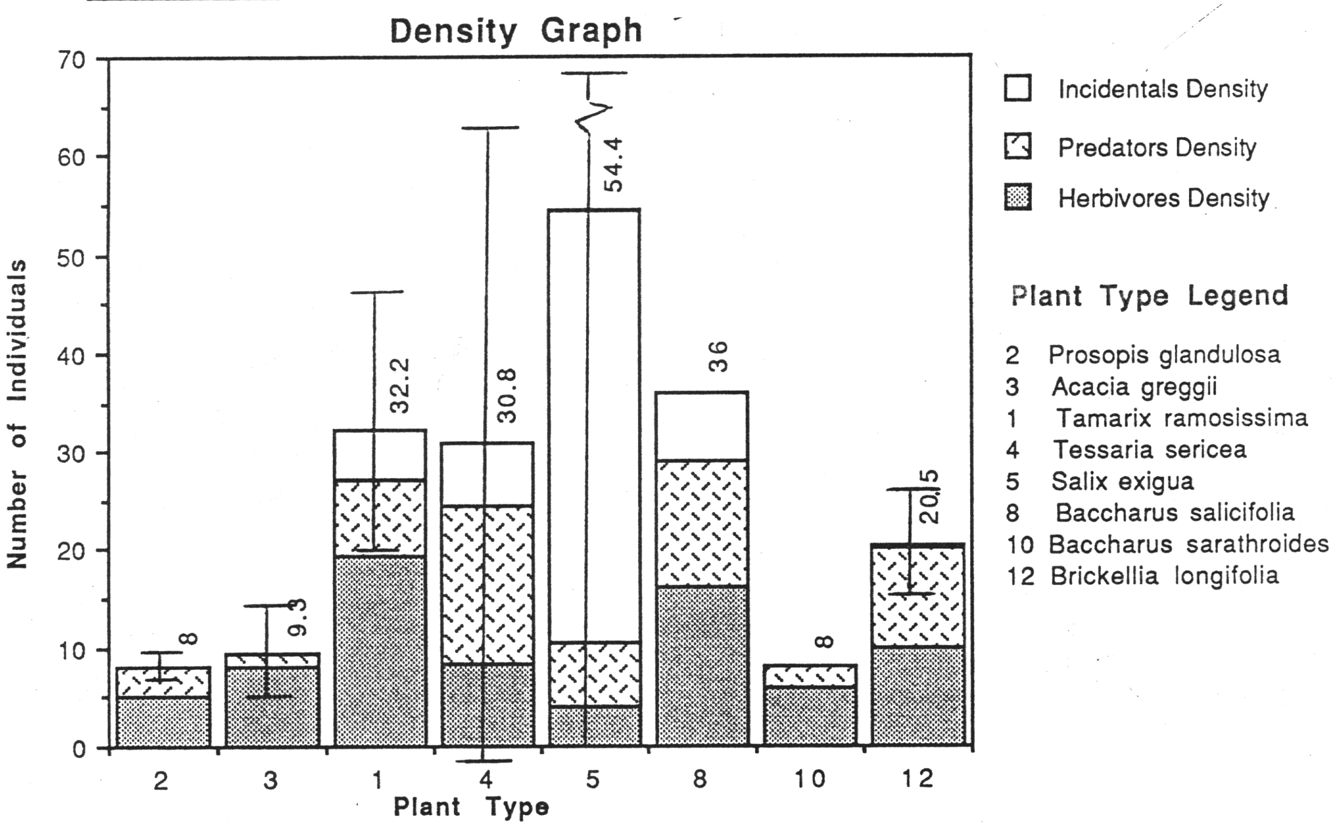


Table 1: Invertebrate taxa encountered in the Colorado River corridor, July-August. 1990. Comments: Colorado River mile and side; plant species (numbers refer to those identified by R. Smith, this volume, NHW = new high water zone, OHW = old high water zone, D= desert, A= aquatic); guild (H = herbivore, P = predator, parasitoid, parasite, D = detritivore, I = incidental); collection technique (1 = 50 sweeps, 2 = spot collection, 3 = ultraviolet light tr; 4 = observation; zone (1=NHW, 2= OHW).

FAMILY:	GENUS SPECIES	COMMENTS
		COLEOPTERA
Alleculidae	sp. 1	20.5R; NHW; H; 3; 1
	sp. 1	34.8R; 12; I; 1; 1
Buprestidae	Hippomelus sp.	8L; 1; H; 2; 1
Cerambycidae	sp. 1	157L; A; I; 2
Chrysomelidae	sp. 1	108.2R; NHW; H; 3; 1
	sp. 3	179R; 13; H; 2; 1
	sp. 2	64.7R; 1; H; 3; 1
	sp. 4	52.5R; 5; H; 1; 1
	sp. 5	20.5R; 12; H; 1; 1
	sp. 4	53R; 5; H; 1; 1
Cicindellidae	sp. 1	76.7R; NHW; P; 2; 1
Coccinellidae	Hippodamia convergens	34.8R; NHW; P; 2; 1
		194L; 20; P; 2; 1
		120.1R; 8; P; 2; 1
		120.1R; 40; P; 2; 1
		53R; 5; P; 1; 1
Curculionidae	sp. 1	120.1R; 8; H; 2; 1
	sp. 2	52.5R; 3; H; 1; 2
	sp. 1	52.5R; 2; H; 1; 2
	sp. 3	20.5R; 12; H; 1; 1
	sp. 4	52.5R; 2; H; 1; 2
Dytiscidae	Thermonactes sp.	166.6L; A ; P; 2;
Elateridae	sp. 1	52.5R; NHW; H; 3; 1
Elmidae	sp. 1	157L; A; D; 2
Haliplidae	sp. 1	61.5L; A; D; 2;

Meloidae	sp. 1	76.7; 20; H; 2; 1
	sp. 2	64.7R; 1; H; 3; 1
	sp. 3	120.1R: 40; H; 2; 1
	sp. 4	52.5R; NHW; I; 2; 1
	sp. 5	53R; 3; H; 1; 2
Scarabaeidae	sp. 1	52.5R; NHW; H; 3; 1
	sp. 2	166.6R; NHW; H; 2; 1
	Polyphylla sp.	52.5R; NHW; H; 2; 1
Tenebrionidae	sp. 1	120.1R; ; I; 2; 1

DIPTERA

Asilidae	sp. 1	120.1R; NHW; P; 2; 1
Chironomidae	sp. 1	52.5R; 4; I; 1; 1
	sp. 2	52.5R; 4; I; 1; 1
	sp. 1	122.1R; 5; I; 1; 1
	sp. 1	53R; 8; I; 1; 1
Culicidae	sp. 1	166.5L; NHW; P; 3; 1
Simulidae	sp. 1	64.7R; NHW; I; 3; 1
	sp. 1	52.5R; 5; I; 1; 1
	sp. 1	52.5R; 4; I; 1; 1
	sp. 1	52.5R; 8; I; 1; 1

HEMIPTERA

Corixidae	Graptocorixa sp.	157.0L; A; P; 2
Gerridae	sp. 1	120.1R; A; P; 2
Lygaeidae	sp. 1	52.5R; 5; H; 1; 1
	sp. 1	52.5R; 3; H; 1; 2
	sp. 1	166.6L; 10; H; 1; 1
	sp. 1	208.8L; 4; H; 1; 1
	sp. 1	52.5R; 8; H; 1; 1
	sp. 1	52.5R; 2; H; 1; 2
Notonectidae	Notonecta lobata	120.1R; A ; P; 2;
Pentotomidae	sp. 1	210; 3; I; 2;
	sp. 2	64.2R; 3; H; 2
Reduviidae	Zelus renardii	120.1R; 12; P; 1; 1
		64.7R; 1; H; 1; 1
		52.5; 3; P; 1; 2
		52.5R; 4; P; 1; 1
		52.5R; 2; P; 1; 2

Tingidae sp. 1	120.1R; 8; H, 2; 1
sp. 1	52.5R; 8; H; 2; 1

HOMOPTERA

Aphidae sp. 1	122.1R; 7; H; 2; 1
sp. 2	65.5R; 13; H; 2; 1
Cicadidae	
Dicerprocta apache	166.6L; 1; H; 2; 1
Cicadellidae Sp. 1	136.5L; 1; H; 1; 1
Sp. 1	52.5R; 8; H; 1; 1
Sp. 2	52.5R; 8; H; 1; 1
Sp. 3	52.5R; 8; H; 1; 1
sp. 1	34.8R; 12; I; 1; 1
sp. 2	34.8R; 12; H; 1; 1
Psyllidae sp. 1	64.2R; 3; H; 1; 2

HYMENOPTERA

Apidae	52.5R; 1, P; 2; 1
Chalcididoidea sp. 1	52.5R; 1; P; 1; 1
sp. 2	52.5R; 1; P; 1; 1
Formicidae	
Pogonomyrmex californicus	209L; NHZ; P; 2; 1
P. rugosa	209L D; P; 2; 2
sp. 1	52.5R; NHW; P; 3; 1
sp. 2	52.5R; 4; P; 1; 1
sp. 3	52.5R; 8; P; 1; 1
sp. 4	64.5R; 2; P; 1; 2
Mutillidae Dasymutilla sp.	52.5R; NHZ; P; 2; 1
Dasymutilla gloriosa	194L; NHZ; P; 2; 1
Pompilidae sp. 1	52.5R; 1; P; 2; 1
Pepsis sp.	122L; 1; P; 4;1
Sphecidae sp.	166.6L; 1; P; 2; 1
Bembix sp.	52.5R; NHW; P; 2; 1
Sceliphron sp.	34.8L; NHW; P; 2; 1
Tiphiidae sp. 1	64.5R; NHW; P; 3; 1
sp. 2	52.5R; NHZ; P; 3; 1
Vespidae	52.5R; 1; P; 2; 1

ISOPTERA

Hodotermitidae	157L; ; D; 2

LEPIDOPTERA

Danaidae	
Danaeus berenice	53R; NHW; H; 2; 1
Sphingidae	
Hyles lineata	52.5R; 5; H; 2; 1
Pachysphinx modesta	136R; ; H; 4; 1
Papilionidae	
Battus philenor	75.5L; NHW; H; 2; 1
Papilio multicaudatus	87.9R; NHW; H; 4; 1
Geometridae sp. 1	136L; 2; H; 2; 1
Nymphalidae	
Asterocampa celtis	8L; OHW; H; 4; 2
Pieridae sp. 1	64.7R; OHW; H; 2; 2
Noctuidae	
sp. 1	20.5R; NHW; H; 3; 1
sp. 2	20.5R; NHW; H; 3; 1

ODONATA

Libellulidae	
Libellula saturata	31.8R ; NHW; P; 2; 1
Agrionidae sp. 1	31.8R; NHW; P; 2; 1
sp. 2	108.8R; A; P; 2;

NEUROPTERA

Chrysopidae sp. 1	120.1R; 4; P; 1 ; 1
	52.5R; 8; P; 1; 1
Corydalidae Corydalus sp.	166.6L; A; P; 2;
Mantispidae sp. 1	52.5R; NHW; P; 3; 1
Myrmeleontidae sp. 1	64.7R; NHW; P; 3; 1
sp. 2	64.7R; NHW; P; 3; 1

PLECOPTERA

unknown family	Deer Creek; A; H; 4

ORTHOPTERA

Acrididae	
Schistocerca shoshone	52.5R; 5; H; 1; 1
sp. 2	65.5R; NHW; H; 2; 1
Schistocerca shoshone	52.5R; 4; H; 1; 1
Blattidae sp. 1	52.5R; NHW; H; 3; 1
Gryllidae	
Oecanthus sp. 1	
Oecanthus sp. 2	120.1R; 4; H; 1; 1
Mantidae Littanutria minor	87.9R; ; P; 2; 1
Tettigoniidae sp. 1	166.6L; NHW; H; 2; 1

TRICHOPTERA

Hydropsychidae sp. 1	87.9R; A; D; 2

CHAPTER 11

PHOTOGRAPHIC RECORD OF BEACHES IN THE GRAND CANYON FROM 1983 TO 1990

Larry Gilbert

INTRODUCTION

Until recent years, the beaches along the Colorado River in the Grand Canyon corridor were in general, taken for granted. Today, with thousands of people per year traveling through the canyon, the value of these beaches has been acutely recognized.

Upon the completion of Glen Canyon Dam in the 1960's, the replenishing of sediments along the beaches below the dam was drastically reduced. Presently, a very small amount of deposition of sediments is supplied by side canyon tributaries. Alternation of frequently used beaches has occurred as a result of the 1983-84 floods. As is often the case, a sudden change in a given situation brings about a recognition and appreciation of its value. The loss of beach front property in the Grand Canyon creates some major concerns. In response to these concerns, Northern Arizona University along with other sponsored agencies, continued their annual research expeditions to gather informative data about the canyon and the changes taking place there.

The specific focus of this report is the visual changes in beaches, recorded photographically, over a period of years. The photographic record of beaches associated with this research report began in 1983, with the second annual Grand Canyon Experience expedition of science teachers.

METHODS

Beach photography, though sounding simple, turns out to be a rather complex and rigorous undertaking. Black and white photographs are taken of beaches from a vantage point above a beach, generally from the top of a cliff or talus slope at the established bench mark. Getting to these points can be both strenuous and dangerous. Year after year, photographs are taken from established points in order to make comparsions with past photographic records. Photographs taken from different points, year to year, cannot be accurately compared and used for analysis. Many beaches encountered in the Grand Canyon such as Nautiloid (L34.7 mile), Nevills Rapid (L75.5 mile), R122 mile, Bedrock (R131 mile), cannot be covered with a single photograph using a 50mm lens assembled on a 35mm camera. Overlapping photographs must be taken from the same point. Care should be taken to insure the photographic reference points, such as large permanent rocks well above the high water line are included in the pictures year to year. When pictures are printed they can then be overlaid to form a composite of the entire beach. Turning the camera 90 degrees from the horizontal allows a greater vertical span, and thus permits reference points from the far side of the river to be included. When developing the composite, two principal reference points on each photograph must be used for alignment. These should be as near the left or right edge as posible.

Cutting off the white outside border will allow two adjoining prints to be mosaicked together with no apparent break. Once the beach photos are mosaicked together on a paper backing, they can be compared to photographs taken in previous years. The same exact procedures must be used in the photography.

INTERPRETATION

The analysis and interpretation of beach photos taken over a period of years can provide information on pattern changes in deposition, human impact, and vegetation growth. Examination of photos taken of beach R122.8 mile (Forster) in 1983, 1985, 1986, 1987, 1989, and 1990, indicate some changes in vegetation growth, especially among tamarisk near the beach. Changes in beach shape and deposition can also be recognized when comparing the 1983, photo with later years.

Some changes can also be observed on L190.2 mile beach. This is a relatively small beach area set back in a narrow cut in the canyon wall. The 1985, photo indicates a very steep sided sand beach dropping sharply into the river. The 1986 print indicates some beach failure is taking place with a loss of sand back into the river. A 1990 photo illustrates a lower beach gently tapering into the river with a new young tamarisk seedling at the center of the beach.

Grapevine (L81.1 mile), an important but relatively small, long and narrow beach appears to be very stable over several years even though it sustains a great deal of human traffic. The 1990 photo of this beach might give the impression that the beach is eroding, but the river flow at this time was about 5000 cfs. Normal flows would cover rocks seen along central river margin of the beach. Vegetation, of which there is almost none, does not appear to have changed over the years.

Some valid general observations can be made from existing beach photographs taken over the years. Limiting their scientific value is the lack of photographic standards. If a photographic record of beaches through the Grand Canyon is to have greater meaning and value, a set of standards must be developed, recorded, and followed.

RECOMMENDATIONS

The following suggestions can serve as a starting point for developing set standards:

1) Use a good quality manual 35mm camera with a hand held light meter. This will accommodate the varied light conditions in the canyon. This camera should be fitted with a standard 50mm or 55mm lens and appropriate filter. Do not use a wide angle lens, such as a 28mm, because it will introduce marginal distortions into photos. The same camera, lens, filter, and light meter must be consistently used.

2) Use the same type film (plus X pan, 125 ASA, pan film).

3) A tripod will help ensure clear photos, providing a foundation on which an optical horizon can be established. When shooting a mosaic panorama of a beach, this will guarantee the same horizon line for each adjoining photo. This method will reduce distortion and the tendency for the beach panorama to curve.

4) Take three photographs of the same beach at three different f stops. For example, if the indicated light reading for the beach is f8.5, take one shot at f8.5, another at f8, and a third one at f16. This will provide three different exposures in order to select the best photograph.

5) Carefully establish camera points from which photographs will be taken; and go back to and re-establish the 1983 camera bench marks. These points must be found exactly each year so some method of marking must be used that does not detract and/or affect the scenic environment. The value of this precise photographic camera point cannot be over emphasized. Interpretation cannot be done accurately without the same point of reference. A map of the beach showing the photograph station and other reference points should be used.

6) Develop a method for locating camera bench marks using the transit. The transit being used by the Beach Profile team might be used for this purpose.

7) Set tripod at same position (number of inches) above camera point to ensure the same down angle on the beach. Keep camera level as it is panned along the beach.

8) Use large chalkboard on which beach identification can be printed. Printing should be as large as possible and heavy or dense so it can be seen in photographs even at some distance. Chalkboard should be placed at a range that the board information can be photographed to insure its readability. Including the approximate river flow in cfs units on the sign is recommended.

9) When photographing any beach, always turn camera 90 degrees to its standard position so that the vertical axis of the film becomes the long side of the photograph. This will increase the vertical view span allowing more reference points to be included in photo including some of the opposite canyon wall.

10) It is recommended that two researchers be assigned to the beach photographic record project.

REFERENCES

Stephens, E.M., E.M. Shoemaker. 1987. In the footsteps of J.W. Powell, photos from 1871-72 and 1968. Johnson Books, Boulder.

George Billingsley, Geologist. Personal comments on photographic records, U.S. Geological Survey, Flagstaff, Arizona.

CHAPTER 12

COLORADO RIVER BEACH CAMPSITE INVENTORY GRAND CANYON NATIONAL PARK, ARIZONA

Jeff Simpson and Bryan Bates

INTRODUCTION

Since 1983, selected beaches of the Colorado River in the Grand Canyon have been periodically inventoried and classified according to camper capacity, shoreline composition, erosional characteristics, and flash flood potential. This report presents the results of the 1990 summer survey of the Colorado River between Lees Ferry (mile 0) and Diamond Creek (mile 225). Comparisons are made to the previous surveys of Brian (1984), Kalinowski (1987), Detring (1988), LaChat (1989) and to Stevens (1990). The focus of this report is to document data recorded on the 1990 Northern Arizona University (NAU) research expedition, compare such data with previous research, and more firmly establish a baseline of defined parameters and methodologies to be used by future researchers.

Beginning with the 1963 impoundment of waters by Glen Canyon Dam, sediments which normally replenish the beaches in the Grand Canyon have been trapped in Lake Powell leaving the downstream campsite beaches in the Grand Canyon to be eroded by flash floods, winds, human contact, and daily river level fluctuations as well as modified by more firmly established riparian flora and fauna. Since 1963, the nature of the campsites has changed and will continue to change.

METHOD

MATERIALS USED:
- inclinometer
- 1990 Campsite Data Form
- measuring tape, 50 ft.

DATA GATHERED:
- shoreline length
- shoreline composition
- beach area
- area with slope less than five degrees
- camper capacity
- mooring characteristics, motorized and non-motorized
- flash flood potential and stream position
- insect infestation
- slope to campsite
- distance to campsite
- beach stability
- shade characteristics

The total moorable high water beach length was measured in feet,including the percentage of sand, rock and vegetation. Since all sites considered are campsites, the limiting factor is the high water rather than low water shoreline. Rock is further subdivided into ledge, boulder, or rock (Table 12-3). As there is little reliable data regarding the nature of shoreline composition before this study, no comparisons were made.

The total area of each beach was determined by measuring (not estimating as in earlier surveys) the width and depth of the main site. With irregular sites, geometric methods were used to calculate the area. When smaller, immediately adjacent areas among vegetation and/or boulders were available for sleeping sites, these were included in the total. Each beach was then assigned a group camp size capacity as follows:

	CAMPER	SQUARE METERS	SQUARE METERS
SMALL	15-20	185-560	1989-6030
MEDIUM	21-30	560-1900	6030-20451
LARGE	31-40	1900+	20451+

Campers include all of the party except the boat crew. Designated beach capacity may vary slightly from the above categories as some of the area included may be uncomfortable for sleeping. The area of the beach with an estimated slope of less than five degrees is incorporated on the data sheets as a measure of beach sleeping capacity.

Data reflecting quality of mooring for motorized and non-motorized craft is based upon the judgments of the crew and other experienced boatmen. Ratings of "poor, fair, good, and excellent" were used depending on ease of docking, loading/unloading conditions, and the need to move the boat due to river level changes.

All measurements relating to water line were made from high water marks as determined from altered vegetation and debris lines. Typically, these demarcations form from flows between 28,000 and 32,000 cubic feet per second (cfs). For four days during the survey, water releases from Glen Canyon Dam were restricted to 5,000 cfs. Subsequent high water precluded gathering some data on beach stability. It is suggested that future studies use this high water mark as a baseline for data.

Flash flood potential was assessed considering runoff area and position of stream relative to campsite. A new parameter, stream position, recorded whether the stream occurred above, below or flowed through the campsite.

Insect infestation was rated as low, moderate or high; low if insects caused little distraction and high if all activities were affected by insects.

Approximate profile slope from mooring to campsite was determined using an inclinometer. Distance from river to campsite is recorded in feet.

The availability of shade was analyzed for the times when shade would be present. Categories were "none, morning, afternoon, and constant" (N, M, A, and C in Table 12-1) with "V" indicating vegetation.

Data were recorded in two forms: tables and anecdotal record. Below are data tables compiling all the findings of the 1990 survey. Available but not included in this report are notes on specific features of each beach.

With the exceptions noted above, this investigation followed guidelines used in the 1983 and 1987 survey. A suggested model for an improved survey form for subsequent studies is included.

RESULTS AND DISCUSSION

Twenty-four beaches were surveyed. While this is a smaller total number than earlier yearly surveys, more information was gleaned from each site. This should be helpful in recognizing changes in campsite characteristics. Of the beaches surveyed, eleven were classified as large, nine as medium, and four as small.

As per Table 12-2, campsite capacity generally agrees with river guides (Stevens, 1990). The 1990 NAU capacity data includes isolated spots suitable for sleeping directly adjacent to the main area, therefore variations between this data and Stevens (1990) may exist. When variations occur between the two surveys (except Lower National), the 1990 NAU survey indicates the larger campsite capacity. Other variations may be explained by continuing erosion or differing interpretation of actual survey area. In order to establish consistency in identifying the beach site, the position of any stream is included in the data and may differentiate upper from middle from lower sites. Because the area of site suitable for sleeping was actually measured in this 1990 survey, the degree of reliability is thought to be relatively high, thus allowing this data to be used as a baseline for future studies.

Of the beaches surveyed, 46% are in active retreat. This is thought to be due to daily river level fluctuations. Cutbanks up to one meter were observed, many having the erosion augmented by daily rapid river level drop.

Shoreline characteristics appear to be in dramatic flux from year to year as evidenced by comparing the 1990 data with LaChat, 1989. However, as the 1989 data is sketchy at best, and no earlier data are available, few reliable trends may be confirmed. Vegetation and rock as a percentage of shoreline appear to be increasing while sand appears to be decreasing (Table 12-3).

Slopes of the beaches ranged from 5 to 20 degrees. Earlier studies determined beach profile, but whether data was in percent or degree form is uncertain.

If insect infestation for each site is assigned a score (low = 1, moderate = 2, high = 3), the average infestation index for beaches surveyed is 1.6, low-moderate. Throughout the survey, commercial boatmen worked to maintain a clean campsite, consistently using the wet sand area for food preparation and dining and actively picking up dropped food. Sites surveyed while in use by private trips did not appear as clean. Whether such would allow for an increase in insect population is unknown.

CONCLUSIONS

As discussed in the results, beach capacity appears to be diminishing. Whether this is due to erosion or growth of vegetation is unclear. Comments by experienced boatmen suggest that erosion is the predominant factor.

Shorelines appear to be in flux with trends indicating vegetation and rock increasing as a percentage of mooring shoreline and sand decreasing.

With continued erosion, mooring has become a problem. This may be due in part to the slumping of the beaches into the river channel, creating a more level cross-section requiring frequent moving of boats.

As attested by the insect infestation, beaches in general are clean. Commercial runners appear to do a good job of maintaining a minimum impact. Better education of private river runners may be worthwhile.

SUGGESTIONS FOR FURTHER STUDY

1. Continue gathering data as per enclosed data sheet.

2. Quantify the percent of vegetation at each site and compare with the total measured area.

3. Utilize time lapse photography of beaches over a 12 - 24 hour period to establish slumping of river front sands. This would help establish the part played in erosion by daily river level fluctuations.

TABLE 1

1990 Colorado River Campsite Beach Inventory Data

MILE/SIDE/NAME	SHORE	CAP.	AREA	MOORING	EQLB	FLOOD	STREAM POS	INSECT	SLOPE	DISTANCE	SHADE
					REACH 1						
7.9 L Jackass Cyn/Badger	360	L	28,800	F/F	STAB	M	ABOVE	LOW	5	120	m
19.2 L 19 Mile Canyon	75	S	7,500	F/F	UN/R	H	INTER	LOW	20	100	-
20.6 R Upper North Canyon	120	S	7,200	F/F	STAB	N	BELOW	MOD	20	15	M
20.7 R Lower North Canyon	276	L	30,000	EP/EP	UN/R	L	ABOVE	LOW	15	0	Ma
29.2 L Shinumo Wash	350	M	16,000	E/E	STAB	N	ABOVE	LOW	10	20	M
34.7 L Nautiloid Canyon	252	M	25,200	F/F	STAB	M	INTER	MOD	20	100	mA/W
					REACH 2						
53.1 R Lower Nankoweap	348	L	>25,000	G/G	STAB	N	N/A	MOD	8	0	ma/W
58.1 R Awatubi	144	L	>25,000	E/E	STAB	M	INTER	LOW	10	10	W
					REACH 3						
61.8 R Lower LCR	200	M	10,000	G/G	UN/R	L	ABOVE	MOD	15	20-150	W
64.7 R Carbon Creek	300	L	40,000	E/E	UN/R	N/L	ABOVE	LOW	20	35	a
75.5 L 75 Mile Creek	135	S	6,400	P/F	UN/R	N	BELOW	MOD-HIGH	20	0	W
81.1 L Grapevine	242	M	13,200	G/G	UN/R	N	N/A	LOW	20	15	a
					REACH 4						
93.5 L Monument Cr/Granite	500+	L	>25,000	G/G	STAB	N	BELOW	HIGH	10	15	MAW
108.3 R Lower Bass	150	L	>25,000	E/E	UN/R	L	BELOW	LOW	8	15	a
120.0 R Upper Blacktail	150	M	2,500	F/G	UN/R	N	BELOW	MOD	20	0-75	N
122.8 L Upper Forster	560	L	>25,000	F/G	UN/R	N	BELOW	MOD	20	32	W

REACH 5

136.6 L Upper Pancho's Kit	80	L	11,680	G/G	STAB	N	N/A	LOW	15	0	C
136.7 L Middle Pancho's Kit	62	M	8,000	P/G	UN/AD	N	N/A	MOD	20	80	A/V
136.8 L Lower Pancho's Kit	95	L	>25,000	E/E	-	N	N/a	MOD	15	0	A

REACH 6

166.6 L Upper National	314	M	12,000	F/F	STAB	M	ABOVE/BELOW	MOD	8	0	N
166.7 L Lower National	114	M	25,000	F/G	STAB	L	BELOW	MOD	8	0	M

REACH 7

190.2 L	65	S	3,250	F/G	STAB	L	BELOW	LOW	15	20	M/CAVE
194.0 L	20-200	L	>25,000	G/G	UN/R	N	BELOW	MOD	18	54	V
208.8 L Granite Park	150	L	>25,000	E/G	UN/R	L	BELOW	LOW	15	20	V

<u>KEY</u>

MILE/SIDE/NAME....river mile as measured from Lee's Ferry, right or left, name
SHORE............length of moorable shoreline in feet
CAP..............capacity for campers as per method, <u>S</u>mall, <u>M</u>edium, or <u>L</u>arge. Calculated from detailed square footage.
AREA.............area capable of being used for camp in square feet
MOORING..........as per method, <u>P</u>oor, <u>F</u>air, <u>G</u>ood, or <u>E</u>xcellent
EQLB.............equilibrium of beach: <u>S</u>table or <u>U</u>nstable. If unstable, <u>A</u>dvancing or <u>R</u>etreating, - indicates that stability could not be determined due to water level
FLOOD............potential for flashflood within described campsite, <u>N</u>one, <u>L</u>ow, <u>M</u>oderate or <u>H</u>igh
STREAM POS........position of stream relative to site: above, below or intermediate. N/A indicates no stream.
INSECT...........infestation level: <u>L</u>ow, <u>M</u>oderate, or <u>H</u>igh
SLOPE............average slope in degrees from high water mark to campsite for sleeping
DISTANCE.........minimum (or range) distance in feet from high water line to campsite for sleeping
SHADE............availability of natural summer shade: <u>M</u>orning, <u>A</u>fternoon, <u>C</u>onstant. <u>V</u>egetation indicates shade by plants. Minimal shade is indicated by lower case letters. Greater shade is indicated by upper case letters.
>................greater than In most cases, if beach area is greater than 25,000 square feet, this symbol is used.

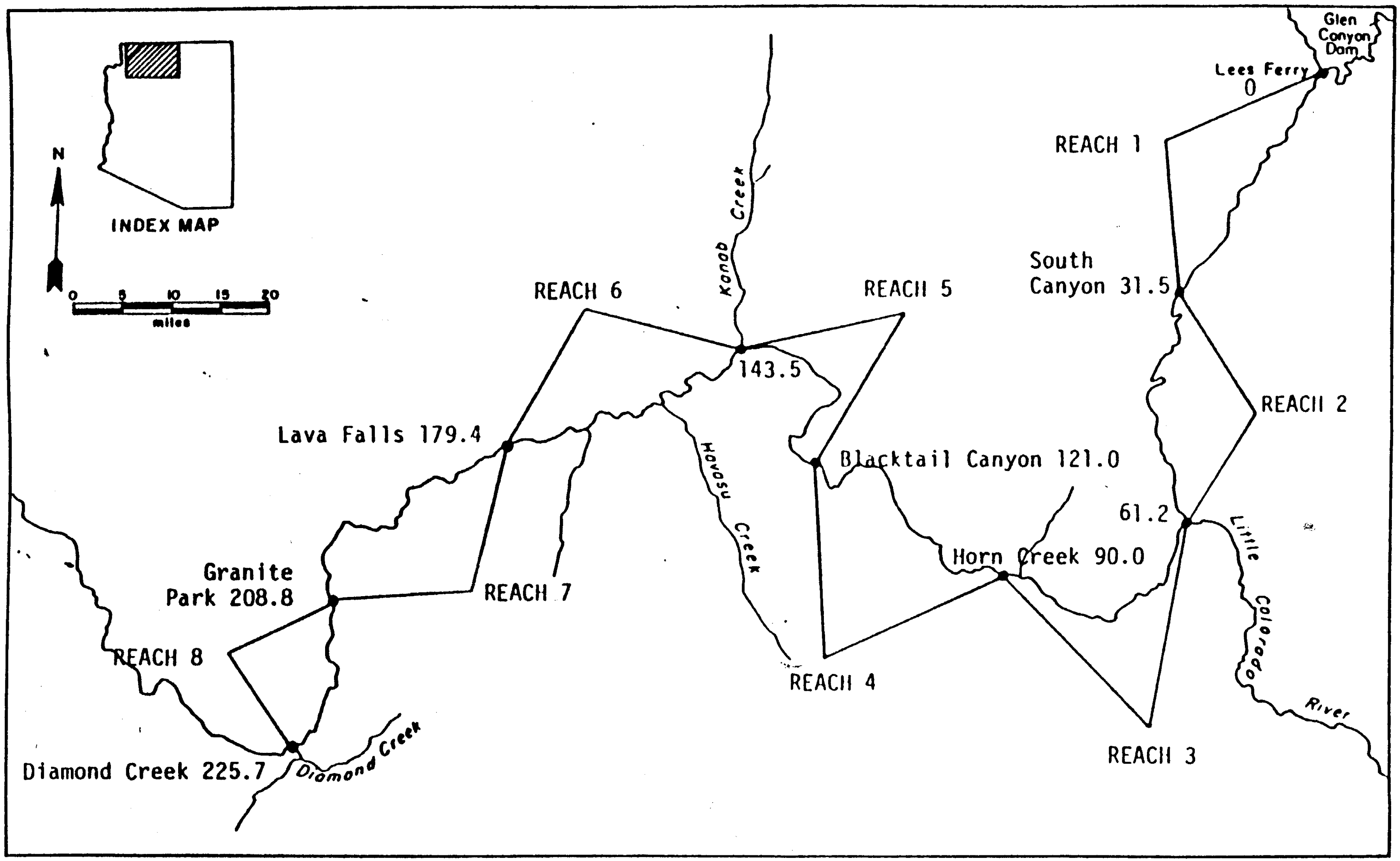

Glen Canyon Dam
Lees Ferry 0
REACH 1
South Canyon 31.5
REACH 2
61.2
Little Colorado River
REACH 3
Horn Creek 90.0
Blacktail Canyon 121.0
REACH 4
REACH 5
143.5
Kanab Creek
Havasu Creek
REACH 6
Lava Falls 179.4
REACH 7
Granite Park 208.8
REACH 8
Diamond Creek 225.7
Diamond Creek
INDEX MAP
N
0 5 10 15 20
miles

TABLE 2
COMPARISON OF EVALUATED CAMPSITE CAPACITY
1990 COLORADO RIVER CAMPSITE INVENTORY

	1987[1]	1988[3]	1989[13]	Stevens[31]	1990
7.9 L Jackass Creek	M	S	L	L	L
19.2 L 19 Mile Canyon	S			S	S
20.6 R Upper North Canyon				S	S
20.7 R Lower North Canyon				L	L
29.2 L Shinumo Wash	M	M	L	S	M
34.7 L Nautiloid Canyon	M	M	M	S	M
53.1 R Lower Nankoweap			L	L	L
58.1 R Awatubi	M	L	L	M	L
61.8 R Lower LCR	S		L		M
64.7 R Carbon Creek	M	M	L	M	L
75.5 L 75 Mile Creek	L	L	L	S	S
81.1 L Grapevine	L	L	L	M	M
93.5 L Monument Creek	S		M	L	L
108.3 L Lower Bass	L	M	L	L	L
120.0 R Upper Blacktail	L	L	L	S	M
122.8 L Upper Forster	L	M	L	L	L
136.6 L Upper Pancho's Kit	L				L
136.7 L Middle Pancho's Kit	M			M	M
136.8 L Lower Pancho's Kit	S			M	L
166.6 L Upper National	L	M		M	M
166.7 L Lower National	L	L	L	L	M
190.2 L	S		S	S	S
194.0 L	L	L	L	M	L
208.8 L Granite Park	L	L	M	L	L

[1] Kalinowski, A., et. al., 1987

[3] Detring, M., 1988

[13] LaChat, 1989

[31] Stevens, 1990

1990 was determined by actually measuring the size of the beaches rather than estimation.

TABLE 3

SHORELINE COMPOSITION
1990 CAMPSITE BEACH SURVEY

	VEGETATION	ROCK	SAND	1989[1]
7.9 L Jackass Creek	5	25	70	60B
19.2 L 19 Mile Canyon	30	60	10	
20.6 R Upper North Canyon	5	75 L	20	
20.7 R Lower North Canyon	0	10 B	90	
29.2 L Shinumo Wash	0	0	100	55B
34.7 L Nautiloid Canyon	0	100 RB	0	50S 50B
53.1 R Lower Nankoweap	90	0	10	40V 40S
58.1 R Awatubi	40	20 RB	40	60S
61.8 R Lower LCR	45	10 R	45	90S
64.7 R Carbon Creek	45	45 B	10	60B
75.5 L 75 Mile Creek	90	0	10	80R
81.1 L Grapevine	0	15 B	85	90S
93.5 L Monument Cr/Granite	90	0	10	65S
108.3 ? Lower Bass	40	10 L	50	70B
120.0 R Upper Blacktail	50	20 L	30	95BL
122.8 L Upper Forrester	80	0	20	
136.6 L Upper Pancho's Kit	0	20 LB	80	
136.8 L Lower Pancho's Kit	80	5 B	15	
194.0 L	90	0	10	
208.8 L Granite Park	30	0	70	60V

[1] Data comes from LeChat, 1989. Data is sketchy at best and shown for comparison purposes only. No other data is available for comparison purposes.

Abbreviations: B = BOULDER R = ROCK L = LEDGE S = SAND V = VEGETATION

1990 CAMPSITE DATA FORM

DATE ________ RECORDER ________ REACH _______ MILE ______ L/R NAME _____________

CAPACITY: SMALL MEDIUM LARGE

Draw map on back if needed.

SHORELINE CHARACTERISTICS

	%	METERS	
VEGETATION	____________	________________	
ROCK	____________	________________	LEDGE, ROCK, BOULDER
SAND	____________	________________	

BEACH CHARACTERISTICS

TOTAL AREA (M}) SAND_______ VEGETATION_______ ROCK_______

AREA WITH SLOPE <5% (M}) SAND_______ VEGETATION_______ ROCK_______

MOORING CHARACTERISTICS

MOTORIZED BOAT: POOR FAIR GOOD EXCELLENT

NON MOTORIZED BOAT POOR FAIR GOOD EXCELLENT

EROSION OF SHORELINE

BEACH EQUILIBRIUM: STABLE UNSTABLE: ADVANCING/RETREATING

__________ ACTIVE CUTBANKS @ _______ M IN HEIGHT

__________ INACTIVE CUTBANKS @ _______ M IN HEIGHT

FLASH FLOOD POTENTIAL: NONE LOW MODERATE HIGH

STREAM POSITION IN RELATION TO BEACH: ABOVE MEDIAL BELOW

INSECT INFESTATION: NONE LOW MODERATE HIGH

USABLE AT HIGH WATER? Y/N APPROXIMATE BEACH PROFILE SLOPE __________ %

DISTANCE FROM SHORE TO CAMPSITE: _________ m SLOPE TO CAMPSITE* _______ %

SHADE DURING SUMMER: NONE MORNING AFTERNOON CONSTANT _____________

* Though data is indicated in percent, recordings are in degrees.

COMMENTS: From the experience of the 1990 survey team, the form below is suggested as a model for subsequent surveys. Gathering this information will standardize beach characteristics, establish minimal data needed, and facilitate yearly comparisons.

RIVER CAMPSITE INVENTORY DATA FORM

DATE ________ RECORDER ________ REACH _______ MILE ______ L/R NAME ____________

Draw map on back if needed.

CAPACITY: SMALL MEDIUM LARGE

TOTAL MOORABLE HIGH WATER SHORELINE LENGTH

SAND _____' VEGETATION _____'(TYPE _______) ROCK _____' LEDGE/BOULDER/ARMOR

BEACH CHARACTERISTICS

TOTAL AREA SAND_______ VEGETATION_______ ROCK_______

USABLE SLEEPING SANDY/VEGETATED AREA WITH SLOPE <5 DEGREES _______

PREDOMINATE VEGETATION TAMARISK WILLOW GRASSES OTHER____________

MOORING QUALITY

POOR/FAIR/GOOD/EXCELLENT MOTORIZED: P F G E NON-MOTORIZED: P F G E

SHORELINE EROSION

BEACH EQUILIBRIUM: STABLE UNSTABLE: ADVANCING/RETREATING

FLASH FLOOD POTENTIAL: NONE LOW MODERATE HIGH

STREAM POSITION IN RELATION TO BEACH: ABOVE MEDIAL BELOW

INSECT INFESTATION: LOW MODERATE HIGH

BEACH PROFILE SLOPE _____DEGREES DISTANCE - SHORE TO CAMPSITE ________'

SHADE DURING SUMMER: NONE MORNING AFTERNOON CONSTANT _____________

COMMENTS:

LITERATURE CITED

Brian, N. and Thomas, J. Colorado River Beach Campsite Inventory, Grand Canyon National Park, Arizona. Colorado River Investigations, Division of Resources Management, Grand Canyon National Park, Arizona, (1984), 47-55.

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LaChat, R., and Pike, C. Grand Canyon Beaches: A Study of Selected Campsites for Suitability. Colorado River Investigations VI, Northern Arizona University (1989), 62-73.

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CHAPTER 13

SOCIOLOGICAL DATA REPORT

PAMELA NYMAN

ABSTRACT

The Northern Arizona University Grand Canyon Research Expedition spent eleven days on the Colorado River. During that time, all contacts with river running groups, individuals along the shore, and aircraft were noted. Numerous contacts were made. Did these contacts make a difference in the quality of the experience to the members of the research team? In terms of contacts, our river trip could be divided into two parts. The first part of the river trip was low in number of contacts; contacts were more numerous in the second part of the trip. Contacts were more noticeable for team members during the second part of the trip.

This river trip was unusual due to the amount of water flow being released through Glen Canyon Dam. When questioned at the end of the trip, it was found that the enjoyment of a majority of the members of the research team were affected by the low water level. Should a more consistent flow of water be released from the dam to heighten the pleasure of river runners? From the perspective of the research team running the river at low water level, regulation would be desirable.

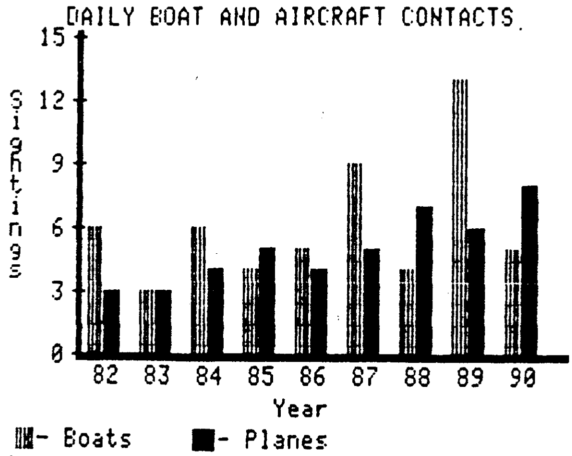
INTRODUCTION

This report summarizes field notes compiled during the Northern Arizona University Colorado River Research Expedition, July 25 through August 4, 1990. To accommodate beach research projects, the Colorado River flow was reduced to 5,000 cfs during a four day period. This study will examine the possibility that the reduced flow impacted river travel by commercial and private river runners.

Comparisons will be made with data from previous NAU research trips with emphasis upon congestion in specific areas of the Colorado River. Data collected from previous studies date back to 1982 which include the number of daily boat contacts, aircraft encounters, attraction point contacts, as well as a log of all beach research and campsite schedules and locations.

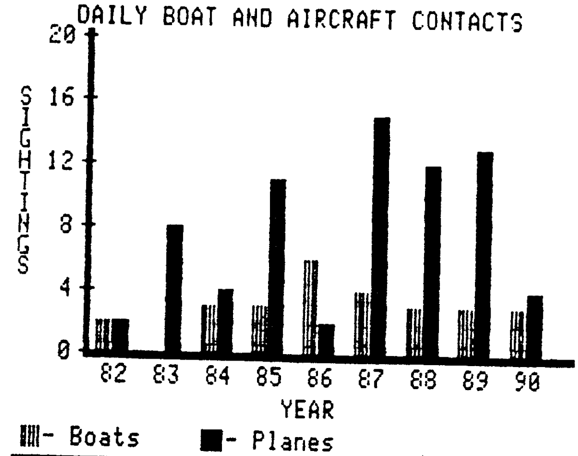
The observer carefully documented every contact during the eleven day trip. Beach position was checked using The Colorado River in Grand Canyon, a Guide (Stevens, 1987).

Figure 1: Summary of Contacts by Day



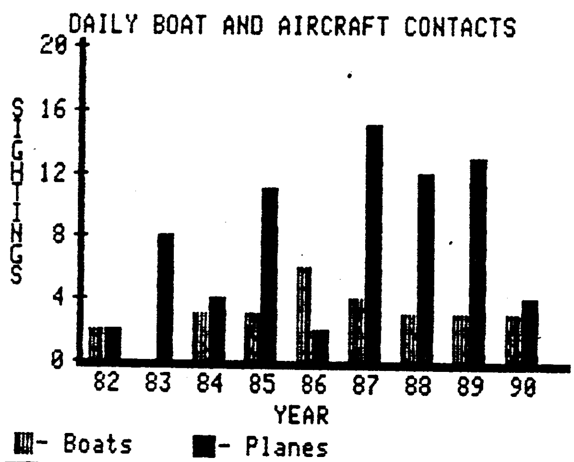
MEAN	6.111111	5	0
MEDIAN	5	5	0
ST. DEV.	3.100179	1.732050	0

Day 1



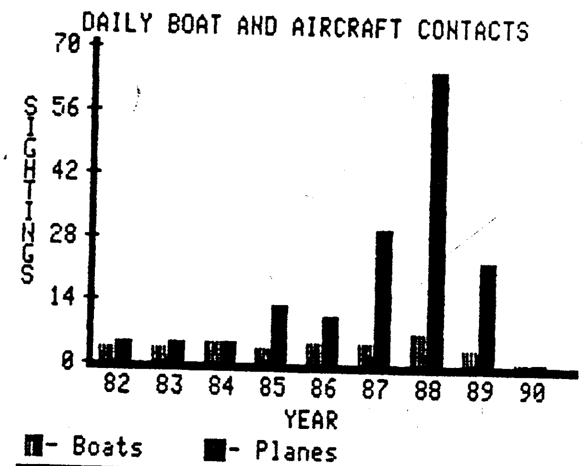
MEAN	3	7.888888	0
MEDIAN	3	8	0
ST. DEV.	1.581138	5.035981	0

Day 2



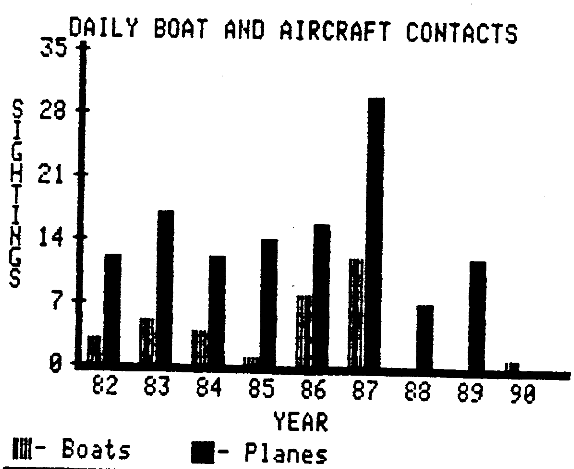
MEAN	3	7.888888	0
MEDIAN	3	8	0
ST. DEV.	1.581138	5.035981	0

Day 3



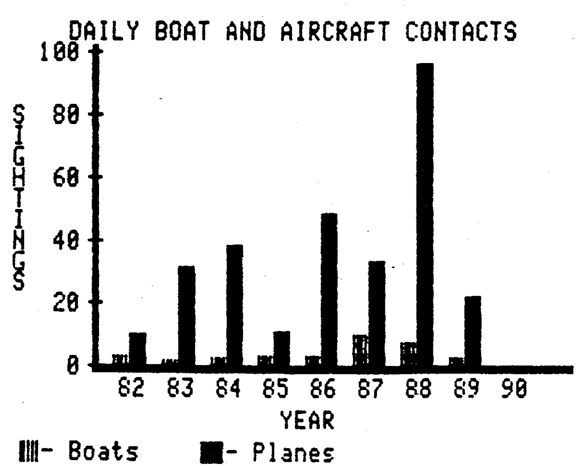
MEAN	4.333333	17.55555	0
MEDIAN	4	11	0
ST. DEV.	1.581138	20.14392	0

Day 4



MEAN	3.777777	13.33333	0
MEDIAN	3	12	0
ST. DEV.	4.055175	8.077747	0

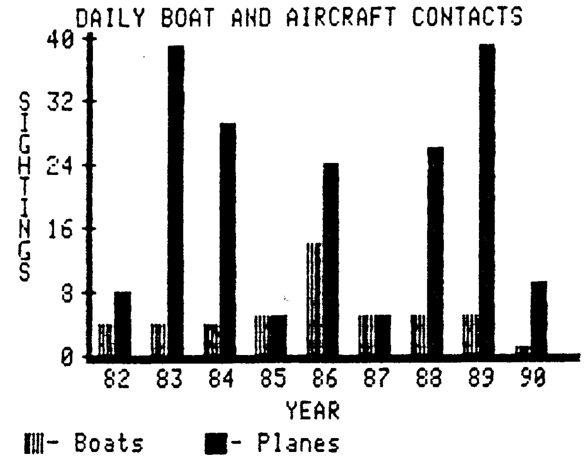
Day 5



MEAN	4.222222	32.55555	0
MEDIAN	4	32	0
ST. DEV.	3.032234	28.46976	0

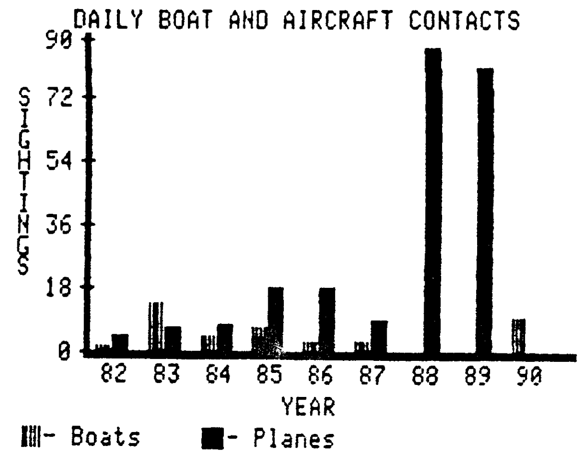
Day 6

Figure 1: <u>Continued</u>



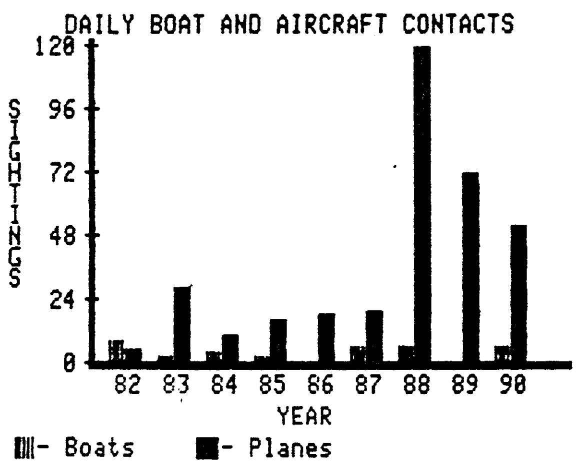
MEAN	5.222222	20.44444	0
MEDIAN	5	24	0
ST. DEV.	3.527668	14.00099	0

Day 7



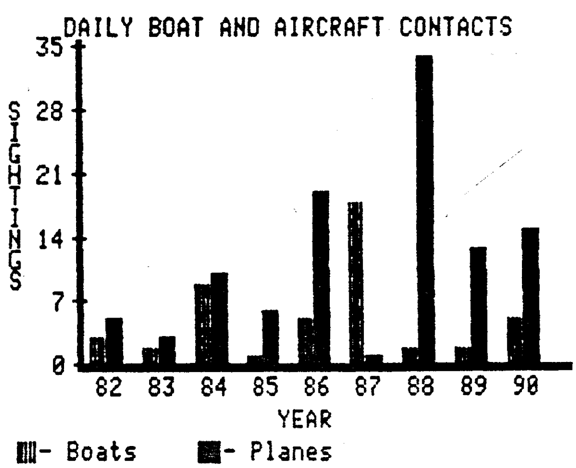
MEAN	4.888888	26.11111	0
MEDIAN	3	9	0
ST. DEV.	4.702245	33.90960	0

Day 8



MEAN	4	37.44444	0
MEDIAN	4	19	0
ST. DEV.	2.598076	37.13862	0

Day 9



MEAN	5.222222	11.77777	0
MEDIAN	3	10	0
ST. DEV.	5.380004	10.20756	0

Day 10

It is important to note that the Canyoneer's motor powered boats used for this research trip have large engines which produce noise. Contact with aircraft was generally based on aircraft engine noise originally, and then a visual contact. Motor noise from the boat may have influenced the contact number in this study. Different results may be possible with oar-powered boats.

TABLE 3. All stops made by research expedition

DAY	MILE	BEACH$	REASON$	TIME
1.000	0.000	LEESFERRY	DEPART	1154.000
1.000	20.000	NORTHCANYON	CAMPSITE	1651.000
2.000	20.000	NORTHCANYON	DEPART	840.000
2.000	29.000	SHINUMO	BEACH RES	1018.000
2.000	29.000	SHINUMO	DEPART	1113.000
2.000	33.000	REDWALLCAV	ATTRACTION	1146.000
2.000	33.000	REDWALLCAV	DEPART	1203.000
2.000	34.700	NAUTILOID	ATTRACTION	1218.000
2.000	34.700	NAUTILOID	BEACH RES	1218.000
2.000	34.700	NAUTILOID	EAT STOP	1218.000
2.000	34.700	NAUTILOID	DEPART	1419.000
2.000	53.000	L.NANKOWEAP	CAMPSITE	1718.000
3.000	53.000	L.NANKOWEAP	DEPART	806.000
3.000	61.500	L.COLORADO	ATTRACTION	1117.000
3.000	61.500	L.COLORADO	DEPART	1232.000
3.000	64.700	CARBONCREEK	CAMPSITE	1435.000
4.000	64.700	CARBONCREEK	HIKE	1004.000
4.000	65.400	CHUAR	DEPART	1025.000
4.000	67.000		BEACH RES	1112.000
4.000	67.000		DEPART	1125.000
4.000	75.400	NEVILLS	EAT STOP	1152.000
4.000	75.300	NEVILLS	DEPART	1249.000
4.000	76.500	HANCE RAPID	WALK AROUND	1423.000
4.000	76.500	HANCE RAPID	DEPART	1609.000
4.000	81.100	GRAPEVINE	CAMPSITE	1658.000
5.000	81.100	GRAPEVINE	DEPART	817.000
5.000	82.000	GRAPEVINERP	BEACH RES	829.000
5.000	82.000	GRAPEVINERP	DEPART	904.000
5.000	88.000	PHANTOM RANC	BEACH RES	955.000
5.000	88.000	PHANTOM RANC	PASSENGER	955.000
5.000	88.000	PHANTOM RANC	DEPART	1120.000
5.000	93.500	GRANITE RAP	BEACH RES	1209.000
5.000	93.500	GRANITE RAP	DEPART	1242.000
5.000	95.800	HERMIT CK	BEACH RES	1335.000
5.000	95.800	HERMIT CK	DEPART	1346.000
5.000	108.300	BASS	BEACH RES	1612.000
5.000	108.300	BASS	CAMPSITE	1612.000
6.000	108.300	BASS	DEPART	846.000
6.000	119.000	BLACKTAIL	BEACH RES	1145.000
6.000	119.000	BLACKTAIL	CAMPSITE	1145.000
7.000	119.000	BLACKTAIL	DEPART	752.000
7.000	122.000	MILE CREEK	BEACH RES	822.000
7.000	122.000	MILE CREEK	DEPART	902.000
7.000	124.000	FOSSIL RAP	BEACH RES	1003.000
7.000	124.000	FOSSIL RAP	DEPART	1032.000
7.000	132.000	STONE CREEK	EAT STOP	1243.000
7.000	132.000	STONE CREEK	DEPART	1355.000
7.000	136.000	DEER CREEK	ATTRACTION	1430.000
7.000	136.000	DEER CREEK	DEPART	1644.000
7.000	136.600	PONCHOS KIT	CAMPSITE	1728.000
7.000	136.600	PONCHOS KIT	BEACH RES	1728.000
8.000	136.600	PONCHOS KIT	DEPART	808.000
8.000	149.000	UPSET RAPID	REST STOP	1108.000

TABLE 3 continued

8.000	149.000	UPSET RAPID	DEPART	1113.000
8.000	156.000	U. HAVASU	EAT STOP	1122.000
8.000	156.000	U. HAVASU	DEPART	1229.000
8.000	157.000	HAVASU CK	ATTRACTION	1239.000
8.000	157.000	HAVASU CK	DEPART	1615.000
8.000	166.600	NATIONAL	CAMPSITE	1700.000
8.000	166.600	NATIONAL	BEACH RES	1700.000
10.000	166.600	NATIONAL	DEPART	821.000
10.000	176.300	SADDLE HRS	REST STOP	1015.000
10.000	176.300	SADDLE HRS	DEPART	1020.000
10.000	179.200	LAVA FALLS	SCOUT	1022.000
10.000	179.200	LAVA FALLS	DEPART	1055.000
10.000	180.000	LAVA FALLS	PASSENGER	1101.000
10.000	182.600	WHITMORE	REST STOP	1140.000
10.000	182.600	WHITMORE	DEPART	1145.000
10.000	.	BLACK ROCK	EAT STOP	1241.000
10.000	.	BLACK ROCK	BEACH RES	1241.000
10.000	.	BLACK ROCK	DEPART	1332.000
10.000	194.000	BOULDER WA	BEACH RES	1402.000
10.000	194.000	BOULDER WA	DEPART	1423.000
10.000	198.000	BOOKOFWORM	TOW BOAT	1519.000
10.000	198.000	BOOKOFWORM	DEPART	1524.000
10.000	208.800	GRANITE PK	CAMPSITE	1722.000
10.000	208.800	GRANITE PK	BEACH RES	1722.000
11.000	208.800	GRANITE PK	DEPART	722.000
11.000	222.000	GRANITE SP	BEACH RES	850.000
11.000	222.000	GRANITE SP	DEPART	909.000
11.000	226.000	DIAMOND CRK	END TRIP	958.000

The research boats made 36 stops. There were 23 research site stops along the river. The river research group travelled in two large Canyoneer's motor powered boats and an eight man oar-powered boat. Forty-one researchers, faculty, staff and boatmen participated in the river trip. In some cases, the oar-powered boat stopped at additional sites for beach research that are not mentioned in this report. Beach research was conducted at all lunch stops. Contacts with boats and aircraft have been shown in Tables 1-3.

METHODS

Field notes were collected in a small notebook containing the following information: day, river mile, location name, miles covered, arrival and departure times, duration of stay, reason for stop, contact size including the number of boats and people, type of group, name of group, type of aircraft, direction of aircraft, and contacts at campsites.

Distinction between commercial river groups, research groups, and private groups were made. Notations were made if a group was encountered earlier in the trip. In this study the observer recorded data on aircraft that were "heard only" as well as visual encounters. Distinctions in aircraft were made based upon the type or number of engines. Research participants aided in data collecting for this study by alerting the observer to aircraft and river travellers.

RESULTS

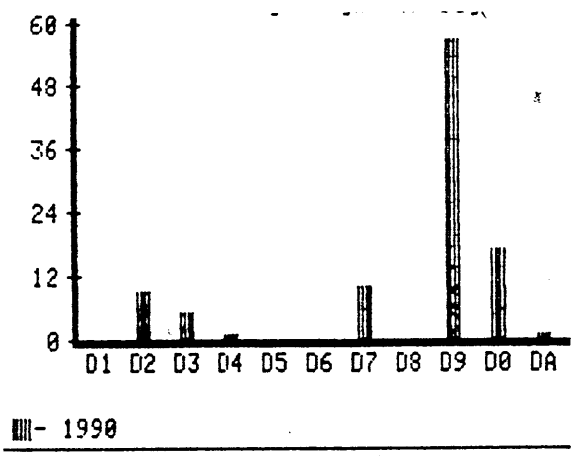
Table 1: Summary of boat encounters

DAY	COMMERCIAL	PRIVATE	RESEARCH	NUMBER
1	60	5	6	71
2	0	23	6	29
3	6	16	12	34
4	0	0	6	6
5	0	22	0	22
6	0	0	0	0
7	0	0	0	0
8	101	105	0	206
9	146	0	0	146
10	88	0	0	88
11	36	0	0	36
Total	437	171	30	638

Table 2: Summary of aircraft encounters

DAY	JET	SINGLE	TWIN	HELICOPTER
1	0	0	0	0
2	2	1	3	1
3	3	0	0	0
4	1	0	0	0
5	0	0	0	0
6	0	0	0	0
7	2	0	4	0
8	0	0	0	0
9	3	2	38	1
10	2	1	10	2
11	1	0	0	0
Total	14	4	55	4

Figure 2: % Aircraft Sightings Per Day



There have been areas in the Grand Canyon that have been consistently used for air traffic. Before 1989, air traffic patterns were not regulated. Beginning in 1989, air corridors were established. Tourist, commercial jets, and private planes now fly in restricted areas and altitudes. The areas of high frequency aircraft contacts have not changed since 1987.

Figure 3: % Airplane Varieties in Canyon

LEGEND	Total
Jets	14
Twin Eng	55
Sing Eng	4
Helicopt	4
Novisual	7

Twin engine planes have out-numbered single engine planes, commercial jets, and helicopters. This observer noticed a consistent flight path over certain areas of the Grand Canyon. National Canyon was one area that had many aircraft encounters. At times, planes crossed the horizon with regularity. Many sightings were less than 1 minute apart. These corridors account for the high numbers of sightings for particular days in the log.

DISCUSSION

The undisturbed and aesthetic nature of the Grand Canyon is an important feature to those who visit it. The data collected throughout the research trip provides a basis of information relating to the quality of experiences of the river runners.

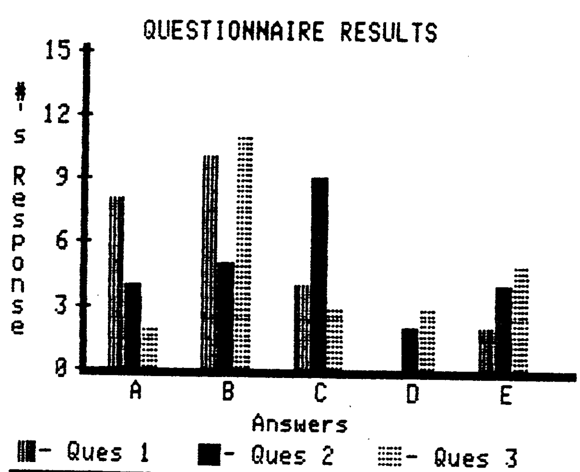
The research group members were given a questionnaire concerning their feelings about a variety of influencing factors on this trip. Some of the factors mentioned in the questionnaire dealt with the number of contacts with boats and planes, the water level of the Colorado River affected by fluctuating discharge from Glen Canyon Dam, and the enhancement of oar versus motorized boat trips.

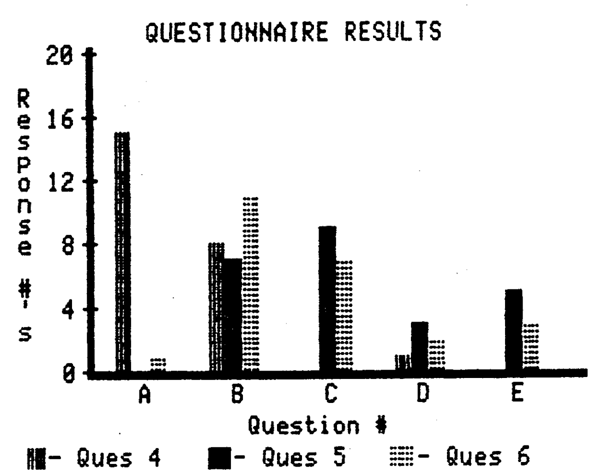
The presence of planes in the canyon did not seem to alter the enjoyment of this group's experience. The number of boat contacts on the first half of the trip were generally not perceived as a distraction to the members of the team; however, the questionnaire indicated that many more members were affected by boat contacts during the high water portion of the trip. Contacts dramatically increased during the high water portion of the trip from the low water portion. The high water contacts number 309 while the low water contacts numbered only 106.

Not only did the lower water level of the Colorado River affect the number of boat contacts, it also affected the enjoyment of 18 out of 24 researchers. This may be due to the difficulty of passage through the rapids from the boatmen's point of view while providing a less exciting ride for the passengers.

A high number of group members, 23 out of 24, reported that oar-powered boats would enhance the recreational river trip and 13 out of 24 stated that research expeditions are best served by the motorized boats.

Figure 4: Summary of Questionnaire Responses





River Trip Experience Questionnaire

Please circle the answer that best represents your experiences on the river trip.

1. Has the low water level affected your enjoyment of the river trip?
   a. strongly agree
   b. agree
   c. disagree
   d. strongly disagree
   e. no opinion

2. Did the presence of planes over the canyon affect your overall enjoyment of the canyon?
   a. strongly agree
   b. agree
   c. disagree
   d. strongly disagree
   e. no opinion

3. Do you think research trips are best served with motorized vehicles like the Canyoneers boats?
   a. strongly agree
   b. agree
   c. disagree
   d. strongly disagree
   e. no opinion

4. Do you think oar-powered boats like the Havasu enhance the recreational river trip?
   a. strongly agree
   b. agree
   c. disagree
   d. strongly disagree
   e. no opinion

5. Did the number of boat contacts in the upper half of the river trip affect your experience on the river?
   a. strongly agree
   b. agree
   c. disagree
   d. strongly disagree
   e. no opinion

6. Did the number of boat contacts in the lower half of the river trip affect your experience on the river?
   a. strongly agree
   b. agree
   c. disagree
   d. strongly disagree
   e. no opinion

REFERENCES

Stevens, L. 1987. The Colorado River in Grand Canyon, a Guide. Red Lake Books, Flagstaff.