TECHNICAL REPORTS FOR GLEN CANYON ENVIRONMENTAL STUDIES LONG-TERM MONITORING PROGRAM

With Accompanying Essay

Conducted by:
Prescott College Students
December 4-30, 1992

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PREFACE

The three-month field course from which these technical reports are an outgrowth is unusual even for Prescott College, unusual in its length, scope and continuity. The inspiration for this exploratory look at the Colorado Plateau stemmed from a desire to offer students an opportunity to become intimately acquainted with this tremendous natural laboratory. Through complete immersion in the landscape, we hoped to foster both an intellectual and an emotional connection to the land and its inhabitants. As instructors for this course, we felt that an integral part of the students' experience would be to involve them in doing science. We believe that a knowledge of how science is done and how it can be used is essential to the foundation of any liberal arts education. Glen Canyon Environmental Studies offered us this opportunity.

Our involvement in the ongoing scientific monitoring studies in Grand Canyon has achieved several important goals. Students learned to employ scientific methodology in the collection of data and completion of their technical reports. Their work has contributed to the scientific database which will be employed in determining how Glen Canyon Dam will be operated in the future. They have witnessed firsthand the changes that a dam can exact upon a riparian ecosystem. This knowledge has helped us place into an historical perspective the political and environmental changes that have occurred on this river system in the 125 years since its initial exploration. Perhaps most importantly, we have learned how scientific information can be applied to critical environmental issues of our time.

It is our belief that an understanding of the uses and limitations of science will stay with these students throughout their lives. Our hope is that cooperative programs such as this one, between scientific agencies and educational institutions, will contribute to the development of a more scientifically and environmentally informed public.

We would like to extend our appreciation to Dave Wegener, Larry Stevens and the staff at GCES for providing this opportunity. We are grateful to Superintendent Robert Chandler and the River Subdistrict at Grand Canyon National Park for approving a permit to undertake this significant endeavor in science and education.

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TABLE OF CONTENTS

INTRODUCTION

Between December 4, and December 30, 1992, students from Prescott College conducted scientific studies on the Colorado River for the Glen Canyon Environmental Studies (GCES). Prescott College is an innovative higher educational institution that embraces experiential education and self-direction as integral parts of the learning process. The Prescott College philosophy recognizes a commitment to the environment with education as a key to understanding the responsibilities of each individual as stewards of the land.

Prescott College's "Re-Exploring Powell's Journey", a three month long environmental studies expedition, was a 735 mile river trip which began at Flaming Gorge Dam in Northern Utah and ended at Pierce Ferry on Lake Mead in Arizona. The group consisted of eleven students and three instructors. The course goals included geological studies, an examination of human impact on the river corridors and an introduction to scientific field methods. The students sought opportunities to conduct scientific research in the pursuit of learning through collecting data, drawing scientific conclusions and organizing this technical report.

The philosophy of the GCES includes a commitment to education as well as research and monitoring the ecosystems of the Colorado River below Glen Canyon Dam. Prescott College students seized the opportunity for hands-on learning by volunteering to collect data for GCES. Their studies included: trout, Bald Eagle and bighorn sheep surveys; air temperatures and weather observations; beach and selected tributary mouth photography; water temperatures for mainstem, backwater and selected tributaries.

This trip was historic for GCES for two reasons. First, it celebrated its ten year anniversary on December 8, 1992. Second, the Prescott College students were the first undergraduate student researchers for GCES. They set the precedent to have future undergraduate students do research for GCES.

DECEMBER BIRD CENSUS WITHIN THE GEOMORPHIC REACHES AND RIPARIAN VEGETATION ZONES OF THE COLORADO RIVER CORRIDOR THROUGH THE GRAND CANYON

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ABSTRACT

Beginning December 4 and ending December 28, 1992, birds were censused at15 sites along the riparian corridor of the Colorado River through Grand Canyon. Data were recorded in both the new high water and old high water vegetation zones at each site, classified by geomorphic reach. The study was composed of 28 transects, each measuring 300 meters in length, in which 21+ species were observed. Although bird community composition differed between the two vegetation zones, bird abundance and species richness were similar. On the other hand, abundance and species richness varied between geomorphic reach types, the wide canyon reaches yielding the greatest number of individuals and species and the narrow canyon reaches consistently yielding the fewest.

INTRODUCTION

The riparian bird community along the Colorado River through the Grand Canyon has been dramatically altered since the completion of Glen Canyon Dam in 1963 (Brown et al. ,1987). The absence of seasonal floods and the lower average river level have provided conditions for the development of riparian vegetation below the pre-dam high water vegetation. The new riparian community has become known as the New High Water Zone (NHWZ) and the pre-dam community as the Old High Water Zone (OHWZ), dominated by *Tamarix chinensis* (Tamarisk) and *Prosopis glandulosa* var. *torreyana* (Mesquite) respectively. A more diverse bird community has moved into the riparian corridor with the development of the NHWZ (Carothers and Brown ,1991).

Between December 4 and December 28 1992, Prescott College students conducted a bird study for Glen Canyon Environmental Studies (GCES) as part of their monitoring program of Glen Canyon Dam and its effects on the Colorado River ecosystem. This study compares bird presence in the NHWZ and OHWZ within each of the 11 geomorphic reaches that compose the Grand Canyon (Schmidt and Graff, 1988). This information can aid in determining abundance and status of the birds using the riparian corridor's changing vegetation zones.

METHODS

During a 26-day oar-powered river trip along the Colorado River through the Grand Canyon, data were collected from within the NHWZ and OHWZ. For the purposes of this study, the NHWZ and OHWZ boundaries

were defined following description by Carothers and Brown (1991) and Brown, Carothers and Johnson (1987). The upper and lower boundaries of the NHWZ corresponds with the upper and lower limits of Tamarisk at each site. Above mile 39, the upper boundary of the OHWZ corresponds with the uppermost *Celtis recticulata* (Netleaf Hackberry), *Fallugia paradoxa* (Apache Plume) and/or *Cercis occidentalis* (Redbud). Below mile 39, the uppermost boundary of the OHWZ corresponds with the uppermost growth of mesquite at each site.

One pair of belt transects was conducted in the NHWZ and OHWZ at 15 individual sites. Transects measured 300 meters in length and varied in width according to the width of the individual NHW/OHW vegetation zones. Efforts were made to conduct the transects during the time of day in which the height of bird activity occurred. As a result, the time of study and location of sites varied with weather, itinerary and qualitative observation, but with one exception were completed by 1:00 pm. Time of observation within each transect varied from 20-60 minutes.

The method for determining transect locations was changed during the study. Initially, the one-hundredth second timer of a digital watch was used to determine the number and direction (upstream or downstream) of paces to the beginning points of each transect. From these points, the transects were conducted simultaneously and in a downstream direction. This method necessarily created staggered, parallel transects (see figure 2). During the first two transects, those of mile 8 and mile 20.5, the activities of workers in one transect appeared to interfere with bird observations for the adjacent transect. As a result, the methodology for determining the transect beginning points was changed.

From mile 35.5, NHWZ and OHWZ transect beginning points were no longer independently chosen, but placed such that they diverged from each other and from sidestream/current camp influence (see figure 3). In cases where only one direction of travel was possible, transects were placed parallel to each other such that NHWZ and OHWZ transects began and ended at the same location along the river corridor (see figure 4).

The following data were recorded at each site: date, beginning and ending time, river mile (Stevens, 1987), weather conditions, names of workers involved, vegetation characteristics, bird species present -- following AOU standard common names, and the numbers and activities of birds within each 10 meter segment of each transect. One worker for each transect recorded data and kept track of meters travelled by pacing, while two to three workers observed bird activity.

RESULTS

Names and numbers of all birds observed in the 28 transects are compiled in table 2. At least 21 species and 235 individuals were encountered. As this number is a conservative estimate, the total numbers actually observed is suspected to be greater.

The total species richness and abudance within each reach and vegetation zone (NHWZ and OHWZ) are shown in figures 5 and 6. Of 27 possible species observed, five occurred only in the OHWZ, seven occurred in only the NHWZ, and 15 occurred in both zones. Great Blue Heron, Hairy/Downy? Woodpecker, Say's Phoebe, Violet-green Swallow, American Dipper?, American Pipit, and Song Sparrow, were seen only in the NHWZ. Verdin, Bewick's Wren?, Loggerhead Shrike, Rufous-crowned Sparrow, and Meadowlark? were observed only in the OHWZ. Total abundance (total number of individual birds observed) ranged from 131-160 in the NHWZ, and 104-111 in the OHWZ.

Birds did not appear to be equally distributed among the 11 geomorphic reaches. No birds were encountered in three of the "gorge" reaches (#8,9,11). Only a single species was observed in four reaches (#1,3,6,7), with no more than three individuals observed in any one. Reach #2 contained three species and three individuals, and #5 contained six+ species (20-21 individuals).

The two most open reaches, #4 and #10, contained the highest abundance and species richness. Reach #4 contained 17+ species (123-143 individuals) and #10 contained 16+ species (81-96 individuals).

Distribution of the species observed in at least three transects are shown in figures 7 and 8. Only 10 species were observed in more than two transects: Red-naped Sapsucker, Say's Phoebe, Common Raven, Bushtit, Rock Wren, Canyon Wren, Ruby- crowned Kinglet, White-crowned Sparrow, Dark-eyed Junco, and House Finch. Dark-eyed Juncos were the most abundant species encountered with a total number of 52-67 individuals. The next most abundant species were the Ruby-crowned Kinglet (32-38), Bushtit (30-34) and White-crowned Sparrow (17-22). Common Ravens, Rock Wrens and Ruby-crowned Kinglets were observed the most consistently (in more geomorphic reaches) than any other species. Of those, the Ruby-crowned Kinglet was by far the most abundant. The other species were more patchily distributed along the length of the Canyon (in fewer reaches). Canyon Wrens were the most consistently observed species above Lower Marble Canyon (#4), but were not seen below that reach.

DISCUSSION

The actual December bird population of Grand Canyon's riparian corridor cannot be concluded based on this study. However, our results are somewhat congruent with Stevens' (1987) river guide bird list and Brown et al.'s (1987) description of the winter bird community in the same location. With the exception of Say's Phoebe sightings, all of the species encountered in at least three of the 28 transects are listed as abundant or common by Stevens (1987). Likewise the species most commonly observed during this study fit the description of the riparian corridor winter birds given in (Brown et al., 1987). According to both sources, we might

expect Mountain Chickadees and Black Phoebes to be more commonly observed. However, we observed Mountain Chickadees within only one reach, and had one possible sighting of a Black Phoebe.

Abundance and species richness were similar for both the NHWZ and OHWZ. However, the composition of species in each zone was somewhat different. Say's Phoebes, White-crowned Sparrows and Dark-eyed Juncos were observed primarily in the NHWZ. Bushtits were observed primarily in the OHWZ. Ruby-crowned Kinglets were observed in both zones in approximately equal numbers (see figure 7). Personal observations outside of this study, yet conducted at the same time, do not completely concur with these results (see appendix A). Although data show that Dark-eyed Juncos and White-crowned Sparrows are more numerous in the NHWZ, flocks of both species were casually observed moving in and out of both zones at miles 209-L and 43.7-L.

Abundance and species richness varied from reach type to reach type (figures 5 and 6). Reaches #2,3,6,7,8,9, and 11 are all characterized as narrow (Schmidt and Graf, 1988) and contained no more than three species or individuals within each. Reaches #1,4,5,and 10 are characterized as wide and, with one exception, contained at least five species and 20 individuals. Reach #1, the exception, was the only wide reach upriver from the mesquite/acacia riparian community. This factor, along with inclement weather could possibly account for the low number of bird observations in this reach (for concurrent casual bird observations within this reach see appendix A). Wide reaches tended to have more extensive riparian vegetation, providing a more condusive habitat for birds (Carothers and Brown, 1991). The NHWZ and OHWZ sections of the narrow reaches were limited by cliffs and steep slopes, thus limiting riparian vegetation growth. This factor also limited availabilty and length of transect sites. The few species observed in the narrow reaches also commonly observed througout the canyon, were Common Raven, Rock Wren, Canyon Wren, and Ruby-crowned Kinglet.

We have found three primary problems with this study. The amount of time spent and the number of transects conducted in each reach were inconsistent to itinerary constraints. Therefore, comparison of data between reaches may not be valid. For example, the reaches in which the most bird observations occurred were also those in which more than one transect was conducted.

Second, the NHWZ and OHWZ vegetation commmunities within a given reach vary in composition, extent and structure. Bird communities are partially controlled by these factors (Carothers and Brown, 1991). Transect sites selected were not necessarily represenative of the range of vegetation found within a given reach and are therefore not necessarily represenative of the bird community within that reach. For example, throughout our travel downriver, we casually observed Say's Phoebes in all of the reaches characterized as wide (#1,4,5, and 10), and several of the narrow reaches (#2,6,8,and 9)(appendix A). However, this study only recorded Say's Phoebes in 2 reaches (figure 8).

Third, because transects were randomly selected, they were not necessarily conducted at the most represenative area within a given site. For example, at mile 171.5-L, casual observation revealed that Rufous-crowned Sparrows, Say's Phoebes and Bushtits were active in the OHWZ adjacent to and downstream of camp, where OHWZ vegetation was well developed. However, the random selection process dictated that the OHWZ transect be conducted upstream of camp where OHWZ vegetation was scarce. During the transect itself no birds were observed. Also, at mile 136.7-L in Reach #8, Yellow-rumped Warblers, Ruby-crowned Kinglets and an unidentified woodpecker were casually observed throughout our stay. However, the random selection process dictated that the NHWZ transect be conducted on a narrow talus slope where no birds were observed.

In order to avoid the problems encountered by this study, the following methodological changes may be useful. Instead of randomly and/or opportunistically selecting transect sites, they should be systematically selected in order that the transects are conducted in represenative vegetation. The transects should be repeated at more than one site within each geomorphic reach so that a more complete bird census is obtained. Finally, the time spent conducting each transect should be standardized.

ACKNOWLEDGEMENTS

We would like to thank GCES for providing the permit, food, boats and other physical support needed for this project. This study was conducted with the assistance of the entire Prescott College Powell Expedition course. This paper was edited with the help of Carl Tomoff. However, any errors are entirely our responsibility.

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Table 1. Geomorphic Reaches of the Grand Canyon

Reach #	Name of Reach	River Miles	Canyon Width
1	Permian section	0.0 - 11.0	Wide
2	Supai Gorge	11.1 - 22.5	Narrow
3	Redwall Gorge	22.6 - 40.0	Narrow
4	Lower Marble Canyon	40.1 - 61.5	Wide
5	Furnace Flats	61.6 - 77.4	Wide
6	Upper Granite Gorge	77.5 - 117.8	Narrow
7	Aisles	117.9 - 125.5	Narrow
8	Middle Granite Gorge	125.6 - 139.9	Narrow
9	Muave Gorge	140.0 - 159.9	Narrow
10	Lower Canyon	160.0 - 213.8	Wide
11	Lower Granite Gorge	213.9 - 225	Narrow

After Schmidt and Graf (1988)

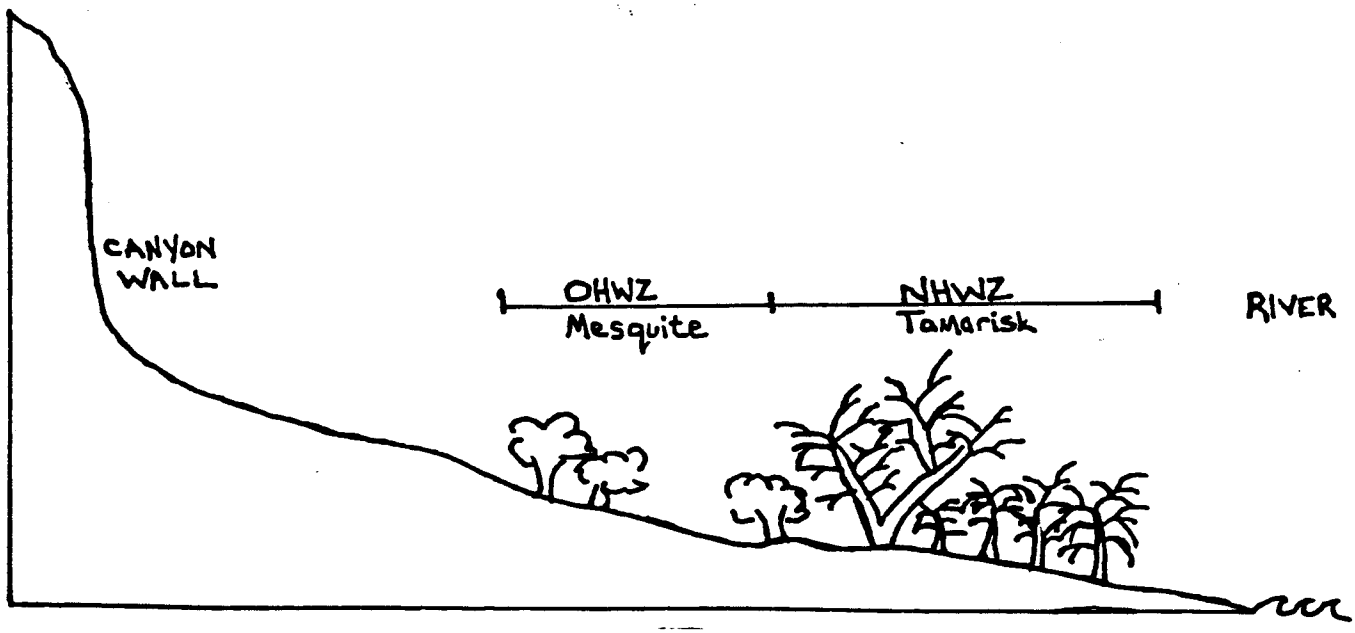

Fig.1. Adapted from Carothers and Brown (1991). Description of New High Water Zone (NHWZ) and Old High Water Zone (OHWZ) as defined by limits of Tamarix chinensis (Tamarisk) and Prosopis glandulosa var. torreyana (Mesquite) respectively.

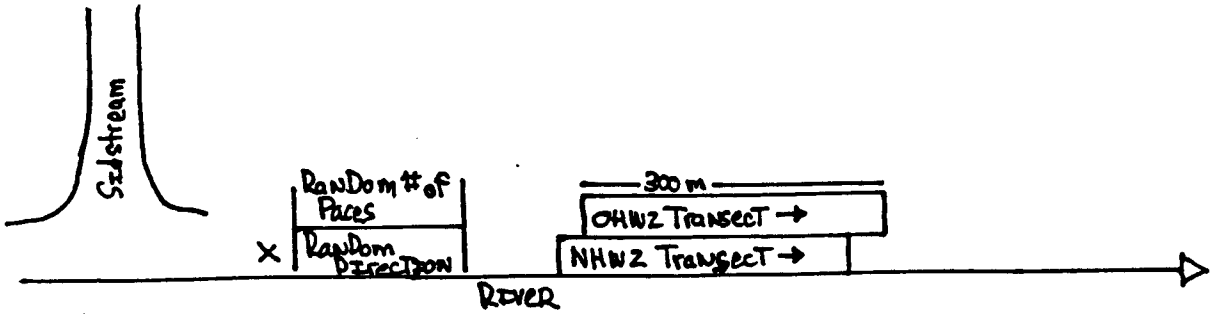

Fig. 2. Initial method for selecting transect location; X – boat landing site; → – direction in which transect was conducted; N/OHWZ – New/Old High Water Zone

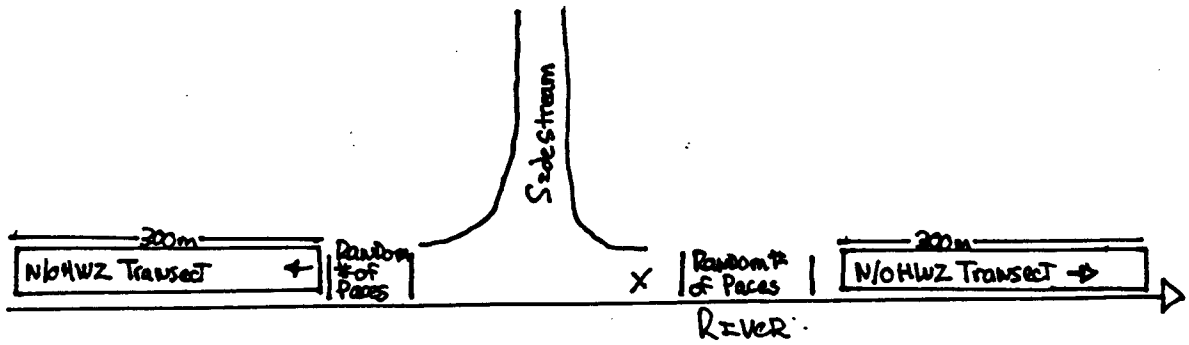

Fig. 3. Revised method for selecting transect location; X – boat landing site; → – direction in which transect was conducted; N/OHWZ – New/Old High Water Zone

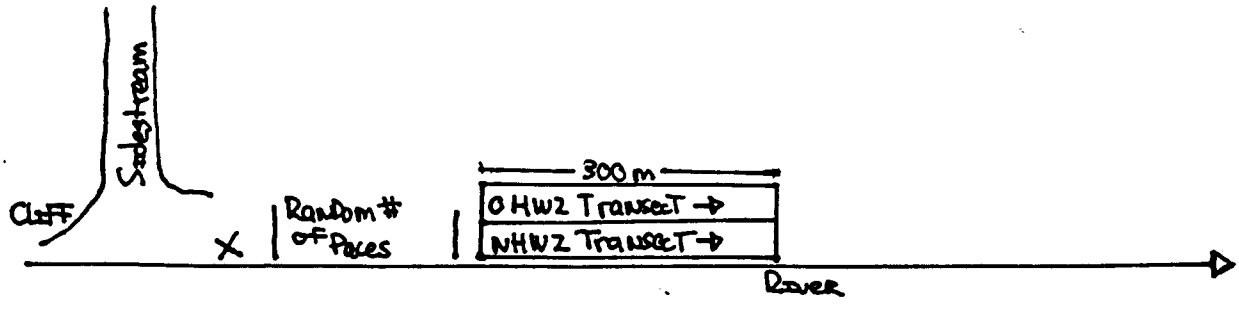

Fig. 4. Method for selecting transect location when only one direction of travel was possible; X - - boat landing site; → – direction in which transect was conducted; N/OHWZ – New/Old High Water Zone

Table 2. Species and abundance of birds observed in new and old high water zones in 11 reaches of the riparian corridor of the Colorado River from Lees Ferry to Lake Mead from December 4 - 20, 1993

REACH	#1		#2		#3		#4				#5		#6		#7	
River Mile	8-L		20.5-R		35.5-L		43.7-L		53-R		69.5-R		95-R		120-R	
NHWZ/OHWZ	N	O	N	O	N	O	N	O	N	O	N	O	N	O	N	O
Great Blue Heron									1							
Red-naped Sapsucker								1	1	1						
Hairy/Downy? Woodpecker									1							
Black Phoebe?																
Say's Phoebe			1?													
Violet-green Swallow																
Common Raven							2-3				2	3				2
Mountain Chickadee							1?	7								
Verdin																
Bushtit							3-7	10		~17						
Rock Wren									1			1	1	1		
Canyon Wren	1	2			1		2	1	1							
Bewick's Wren?																
American Dipper?			1?													
Ruby-crowned Kinglet			1				1-2	3	5	8-12	4	1				
Western Bluebird																
American Pipit											5-6					
Phainopepla																
Loggerhead Shrike										1?						
Yellow-rumped Warbler																
Rufous-crowned Sparrow										2						
Song Sparrow											2					
White-crowned Sparrow							1			1						
Sparrow spp.									2	4						
Dark-eyed Junco							30-40			10						
Meadowlark?										1						
House Finch										1						
unidentified passerine									3		2					
TOTAL INDIVIDUALS	1	2	3	0	1	0	40-56	22	15	46-50	15-16	5	1	1	0	2
TOTAL SPECIES	1	1	3	0	1	0	7	5	7+	10	4+	3	1	1	0	1

N – New HIgh Water Zone; O – Old High Water Zone; ? – not a positive identification

Table 2. continued

Reach #	#8		#9		#10								#11		TOTAL
River Mile	136.7-L		157-L		171.5-L		188-R		209-L		209-L		237-R		INDIVIDUALS
NHWZ/OHWZ	N	O	-	O	N	O	N	O	N	O	N	O	N	-	PER SPECIES
Great Blue Heron															1
Red-naped Sapsucker															3
Hairy/Downy? Woodpecker															1
Black Phoebe?											1?				1?
Say's Phoebe					1		1?				2				3-5
Violet-green Swallow									1						1
Common Raven							1								10-11
Mountain Chickadee															7-8
Verdin										1					1
Bushtit															30-34
Rock Wren											1	2			7
Canyon Wren															8
Bewick's Wren										1					1?
American Dipper?															1?
Ruby-crowned Kinglet							2	2-3	2	2		1			32-38
Western Bluebird										4	8				12
American Pipit															5-6
Phainopepla										3	1-2				4-5
Loggerhead Shrike										1					1-2
Yellow-rumped Warbler								2			1-2				3-4
Rufous-crowned Sparrow															2
Song Sparrow															2
White-crowned Sparrow											15-20				17-22
Sparrow spp.															6
Dark-eyed Junco										2	10-15				52-67
Meadowlark?															1?
House Finch									2	1					4
unidentified passerine							2	1	2	3	2				15
TOTAL INDIVIDUALS	0	0	-	0	1	0	6	5-8	7	18	41-53	3	0	-	81-96
TOTAL SPECIES	0	0	-	0	1	0	3+	2+	3+	8+	8+	2	0	-	27+

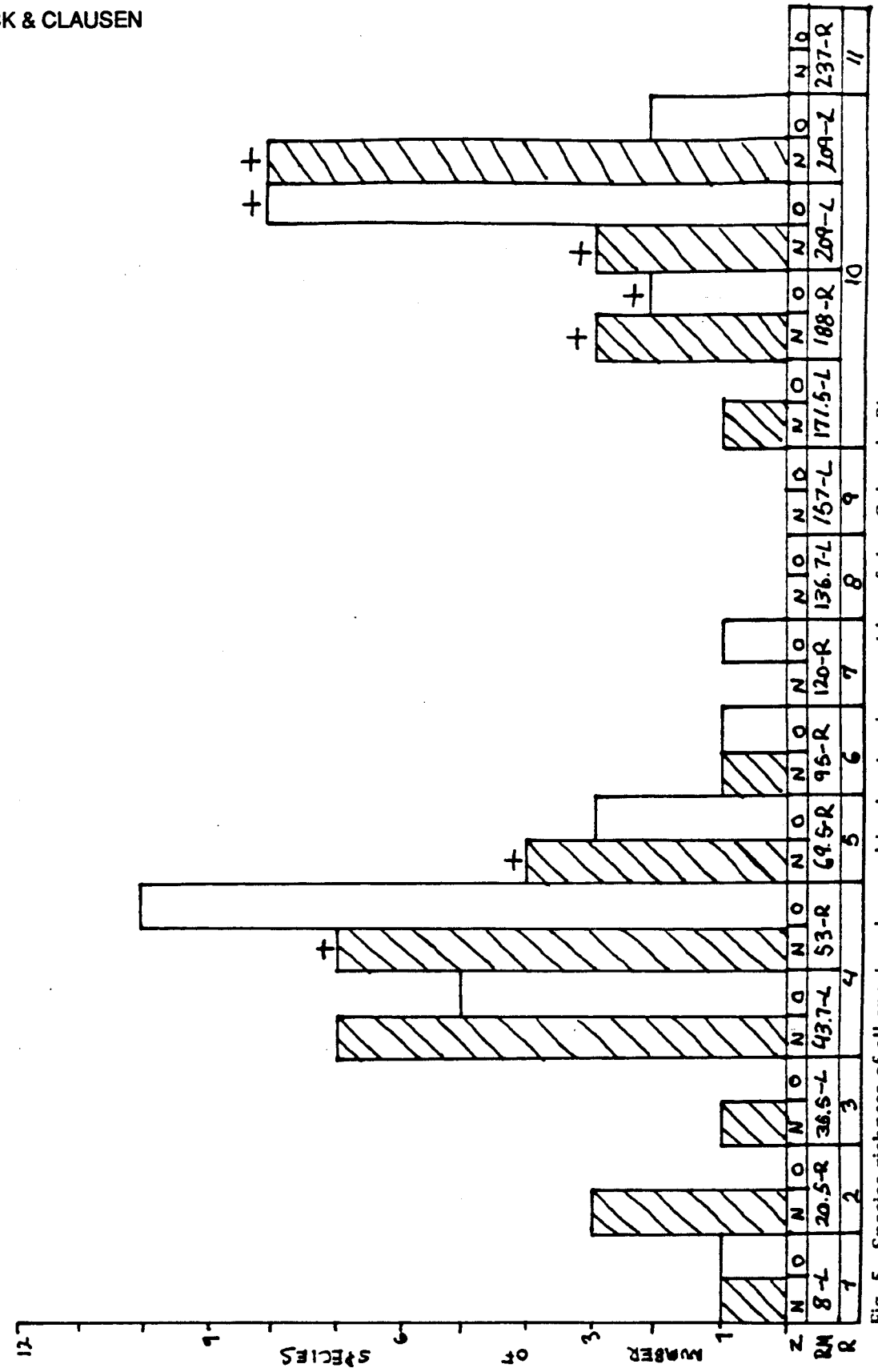

Fig. 5. Species richness of all species observed in the riparian corridor of the Colorado River from Lees Ferry to Lake Mead between December 4 - 20, 1992. Z: N – New High Water Zone, O – Old High Water Zone; RM – River Mile Left or Right (Stevens 1987); R – Reach #

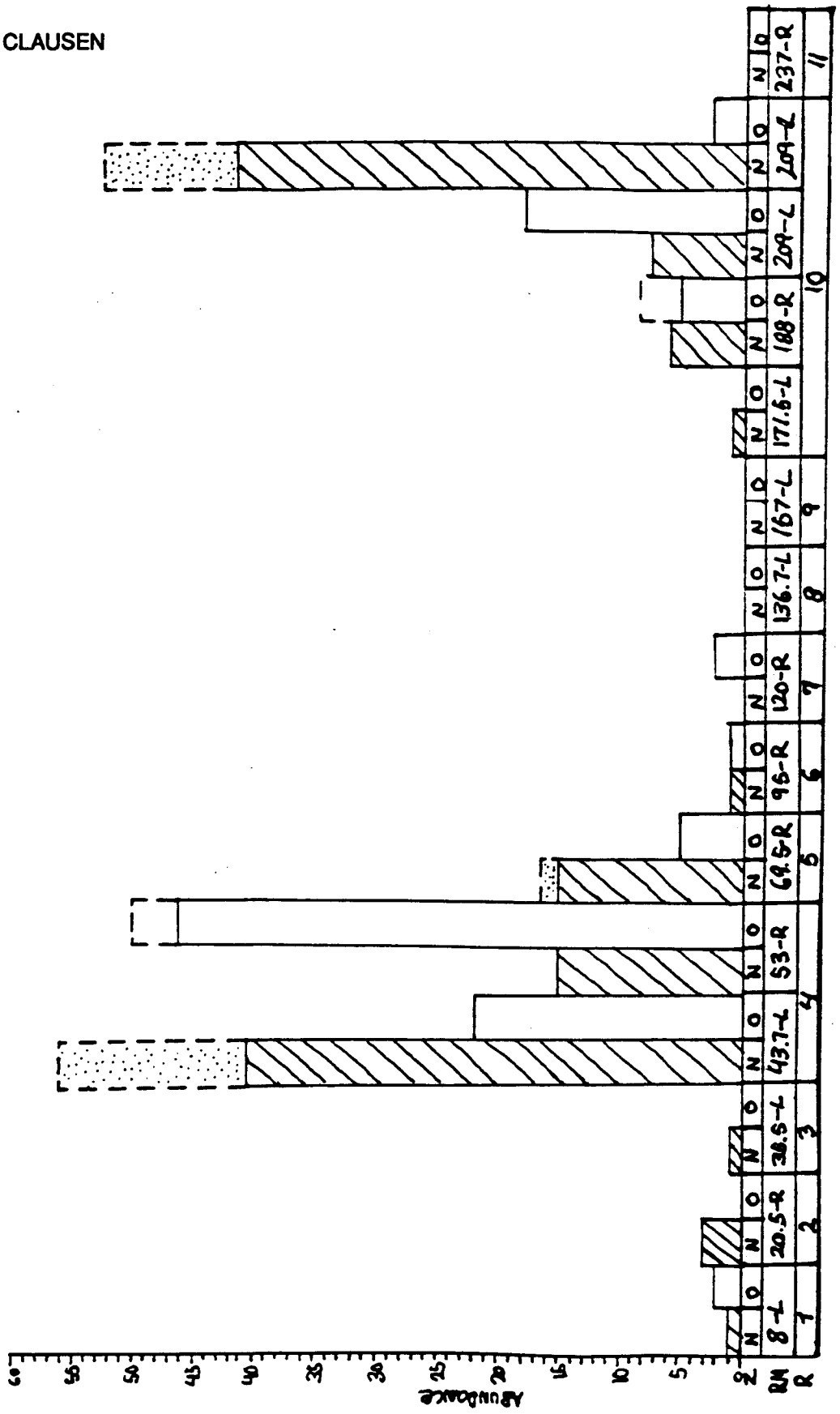

Fig. 6. Abundance of all species observed in the riparian corridor of the Colorado River from Lees Ferry to Lake Mead between December 4 - 28, 1993. Z: N – New High Water Zone, O – Old High Water Zone; RM – River Mile Left or Right (Stevens 1987); R – Reach #

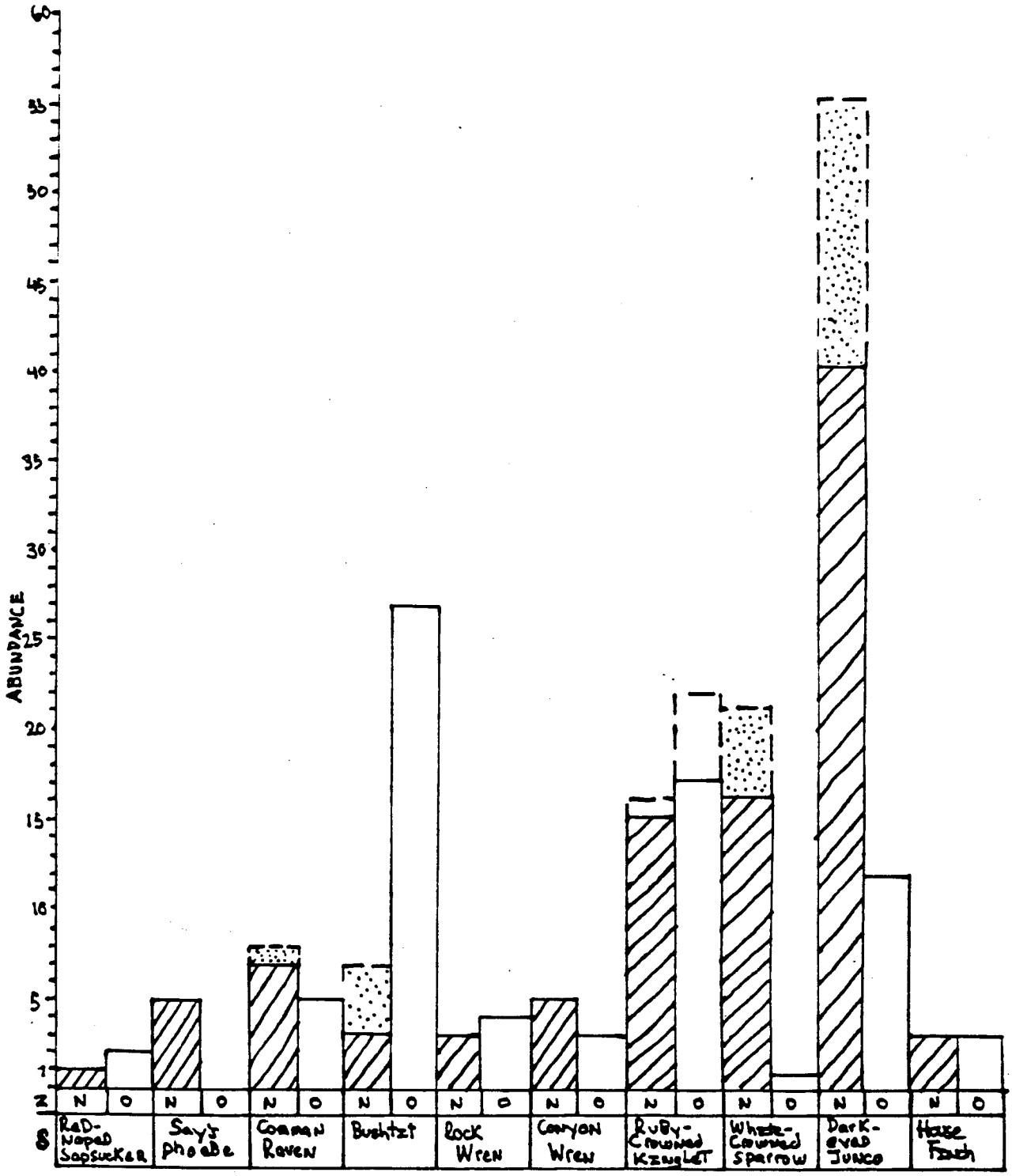

Fig. 7. Abundance and habitat selection by species observed in at least 3 transects in the riparian corridor of the Colorado River from Lees Ferry to Lake Mead between December 4 - 20, 1992. Z: N – New High Water Zone, O – Old High Water Zone; S – Species

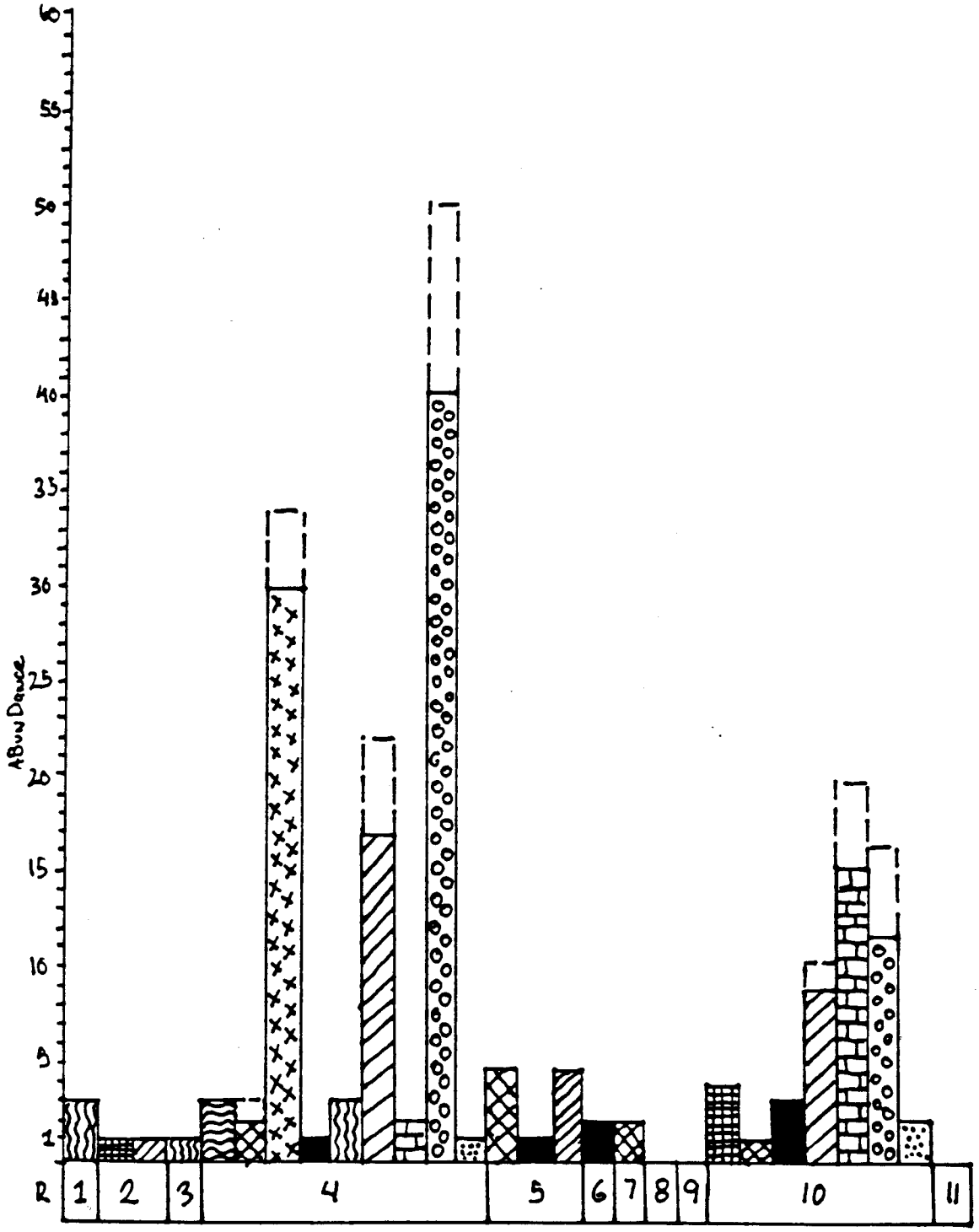

Fig. 8. Abundance and distribution of birds observed in at least 3 transects in the riparian corridor of the Colorado River from Lees Ferry to Lake Mead between December 4 - 20, 1992. R - Reach# - Canyon Wren; - Say's phoebe; - Ruby-Crowned Kinglet; - Red-Naped Sapsucker; Common Raven; Bushtit; Rock Wren; White-crowned Sparrow; Dark-eyed Junco; House Finch.

Appendix A. CASUAL BIRD OBSERVATIONS* ALONG THE COLORADO RIVER THROUGH GRAND CANYON, DECEMBER 4 - 28, 1992.

SPECIES/DATE	TIME OF SIGHTING	RIVER MILE	# INDIVIDUALS	COMMENTS
Northern Harrier				
7/12/92	0920	31.6	1	flying
10/12/92	1420		1	flying
Osprey				
17/12/92	1015-1630	104-120	1	
Red-tailed Hawk				
4/12/92	1100-1600?	2-8	1	soaring
5/12/92	1020-1645	8-20.5	1	soaring other sightings not noted
Golden Eagle				
16/12/92	0915-1630	93.5-104	1	soaring other sightings not noted
American Kestrel				
8/12/92	1120-1525	44-52	1	soaring other sightings not noted
Peregrine Falcon				
22/12/92	afternoon	130	1	flying upstream

* not all bird observations are included in this list. Observations recorded as part of the waterfowl study, Bald Eagle study and/or passerine bird study are not included. Other casual observations may not have been noted.

SPECIES/DATE	TIME OF SIGHTING	RIVER MILE	# INDIVIDUALS	COMMENTS
Red naped Sapsucker?				
Hairy/Downy Woodpecker?				
19/12/92	1107-1205	136.7-L	1	NHWZ
Say's Phoebe				
4/12/92	1100-1600	~2-7	3	NHWZ; observed from boats
5/12/92	1020-1645	8-20.5		feeding onshore
7/12/92	1120-1535	44-52		
14/12/92	1045	69		feeding onshore
15/12/92	~0915	81.5	2	
20/12/92	1000-1630	136.5-151	1	feeding
20-21/12/92		140-159.9	1+	
22/12/92	0830	171.5	2	OHWZ
Common Raven				
4/12/92	1100-1600	2-7	1	air; from boats
7/12/92	0940-1700	31.5-43.5	2	
observed througout canyon				most sightings not noted
Bushtit				
5/12/92	1030-1130	8-20.5	several	NHWZ
6/12/92	~1000	20.5-R	17	NHWZ
9/12/92	0900-1200	53-R	20+	OHWZ
10/12/92	1001-1048	53-R	several	OHWZ
22/12/92	0900-1010	171.5	~22+	OHWZ
23-26/12/92	throughout day	209-L	100+	OHWZ and above

SPECIES/DATE	TIME OF SIGHTING	RIVER MILE	# INDIVIDUALS	COMMENTS
Ruby-crowned Kinglet				
6/12/92	~1000	20.5-R	1	OHWZ
7/12/92	0940-1700	31.5-43.5	2	OHWZ
7/12/92	1320	35.5-L	1	NHWZ
8/12/92	0900-0930	43.7-L	5+	Tamarisk and Mesquite
8/12/92	1025-1107	43.7-L	3	Mesquite
10/12/92	1001-1048	53-R	no count	OHWZ
19/12/92	1400-1500	136.7-L	no count	NHWZ and OHWZ
23/12/92	0949-1050	188-R	1	NHWZ
American Pipit				
23-26/12/92	throughout day	209-L	no count	air; above riparian
Yellow-rumped Warbler				
19/12/92	1107-1205	136.7-L	4	NHWZ
26/12/92	1050-1150	209-L	2+	NHWZ
Rufous-crowned Sparrow				
4/12/92	~0900	0-R (Lees Ferry)	1	OHWZ
8/12/92	0923	43.7-L	1	NHWZ
22/12/92	~0900	171.5-L	2	OHWZ
White-Crowned Sparrow				
5/12/92				
9/12/92	0915	8-L	2	NHWZ and OHWZ
23-26/12/92	0900-1200	53-R	1	OHWZ; immature
	throughout day	209-L	3+ flocks	NHWZ & OHWZ

SPECIES/DATE	TIME OF SIGHTING	RIVER MILE	# INDIVIDUALS	COMMENTS
Rock Wren				
5/12/92	1130	8	2	OHWZ
6/12/92	1000-1530	20.5-31.5	3	rock wall
6/12/92	0920-0955	20.5-R	1	scour zone
10/12/92	1120-1500	52-61.5		
20-21/12/92		140-159.9	several	on rock walls
21/12/92	1014-1040	157-L	1	
28/12/92	1012-1045	237-R	2	
Canyon Wren				
5/12/92	1020-1645	8-20.5	10	
6/12/92	0920-0	20.5-R	1	OHWZ
6/12/92	1000-1530	20.5-31.5	abundant	NHWZ
7/12/92	0940 1700	31.5-43.5		
7/12/92	1250-1310	35.5-L	2+	NHWZ
20-21/12/92		140-159.9	several	
Bewick's Wren				
25/12/92	AM	209-L	1	OHWZ
American Dipper				
5/12/92	1020-1645	8-20.5	3	scour zone
8/12/92	1120-1525	44-52	1	feeding near shore
15/12/92	1600	92	1	

SPECIES/DATE	TIME OF SIGHTING	RIVER MILE	# INDIVIDUALS	COMMENTS
Dark-eyed Junco				
5/12/92	1030-1130	~8-12	several	NHWZ
8/12/92	0900	43.7-L	30-75+	flocks moving between 2 zones OHWZ and NHWZ
9/12/92	0900-1200	53-R	20+	NHWZ
12/12/92	1045-1145	69.5-R	6	
Great-tailed Grackle				
4/12/92	~1100	0-R (Lees Ferry)	1	at boat ramp
House Finch				
9/12/92	0900-1200	53-R	1	OHWZ

A WATERFOWL SURVEY OF THE COLORADO RIVER IN THE GRAND CANYON FOR DECEMBER, 1992

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ABSTRACT

During a 27 day December 1992 river trip in the Grand Canyon along the Colorado River, observations of waterfowl were recorded for the Glen Canyon Environmental Studies. A group of Prescott College student researchers collected this data. A total of 16 species were seen for the entire trip. The Permian geomorphic reach had the highest diversity of waterfowl in Grand Canyon National Park. Lees Ferry, at the beginning of the Permian reach, is the first moving water on the southward migration for nearly 200 miles. The steep walled gorges tended to have less species richness and number of individuals than the reaches where the canyon was more open.

INTRODUCTION

Between December 4 and December 30, 1992, Prescott College student researchers observed waterfowl on the Colorado River through the Grand Canyon from Lees Ferry [mile 0] to the Grand Wash Cliffs [mile 277]. Previous research on birds of the Colorado River through Grand Canyon has been conducted by Brown, Carothers and Johnson (1987) who have compiled a synthesis of birding history in the Grand Canyon.

The Colorado River acts as a significant riparian corridor for migratory waterfowl. These data on waterfowl will assist resource managers in operations of Glen Canyon Dam. Data gathered will become part of a long term monitoring program conducted by the Glen Canyon Environmental Studies.

METHODS

A daily waterfowl species log was kept over a 27 day Colorado River trip between Lees Ferry and Pierce Ferry. Observations were made only while moving down river on the rafts. We rafted a total of 19 days. Rate of encounter was determined by dividing the number of individuals seen by the total amount of time spent observing in each geomorphic reach. Four designated observers participated on the boats. Three workers identified and counted waterfowl as one worker recorded data. Data collected included; species identification, sex of the individuals, number of indivduals, behavior, location and time of sightings.

RESULTS

The waterfowl sightings were broken up into 12 Geomorphic reaches defined by Schmidt and Graf (1990). Table 1 lists the different geomorphic reaches and the river mileage at which they occur and number of hours spent observing in each reach. Table 2. summarizes the waterfowl data including species, number of individuals and in which geomorphic reach they appeared and number of hours spent observing in each reach. Great Blue Herons, Canada Geese, Mallards and Common Mergansers were the most common waterfowl observed. The Eared Grebe, Surf Scoter, Lesser Yellowlegs? and gull were only seen once and occurred individually.

Species richness per geomorphic reach is represented in figure 1. The highest rate of encounter occurred in the Permian Reach with 2.53 individuals per minute which correlates with species richness represented in figure 2. The lowest rate of encounter were the Lower Canyon at 0.001, the Aisles and the Upper Granite Gorge had rates of 0.008. Generally after the Permian section, rate of encounters did not exceed 0.39 of the Lower Marble Canyon reach.

TABLE 1. Geomorphic Reaches of the Grand Canyon along the Colorado River.

River Mile	Name of Reach	Observation Time
0-11	Permian Section (1)	6:37 hours
11-22.5	Supai Gorge (2)	5:15 hours
22.6-40.0	Redwall Gorge (3)	11:50 hours
40.1-61.5	Lwr. Marble Canyon (4)	8:45 hours
61.6-77.4	Furnace Flats (5)	9:45 hours
77.5-117.8	Upper Granite Gorge (6)	25:00 hours
117.9-125.5	Aisles (7)	2:00 hours
125.6-139.9	Middle Granite Gorge (8)	6:45 hours
140-159.9	Muav Gorge (9)	7:30 hours
160-213.8	Lwr. Canyon (10)	15:30 hours
213.9-240	Lwr. Granite Gorge (11)	7:30 hours
240-277	Lake Mead (12)	6:00 hours

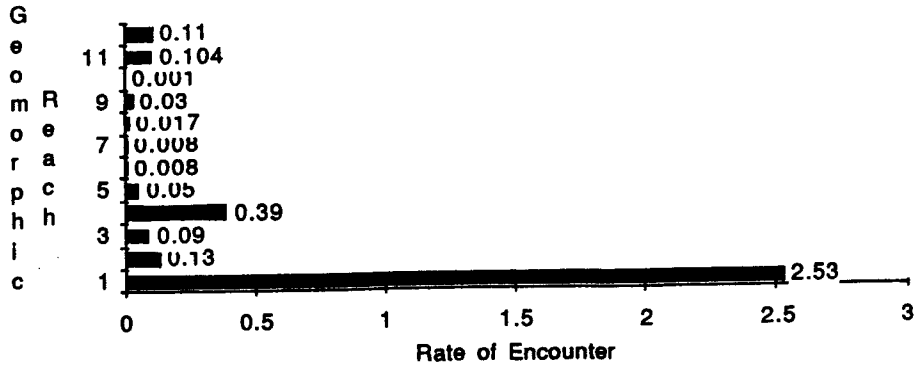

Figure 1. Rate of encounter represented per geomorphic reach

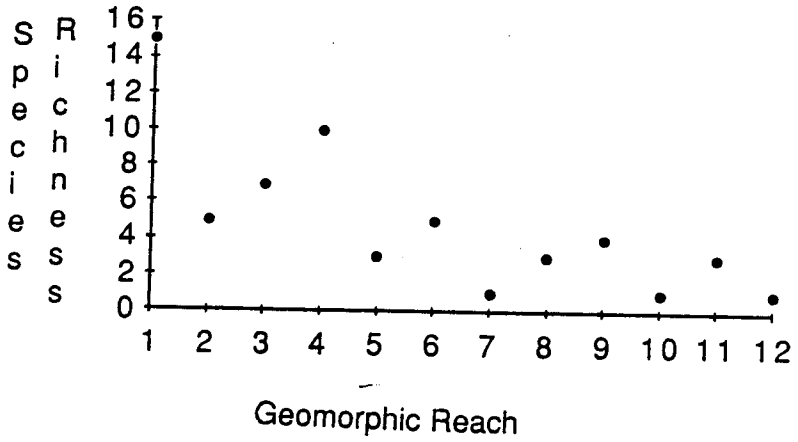

Figure 2. Species richness of waterfowl represented for each geomorphic reach.

TABLE 2. Summary of total number of individuals, species and occurrence in each geomorphic reach. The species are listed in taxonomic order.

# of Individuals	Species	Geomorphic Reach
1	Eared Grebe	4
20	Great Blue Heron	1,3,4,6,7,8,9,10,11
101	Canadian Geese	1,2,3,4,6,8,9,11
95	Mallard	2,3,4,6,9
44	Gadwall	1
22	American Widgeon	1
19	?Canvasback\Redhead	9,11
141	Redhead	1,8
1	Surf Scoter	1
343	Common Goldeneye	1,4
44	Bufflehead	1
32	Common Merganser	1,2,5,6,7,11
5	Killdeer	1
1	?Lesser Yellowlegs	3
3	Spotted Sandpiper	3
1	Gull species	1
459	Unknown ducks	all reaches

DISCUSSION

The Permian section, mile 0 to mile 11, had the greatest abundance of species and number of species of all the geomorphic reaches. This can be misleading because the highest number of species were seen only at Lees Ferry. Possible reasons for the diversity at Lees Ferry could be that it is the first moving water on the southward migration for 200 miles from the beginning of Lake Powell. Also the open geomorphology of Lees Ferry allows easier access for migratory birds. Simply Lees Ferry is not a canyon. The water is clear having just been released from Glen Canyon Dam just 15 miles upstream of Lee's Ferry. The clear water allows for more aquatic vegetation, the main food source for many waterfowl species. In Marble Canyon, which began about a half mile downriver from the Paria River, species numbers declined.

One human caused factor limiting the species use on the observation day December 5, was a National Park Service motor boat doing beach clean up work. The boat was ahead of the observers and the noise of the motor scared the waterfowl dispersing them from the area.

The Lower Marble Canyon reach was the second most abundant area for species richness. This could be due to the influence of the large Nankoweep Creek drainage acting as a corridor for migrating waterfowl.

The most open geomorphic reach, Furnace Flats had relatively low species richness (figure 2). This low number of species could be due to the 5000 foot depth of the canyon from river to rim, creating a sizable obstacle for waterfowl.

Steep-walled geomorphic reaches tended to have very low species richness and number of individuals (figure 1). Great Blue Herons were found in almost all of the steep-walled canyon sections (table 2). It appears that waterfowl habitat preference does not include steep-walled canyons.

The 459 unknown ducks probably include no additional species to the list but could influence the species richness. Most of the unknown ducks were flying at a distance too far to make a positive identification.

Overall species richness declined through the canyon. Perhaps the waterfowl leave the Colorado river system at Lees Ferry and fly overland to avoid the geographic obstacle of the Kaibab Plateau, searching for other wetland areas to the south. Waterfowl may only use Lees Ferry and avoid the entire Grand Canyon during migration. Food resources may decrease as one moves down from Lees Ferry due to increasing turbidity and sediment in the river preventing abundant aquatic vegetation to grow.

Further studies on waterfowl use of the Colorado River should examine the distribution and abundance of food resources. Habitat preference and use by waterfowl should also be examined.

ACKNOWLEDGEMENTS

We would like to thank GCES for this excellent oppurtunity to intimately study and learn about the Grand Canyon and the Colorado River. We would like thank Dave Wegner and Larry Stevens for their guidance and instruction for this study. Andre Potochnik and Christa Sadler were instrumental in making this trip a reality. We also thank Julie Munsell and Kim Buck for birding with us on the boats.

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WINTER BALD EAGLE SURVEY OF THE COLORADO RIVER IN GRAND CANYON, ARIZONA FOR DECEMBER, 1992

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ABSTRACT

Between December 4 and December 29,1992 a study was conducted by Prescott College student researchers for the Glen Canyon Environmental Studies (GCES) monitoring the visitation of Bald Eagles (*Haliaeetus leucocephalus*) in the Grand Canyon. The study emphasized four trout spawning tributaries of the Colorado River: Nankoweap Creek, Clear Creek, Bright Angel Creek and Tapeats Creek. The data collected showed that 21 of the 23 sightings occurred in the first 61 river miles, upstream from the confluence with the silt-laden Little Colorado River. The absence of expected eagles, especially immature Bald Eagles, at the trout spawning tributaries may be attributed to the lack of spawning trout.

INTRODUCTION

When Glen Canyon Dam was constructed in 1963, the dynamics of the Colorado River ecosystem from Lees Ferry (river mile 0) to Pierce Ferry (river mile 280) were altered. The combination of lack of sediment, colder dam-released water and introduction of exotic fish such as trout, has made this region more inviting to Bald Eagles for visitation on their winter migration southward. In 1986 significant numbers of Bald Eagles were observed feeding and wintering in the Grand Canyon. As a result of this observation a study was initiated by GCES to examine this phenomenon. The study suggests that the Grand Canyon is increasingly visited annually by Bald Eagles. Between December 4 and December 29,1992 a group of student researchers conducted a study on the presence of Bald and Golden Eagles in Grand Canyon, Arizona concentrating on the mouths of four trout spawning tributaries. These creeks are: Nankoweap Creek (mile 52), Clear Creek (mile 84), Bright Angel Creek (mile 88), and Tapeats Creek (mile 133). This study is one of many that will be added to the database for the long-term monitoring project conducted by GCES.

METHODOLOGY

Researchers collected data from sightings of Golden and Bald Eagles along the river corridor. Date, time, river mile, and behavior were documented for each of the sightings. All river miles referred to were taken from Stevens (1983). Special attention was paid to specific trout spawning tributaries, Nankoweap, Clear Creek, Bright Angel, and Tapeats Creek, where eagles have previously been sighted feeding. Researchers watched for eagles at or near the mouth, and walked up these tributaries at

least 200 meters. Other side streams were also examined from the mainstem and any sightings noted.

RESULTS

Table 1 lists the results of this study. The total number of Bald Eagle sightings was 21. The sightings of eagles are listed in chronological order from Lees Ferry to Pierce Ferry. The bulk of the data was recorded upstream from the mouth of the Little Colorado River (mile 61). The Little Colorado River (LCR) was extremely turbid. After this silt-laden tributary had merged into the Colorado there was only one sighting of a Bald Eagle, which occurred directly across from the mouth of the LCR. Only 2 Golden Eagles were sighted throughout the study, 1 at river mile 56 and one at river mile 97.

TABLE 1. Sightings and observations of Golden and Bald Eagles along the Colorado River in Grand Canyon, Arizona.*

DATE	TIME	MILE	TYPE	OBSERVATIONS
12/4/92	1215	2	MB	-Circling 100 M above R cliff
12/5/92	1330	13	MB	-Flying DS 200 M twice, overtaking observers; the 2nd time draping wings down as though drying.
	1415	16	MB	-Flying US landing on R cliff 300 M in front of group
	1420	16.5	MB	-Flying DS low
	1650	18.5	MB	-Flying DS (possible resight?)
12/6/92	1530	31.8	MB	-Flying above Vasey's Paradise and then leaving DS
12/7/92	0934	31	MB	-Flying US turned around, flew 1/2 way back DS to Vasey's then back and out of sight
	1454	39	MB	-Flying DS
	1454	39	MB	-Perched up high on boulder L side. when approached joined other bird and flew DS
	1532	40	MB	-Perched (Redwall ledge) R (possible resight?)
	1551	41.5	MB	-Perched on L dead mesquite in OHWZ watched group go by (possible resight?)
	1700	44	MB	-Perched on R side on boulder, flew DS (possible resight?)
12/8/92	1207	47	MB	-Walking along shore of lower Saddle Canyon beach (R side) Took off DS when approached
	1345	49.5	MB	-Flying US and passed observers (possible resight?)
	1440	51.5	MB	-Flying US, passing observers
12/9/92	1644	53	IB	-Flew US past camp toward Nankoweap mouth

Table 1 (Cont.)

12/10/92	1053	53	MB	-Flying DS on L side
	1315	56	MG	-Flying US, circled over Kwagun Creek, then continued US
	1345	57.5	MB	-Sitting on boulder L side, watched 3 boats pass, flew DS
	1415	59	MB	-Perched 30 M above river L, flew US (possible resight?)
	1500	61	MB?	-Flying DS
12/11/92	0915	61	MB	-Across from the LCR on R side, circling, then on the Tonto Bench, lost in low clouds
12/16/92	1315	97	MG	-Flying in the air currents on R side, above cliffs

* Table 1. abbreviations: MB, Mature Bald; IB, Immature Bald; MG, Mature Golden; R, Right; and L, Left; DS, downstream; US, upstream.

DISCUSSION

Most of the sightings of Bald Eagles occurred upstream of the turbid LCR. This supports the theory that, because the Colorado River is no longer silt-laden as it was before the dam, it provides a better fishing environment for Bald Eagles (Carothers and Brown, 1991). This theory states that without the silt from the upper Colorado drainage in the water there is higher visibility, allowing the eagles to hunt.

The number of Bald Eagles sighted at the tributaries was lower than during previous years' studies (Carothers and Brown, 1991). The data recorded at the main trout spawning tributaries (Howard, 1993) indicate that spawning was not occurring at this time. This may be the reason that there was no activity noted at these localities. These data support the hypothesis that spawning and most Bald Eagle visitation in the Colorado River corridor coincide with each other (Carothers and Brown, 1991).

Data collected from earlier studies indicated that the ratio of immature Bald Eagles to mature Bald Eagles was two to one at the main trout-spawning tributaries (Carothers and Brown, 1991). Carothers and Brown have explained this because of the easy availability of food during spawning for the more inexperienced immature Bald Eagles. The lack of spawning taking place during this study might explain why there were very few immature Bald Eagles sighted during the research trip.

The data compiled in this research could be more valuable if there was more time spent at localities where eagles are known to feed. This would enable the researcher to gain more information on the behavior of the eagles. While these data do not indicate many trends on their own, as part of the larger data base compiled by GCES, these data might be useful in establishing patterns of seasonal use of the river corridor and tributaries.

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TROUT SURVEY OF SELECTED TRIBUTARIES OF THE COLORADO RIVER IN GRAND CANYON NATIONAL PARK, DECEMBER, 1992

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ABSTRACT

A December 1992 survey of tributaries of the Colorado River indicated that trout had not yet entered these tributaries for spawning. No evidence of spawning beds was noted and the number of trout sightings was low. A total of 27 trout were observed in five tributaries. Of these trout, 15 were sighted at the mouths of the tributaries, six were sighted 0 to 100 meters from the mouth, one was sighted 100 to 200 meters from the mouth, and five were sighted 200 to 300 meters from the mouth. Mainstem water temperatures ranged from 47.5° to 50.4° F, and tributary temperatures ranged from 37.2° to 49.6° F. Visibility was generally good in tributaries. Two trout were captured and both were visibly healthy males with no wounds or external deformities.

INTRODUCTION

Between 4 December and 29 December, 1992 Prescott College student researchers counted trout in six perennial tributaries of the Colorado River through the Grand Canyon from Lees Ferry to Pearce Ferry. Tributaries examined were Nankoweap Creek (mile 52), Clear Creek (mile 84), Bright Angel Creek (mile 88), Crystal Creek (mile 98), Tapeats Creek (mile 133) and Deer Creek (mile 135). This research will provide base-line data for the long-term monitoring study conducted by Glen Canyon Environmental Studies (GCES).

METHODS

Beginning at the mouth of each creek, observers walked upstream along the banks counting trout and described stream conditions in 100 meter reaches. Observers continued walking upstream and counting trout until no trout were sighted for 2 consecutive 100 meter reaches. The mouth of the stream is defined for this study as the eddy or zone of mixing of the tributary and the mainstem waters. Reaches were measured from the point where the tributary bank intersected the river bank.

The temperature of the main stem of the Colorado River and temperature of each tributary was recorded beginning at the mouth and continuing at 100 meter intervals. All temperatures are recorded in degrees Fahrenheit. Trout were identified by species when possible and recorded along with stream conditions, air temperature, and weather conditions at each tributary. The presence of redds, or spawning beds,

was also noted. Any trout captured incidentally by fishermen were examined for tags, wounds and other deformities.

Instruments used included digital thermometers provided by GCES and analog alcohol thermometers as backups. All river miles and place names cited are according to Belknap (1992).

RESULTS

Nankoweap Creek
Date: 9 December 1992
River Mile: 52R
Weather: clear, sunny
Air Temperature: 42.4° F at 1035, 53.6° F at 1255.
Creek Mouth Water Temperature: 50.1o°F
Main Stem Water Temperature: 50.4° F
Total Trout Observed: 13 rainbow trout
Mouth: 13 rainbow trout
0 to 100 meters: 0 trout observed, creek temp. 42.8° F
100 to 200 meters: 0 trout observed, creek temp. 43.2° F
200 to 300 meters: 0 trout observed, creek temp. 43.2° F
300 to 400 meters: 0 trout observed, creek temp. 42.3° F
400 to 500 meters: 0 trout observed, creek temp. 42.1° F

Trout observed were moving in shallow, swift water at or near the mouth of Nankoweap Creek often in pairs but predominantly singly. Observers sighted 2 individuals with red coloration abdominally and anterior to gills. These 2 individuals moved with and freely around positively identified rainbow trout. No evidence of redds was noted.

Nankoweap Creek was clear, visibility excellent. Approximate stream depth varied from 0.25 meters to 1.0 meter and stream width from 0.3 meters to 2.0 meters with small bifurcations and meanders. Water level was well below recent flood stage as noted by presence of recent debris deposits above creek banks.

Further remarks:

One trout, a male rainbow 12" long and approximately 1.5 pounds was captured 500 meters below the mouth of Nankoweap Creek in the main stem of the Colorado River. An examination of the trout revealed no tags, wounds, lesions or external deformities. The alimentary canal contained over 20 undigested insect larvae and approximately 3 grams of intermixed and undigested *Cladophora glomerata* algae and *Gammarus lacustris*. No internal deformities were noted.

HOWARD

Clear Creek
Date: 15 December 1992
River Mile: 84.25R
Weather: clear, sunny

Air Temperature: 44.6° F at 1040
Main Stem Water Temperature: 48.9° F
Creek Mouth Water Temperature: 47.3° F
Total Trout Observed: 1 rainbow trout
Mouth: 0 trout
0 to 100 meters: 1 rainbow trout, creek temp. 40.8° F
100 to 200 meters: 0 trout observed, creek temp. 41.0° F
200 to 300 meters: 0 trout observed, creek temp. 41.1° F

Clear Creek was clear, with good visibility. Approximate stream width varied from 1.0 to 3.0 meters at the mouth to 0.75 to 3.0 meters farther upstream. Approximate stream depth varied from 0.5 meters to 1.0 meter. Clear Creek was flowing below recent flood stage. No evidence of redds was noted.

Bright Angel Creek
Date: 15 December 1992
River Mile: 87.6R
Weather: Clear, sunny
Air Temperature: 47.5° F
Main Stem Water Temperature: 47.5° F
Creek Mouth Water Temperature: 42.3° F
Total Trout Observed: 6 rainbow trout
Mouth: 2 rainbow trout, creek temperature 42.3° F
0 to 100 meters: 4 rainbow trout, creek temp. 42.3° F
100 to 200 meters: 0 trout observed, creek temp. 42.3° F
200 to 300 meters: 0 trout observed, creek temp. 42.3° F
300 to 400 meters: 0 trout observed, creek temp. 42.2° F

Bright Angel Creek was clear, with good visibility in shallow areas and limited visibility in deeper pools below gabions (rock dams). Visibility at the mouth was poor due to high sediment content of the Colorado River. Trout sighted above creek mouth were concentrated in constructed gabion pools. No evidence of spawning activity or redds was noted.

Crystal Creek
Date: 16 December 1992
River Mile: 98R
Weather: partly cloudy, 10+ mph. wind
Air Temperature: 54.0° F at 1310
Main Stem Water Temperature: 47.8° F

Creek Mouth Water Temperature: 37.2° F
Total Trout Observed: 0
Mouth: 0 trout observed, creek temp. 37.2° F
0 to 100 meters: 0 trout observed, creek temp. 37.2° F
100 to 200 meters: 0 trout observed, creek temp. 37.2° F

Crystal Creek was clear and very shallow. Creek depth varied from 0.1 to 0.75 meters. Creek width varied from 0.3 to 0.75 meters. No evidence of redds was noted.

Tapeats Creek
Date: 18 December 1992
River Mile: 133.75R
Weather: cloudy, wind gusts approximately 10-15 mph.
Air Temperature: 42.1° F at 1620
Main Stem Water Temperature: 48.2° F (mile 128)
Creek Mouth Water Temperature: 49.6° F
Total Trout Observed: 4 rainbow trout + 3 possible rainbow trout
Mouth: 0 trout observed, creek temp. 49.6° F
0 to 100 meters: 1 rainbow trout, creek temp. 49.4° F
100 to 200 meters: 1 rainbow trout, creek temp. 49.0° F
200 to 300 meters: 2 positive + 3 possible rainbow trout, creek temp. 48.7° F
300 to 400 meters: no data
400 to 500 meters: no data

Tapeats Creek was flowing with great turbulence, causing poor visibility. Trout observed were located in clear pools below falls and in shallow areas above a bifurcation 150 meters above the mouth. Observations ceased at 300 meters due to approaching darkness and threatening weather conditions. No evidence of spawning behavior or redds was noted.

Deer Creek
Date: 18 December 1992
River Mile: 136.5R
No data collected at Deer Creek because of darkness.

Further Remarks:

One male rainbow trout was captured by hook and line 20 meters upstream from the mouth of Deer Creek in the mainstem of the Colorado River. This individual was examined and measured to be 13.25 inches in length and weighed approximately 1.5 pounds. This individual exhibited red coloration laterally and anterior to gills. An examination of contents of

alimentary canal revealed an exclusive diet of *Gammarus lacustris* at the time of capture. No tags, wounds or lesions were noted and no deformities were evident externally or internally. Casual observation revealed no trout or redds present from the mouth of Deer Creek to Deer Creek Falls.

Summary of Results

Of the 24 positive trout sightings and 3 possible trout sightings, 56% (15 individuals) were sighted at the mouths of tributaries. Sightings of trout from the mouths of tributaries to 100 meters upstream totalled 22% (six individuals). One (1) individual was sighted between 100 and 200 meters from the mouth, representing 4% of the total trout observed. A total of five trout (two positive and three possible) were observed 200 to 300 meters from the mouth. These individuals represent 19% of all trout sightings in this survey. No individuals were observed in any tributary beyond 300 meters from the mouth.

DISCUSSION

No evidence of spawning activity or of spawning redds was noted in this study. Although trout were observed in the mainstem and mouths of tributaries, no direct evidence of migration up tributaries was discovered. Limitations of this study include poor visibility in creek mouths below the Little Colorado River due to high sediment content, variation in time of observation, and possible instrument malfunction (thermometers). Additionally, the logistical limitations imposed by the nature of downstream travel on the Colorado River in winter conditions prevented a thorough examination of Tapeats Creek and very limited observations of Deer Creek.

ACKNOWLEDGEMENTS

I would like to thank GCES for this opportunity to study the Grand Canyon and Colorado River. Thanks to David Wegner and Larry Stevens for their assistance with our project, and to Andre Potochnik, Christa Sadler, and Julie Munsell for their supervision and encouragement. I also offer gratitude to Jhala French and Julie Munsell for assistance in collecting data, and to Ed and JoAnn Howard who made this research trip possible for me.

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DECEMBER 1992 MAMMAL SURVEY ALONG THE COLORADO RIVER THROUGH GRAND CANYON, ARIZONA, DECEMBER 1992

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ABSTRACT

A December, 1992 mammal count along the Colorado River in Grand Canyon was conducted by a 14 member Prescott College student research group. The researchers recorded species, date, time, river mile, bank (left or right), sex, number of individuals, and behavior. Researchers documented 6 species during the 26 day study. General distribution patterns include: desert bighorn in the Middle Granite Gorge, river left; mule deer near side canyons; beaver in the first and last 55 miles of the canyon; coyotes in open areas; and rock pocket mice and jackrabbit in human influenced areas. This study will be incorporated into the Glen Canyon Environmental Studies (GCES) long-term monitoring program.

INTRODUCTION

Between December 3 and December 28, 1992 a group of Prescott College student researchers recorded all mammal sightings and behavior between Lees Ferry and Pierce Ferry along the Colorado River through Grand Canyon. The research conducted will be incorporated into the GCES long-term monitoring program. The mammal counts will serve an integral role in determining Glen Canyon Dam's effects on the ecosystem within Grand Canyon.

METHODS

Sightings of mammalian wildlife on the Colorado River between Lees Ferry and Pierce Ferry were obtained from boats, river banks, and side canyons. Most of the sightings were obtained directly from boats. Whenever possible, side tributaries were explored and all sightings noted.

Data fall into two categories: 1) actual sightings and 2) scat, tracks, trails, etc. These data do not account for the possibility of double sightings.

Additional data collected were date, time, river mile, bank (left or right), number of individuals, sex of individuals, location, and behavior. The river mileage were ascertained from Belknap (1992). All results are listed in Table 1.

RESULTS

Table 1. Mammal sightings for December, 1992 along the Colorado River in Grand Canyon, Arizona

Species		Date	Time	Mile	Bank	#	Sex	Locality	Remarks
Beaver *Castor canadensis*	1	12/3/92	1830	0		1	?	in river boats	-swimming near the
	*2	12/7/92		~37	L,R				-beaver chutes
	3	12/7/92	1600	~37		1	?	in river	-swimming L to R, then diving under-water
	*4	12/8/92		50	L,R				-chutes both banks -trench that looked like human con-structed beaver habitat
	5	12/10/92	1145	54.5		1	?	in river	-slapped tail, then dove underwater
	6	12/18/92	1100	122	L	2	?	bank/river	-1 slid down chute, L bank in river -1 swimming in river
	*7	12/28/92		245.5	R				-beaver chutes
	*8	12/28/92		254-255	R				-beaver chutes
	*9	12/28-12/29/92	1900-0700	260-276				in river	-beavers heard slapping tails during night
Bighorn Sheep *Ovis canadensis*	1	12/18/92	1600	133.5	L	10	4M?	above OHWZ	-eating brittlebush (*Encelia farinosa*) -~30 meters above river
	2	12/18/92	1635	135.5	L	1	M		-eating brittlebush
	3	12/18/92	1637	135.5	L	1	M		-300 meters down river from the pre-vious individual
	4	12/25/92	1030	209	L	2	1M 1F	desert	-~ 1 km up Granite Park Canyon lying down, watching us
Coyote *Canis latrans*	*1	12/11/92	2130	69	R	?	?		-several heard near Basalt Canyon
	2	12/13/92		~70	R			bank	-scat
	3	12/24/92	2400	209	L				-heard at Granite Park
	4	12/28/92	1430	250.5	R	1	?	bank	-running along granite ledges and up side creek
Jackrabbit *Lepus californicus*	1	12/4/92	0745	0.25	R	1	?	bank	-in Tamarisk (*Tamarix pentandra*) -Lees Ferry
Mule Deer *Odocoileus hemonus*	*1	12/8/92		50	L				-scat
	2	12/9/92	1110	52	R	1	F	side creek	-in Mesquite (*Prosopis juliflora*) -Little Nankoweap Ck.,fully mature -ran when spooked

Table 1 (Cont.)

	*3	12/9/92		52-53	R				-tracks, scat, bedding sites
	4	12/10/92	1200	55.5	R	2	F?	OHWZ	-eating unknown grasses
	5	12/10/92	1415	59	R	1	M	desert	-lying ~10 m above river
	6	12/15/92	1145	87.5	R	6	2M 4F?	side creek	-1 spike buck, 1 six pt. -2 does, 2 female(?) fawns -Bright Angel Cr,100 meters from Phantom Ranch -extremely approachable -eating and watching observers
	*7	12/21/92		171.5	L			side creek	-tracks,~ 0.8 km up Mohawk Canyon
	8	12/22/92	1500	184	L	2	1M 1F	aboveOHWZ	-eating unknown grasses -male had only 1 antler
	9	12/22/92	1505	184.5	R	1	?	NHWZ	-in the tamarisk
	10	12/22/92	1535	186	L	2	1M 1F	OHWZ	-lying down in grass
	*11	12/25/92		209	L			side creek	-tracks, ~0.6 km up Granite Park Cyn.
Rock	1	12/3/92	2005	0	R	1	?	camp	-Lees Ferry
Pocket	2	12/5/92	2030	20.5	R	3+	?	camp	-around the kitchen
Mouse	*3	12/7/92		33	L				-tracks, Redwall Cavern
Perognathus intermedius	*4	12/19/92		137	L			camp	-tracks, under overhanging wall
	5	12/24/92		209	L		?	camp	-found frozen in handwash bucket

Abbreviations used in this table: * denotes not actually sighted; L/R denotes left or right bank of river; M/F denotes male or female; OHWZ and NHWZ denote old and new high water zone, respectively (as defined by Buck and Clausen, 1993).

DISCUSSION

During the 26 day observation period six species of mammals were observed. Patterns can be suggested from these observations.

Mule deer (*Odocoileus hemionus*) were the most commonly sighted mammals. They tended to appear most often near or in side canyons. They were usually observed near the river in the late afternoon. The six mule deer seen at Phantom Ranch were obviously influenced by the regular presence of people.

Beavers (*Castor canadensis*) were seen only in the upper and lower 55 miles of the canyon, with the exception of one sighting of two individuals

at mile 122. All of the sightings were in open areas of the canyon, where there are wider, more heavily vegetated banks. This vegetation consisted mostly of coyote willow (*Salix exigua*) and tamarisk (*Tamarix pentandra*).

Coyotes (*Canis latrans*) were heard near both Basalt Canyon and Granite Park Canyon. Both of these canyons are especially open canyons. One *Canis latrans* was seen in an open area near a side canyon at mile 250.5.

Bighorns sheep (*Ovis canadensis*) were observed exclusively on steep, rocky slopes. All but one sighting was in the Middle Granite Gorge. The other sighting was up Granite Park Canyon. They were most commonly seen in the desert vegetation and always on river left.

Rock pocket mice (*Perognathus intermedius*) were observed only in camps or highly visited areas. The single jackrabbit (*Lepus californicus*) sighting was also in a human influenced area (Lees Ferry).

This study does not provide any conclusive evidence about species habitats, however it can provide a view of habitat patterns for December, 1992. These data can be integrated into the larger GCES data base, to develop a more conclusive understanding of mammal habitats. Limitations of this study include, but are not restricted to limited observation time in some areas, inclement weather, and inconsistent exploration of side canyons.

Data may be influenced by the erratic pace of downstream travel and the occurrence of layover days at certain camps. In other words time spent observing was not consistent in every area of the canyon.

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DECEMBER WATER TEMPERATURES ALONG THE COLORADO RIVER THROUGH GRAND CANYON

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ABSTRACT

This study presents mainstem, backwater and tributary temperatures of the Colorado River through Grand Canyon for December, 1992. The data express a general cooling trend in mainstem and backwater temperatures with distance downstream from Lees Ferry. Backwater temperatures were typically cooler than corresponding mainstem temperatures. These trends may be attributed to cooler ambient air temperature and the influx of colder tributary water.

INTRODUCTION

With the closing of the floodgates of Glen Canyon Dam in 1963, the aquatic and riparian ecosystems of the Colorado River through Grand Canyon changed dramatically. Clear, cold dam-released water, lacking the wide seasonal temperature fluctuations of pre-dam flows, now forms the basis of these ecosystems (Carothers and Brown, 1991). A water temperature study was conducted by Prescott College student researchers from December 4 through December 24, 1992 on the Colorado River and nine of its tributaries through the Grand Canyon. The data collected contribute to a long-term monitoring study begun by the Glen Canyon Environmental Studies (GCES) in 1982. The purpose of this study is to provide a better understanding of seasonal water temperature variations in the river corridor, as well as the possible affects of fluctuating dam releases on these temperatures and the riparian ecosystem.

METHODS

Mainstem, backwater, and tributary temperatures were recorded between Lees Ferry (river mile 0) and Granite Park (river mile 209). All temperatures were taken with either a Micronta digital thermometer, accurate to +/- 0.1° F, or a back up analog thermometer, accurate to +/- 0.5°F.

One or two mainstem water temperatures were recorded every ten miles. Temperatures were recorded both from mid-stream and along shore. Shoreline temperatures were recorded in current moving downstream, not in eddy currents. Temperatures taken at peak and trough water levels were recorded at selected sites. Peak and trough water levels were estimates based on observation of daily water fluctuations (see appendix A for actual flows). Temperatures of selected tributaries were recorded approximately 100 meters from the mouth, away from the influence of the mainstem.

At least one backwater temperature was recorded in each of the twelve geomorphic reaches of the Grand Canyon (appendix B), excluding the upper and lower granite gorges. A backwater is defined as a channel along the shore which is periodically restricted from circulation with the main channel by a sand deposit (see reattachment bar; Carothers & Brown, 1991). A backwater will appear as a distinct feature at low river levels but will become part of a larger eddy at higher water levels. Backwaters vary in size, shape, and direction of opening to mainstem. Temperatures were recorded at a total of 10 backwater sites.

Maps were drawn of all backwater sites indicating approximate size, shape and location of temperature recording (appendix C). Photographs were taken at most backwater sites, documenting location of recorded temperatures. Additional data collected include site name, river mile and bank, date, time, aspect of backwaters, ambient temperatures and weather conditions, fish sightings and comments.

Ambient temperatures were recorded simultaneously with all water temperatures. All river miles were taken from Stevens, 1983. No data were collected below river mile 209 due to equipment failure.

RESULTS

Results are presented in tables 1,2,3 and 4. The data express a general cooling trend in mainstem and backwater temperatures with distance downstream from Lees Ferry (mile 0). Mainstem water temperatures ranged from 50.5 to 45.0° F. Backwater temperatures ranged from 50.5 to 40.0° F. Backwater temperatures tended to be cooler than corresponding mainstem water temperatures (see tables 1,4). No obvious trends occurred between water temperatures and water depth or peak and trough water levels. Ambient air temperatures were consistently lower than mainstem and backwater temperatures, by as much as 18.0° F. The temperatures of tributaries ranged from 37.0 to 51.3° F, in general several degrees colder than mainstem temperatures.

TABLE 1. Mainstem water temperatures (°F).

Name	Mile	Date	Time	Water Temp.	Location of Temp.[1]	Air Temp.	Sky Cond.
Hot Na Na	16.5	12/5	1500	50.5	M	40.5	overcast
North Cyn.	20	12/6	0750	50.5	R	32.7	clear
Shinumo	29	12/6	1430	50.5	M	39.7	clear
Redwall	33	12/7	1025	49.8	L	35.2	overcast
Marble Cyn. Dam Site	39	12/7	1500	50.0	M	38.5	overcast
_	45	12/8	1130	50.4	M	42.8	clouds
_	50	12/8	1400	50.0	M	40.0	clouds
Nankoweep	52.5	12/9	1041	50.4	R	42.4	clear
Kwagunt	56	12/10	1330	49.3	M	45.9	overcast
L.C.R.	61	12/11	0900	49.0*	R	_	overcast
Basalt	70	12/12	0900	49.5*	R	_	clouds
Grapevine	81	12/14	1730	48.9	L	39.7	clear
Bright Angel	87.5	12/15	1200	47.5	R	41.0	clouds
Granite	93	12/16	0812	48.0	L	39.2	clear
Crystal	98	12/16	1336	47.8	L	39.6	clear
Little Ruby	104	12/17	0730	48.9	R	39.7	overcast
Rancid Tuna	113	12/17	1340	49.1	M	48.4	clear
_	119	12/17	1600	49.1	M	42.4	clouds
Blacktail	120	12/18	0845	48.0	R	41.7	rain
Specter	128	12/18	1300	48.2	L	45.3	clouds
Poncho's	136	12/20	0833	47.5*	L	31.0*	clear
Kanab	142	12/20	_	47.5*	R	38.0*	clear
Ledges	151.5	12/20	1620	47.5*	R	36.0*	clear
Havasu	157	12/21	1115	47.0*	M	_	clear
Mohawk	171.5	12/22	1042	46.6	M	37.0*	clear
Lava	179	12/22	1330	46.0*	M	43.0*	clear
Whitmore	188	12/23	0940	45.0*	R	34.0*	clear
_	198	12/23	1317	45.5*	M	44.0*	clear

[1]Indicates where temperatures were recorded; midstream (M), left bank (L), right bank (R).

*Indicates temperatures recorded with an analog thermometer.

TABLE 2. Peak and trough water temperatures (°F).

	Name	Mile	Date	Time	Water Temp.	Air Temp.	Sky Cond.	Location[1]
p[2]	Nankoweap	52.5	12/9	1041	50.4	42.4	clear	R
T	"	"	"	1910	49.6	41.4	clear	R
P	"	"	12/10	0815	49.6	41.0	overcast	R
P	Basalt	70	12/12	0900	49.5	_	clouds	R
P	"	"	12/13	0845	49.5*	_	clouds	R
T	"	"	"	1753	49.5	43.9	clouds	R
T	Grapevine	81	12/14	1730	48.9	37.7	clear	L
P	"	"	12/15	0900	47.1	39.4	clouds	L
T	Little Ruby	104	12/17	0730	48.9	39.7	overcast	R
P	Rancid Tuna	113	"	1340	49.1	48.4	clear	M
P	Blacktail	120	12/18	0845	48.0	41.7	rain	R
T	Tapeats	136	12/20	0833	47.5*	31.0*	clear	L
P	Whitmore	189	12/23	0940	45.0*	34.0*	clear	R

[1]Indicates where temperatures were recorded; midstream (M), left bank (L), right bank (R).

[2]Indicates peak(P) and trough(T) water levels.

*Indicates temperatures recorded with an analog thermometer.

TABLE 3. Tributary water temperatures (°F).

Name	Mile	River Bank[1]	Date	Time	Water Temp.	Air Temp.	Sky Cond.
Nankoweap	53	R	12/9	1115	42.8	53.6	clear
L.C.R.	61	L	12/10	1615	47.0	_	overcast
Clear	84	R	12/15	1030	40.8	44.6	clouds
Bright Angel	87.5	R	12/15	1200	42.3	47.5	clouds
Crystal	98	R	12/16	1334	37.4	36.0	clear
Tapeats	133.8	R	12/18	1630	48.7	_	clouds
Deer	135	R	12/19	1315	51.3	40.1	clear
Kanab	143	R	12/20	1230	37.0*	34.0*	clear
Havasu	156.8	L	12/21	1020	48.9	37.0	clear

[1]Indicates from which bank of the river tributary enters; right bank(R), left bank(L).

*Indicates temperature recorded with an analog thermometer.

TABLE 4. Backwater temperatures (°F).

#	Mile	River Bank[1]	Date	Time	Water Temp.	Air Temp.	Aspect [2]
1	3	L	12/4	1200	49.6	49.1	D
2	16.5	L	12/5	1445	49.5	_	D
3	21.8	R	12/6	1050	50.5	34.2	U
4	33	L	12/7	1030	49.5	35.8	D
5	44.5	L	12/8	1045	48.2	43.5	U
6	50	L	12/8	1400	50.5	48.7	U
7	58.3	R	12/10	1406	50.3	_	U
8	119	R	12/17	1600	48.2	39.1	U
9	137	L	12/20	0845	44.0*	34.0*	U
10	172	L	12/22	1055	40.0*	36.0*	U

[1]Indicates from which bank of the river temperatures were recorded; right bank(R), left bank(L).

[2]Indicates which way the backwater faces; upstream(U), downstream(D).

*Indicates temperatures recorded with an analog thermometer.

TABLE 5. Mean, median, high and low of compiled mainstem, peak, trough, tributary and backwater temperatures (°F).

	Mean	Median	High	Low
Mainstem	48.4	48.9	50.5	45.0
Peak	48.6	49.5	50.4	45.5
Trough	48.7	48.9	49.6	47.5
Tributary	44.1	42.8	51.3	37.4
Backwater	48.0	49.5	50.5	40.0

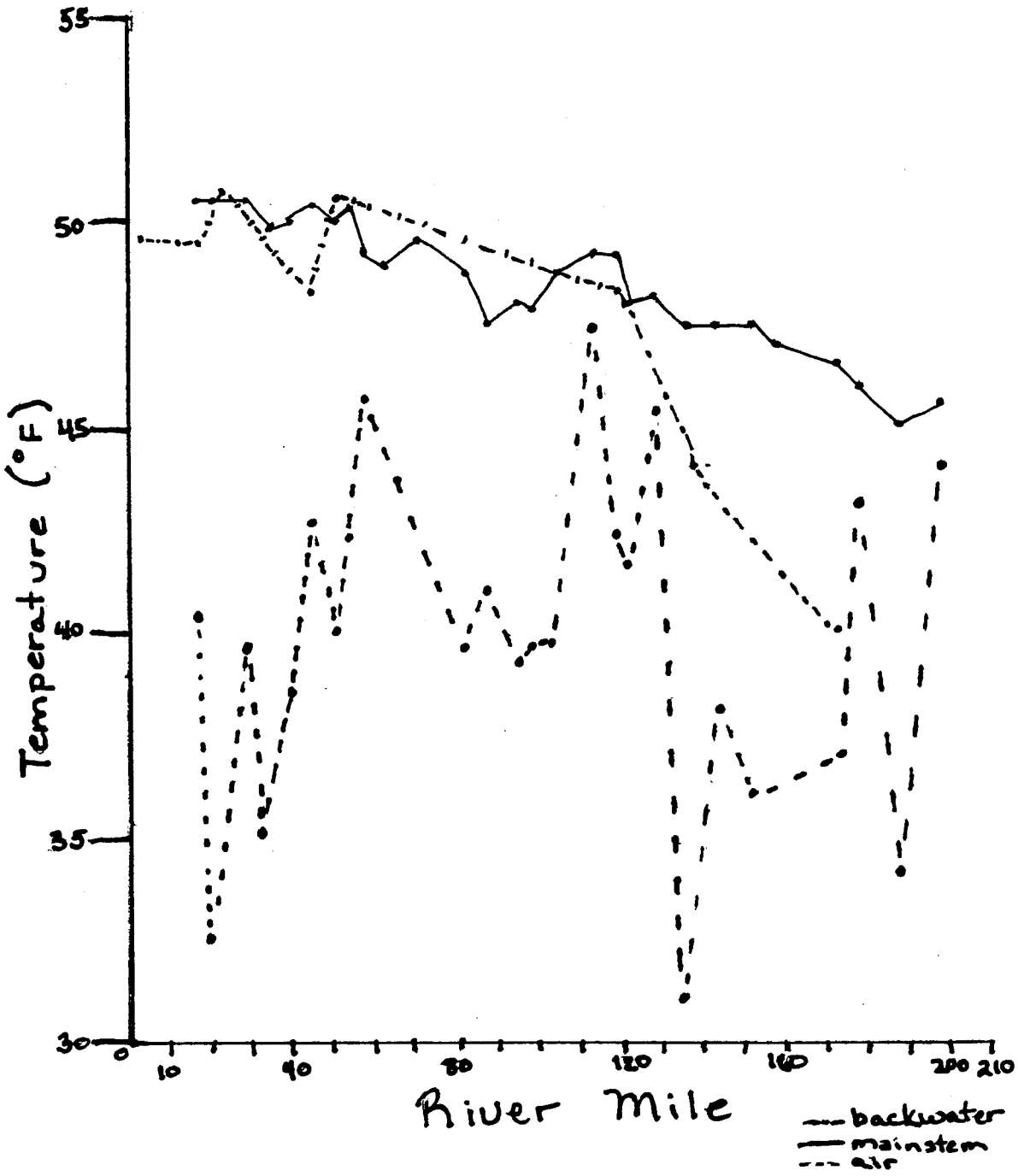

FIG. 1. Mainstem, backwater and air temperature fluctuations with distance downstream from Lees Ferry. Air and water temperatures were taken simultaneously.

DISCUSSION

The cooling trend in mainstem and backwater temperatures may be attributed to colder ambient air temperatures and/or the influx of colder water from tributaries. The tendency of backwater temperatures to be lower than mainstem temperatures could also be caused by colder ambient air temperatures. It is possible that at high water flows, backwater temperatures are influenced more by mainstem temperatures while at low flows backwaters are relatively isolated from mainstem flows and influenced more by ambient air temperatures. If ambient air temperatures have a significant affect on backwater temperatures, one could expect that backwaters would be warmer in the summer months when ambient air temperatures are significantly higher than mainstem water temperatures.

Overall, mainstem water temperatures did not vary greatly. This may be attributed to the low fluctuations in dam releases (appendix A) and the relative similarities between ambient air temperatures and water temperatures. Tributary temperatures are dictated largely by their source. Colder tributaries are probably a result of snow melt, while warmer tributaries are spring fed.

In general, turbid water absorbs solar heat (low albedo or reflectivity) while clear water reflects it (high albedo). Although the river was muddy from the Little Colorado River (mile 61) to Granite Park (mile 209), the albedo affect was probably negligible due to the low percentage of solar incidence. During this study the low angle of the winter sun and the abundant number of cloudy days contributed to low solar incidence on the river itself.

These suggested temperature trends may be supported if these data were to be subjected to statistical analysis, as part of the larger body of annual and seasonal temperature data collected by GCES.

CONCLUSION

Data will continue to be added to this study through GCES research. Long-term monitoring will provide information needed to create a management plan for Glen Canyon Dam operations. This study, conducted by volunteer student researchers, provided off-season data for GCES and gave the students hands-on research experience. It would be valuable to continue this educational/research relationship by creating an ongoing program. An essential component of the program would be a thorough introduction to the history and goals of GCES, as well as training in research methodologies and equipment use. It is equally important that the student researcher understand the purposes of their individual studies. Utilizing student researchers is one way that GCES can fulfill its goals of public education and monitoring the river corridor.

ACKNOWLEDGEMENTS

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APPENDIX A
Peak and Trough Water Releases (in cfs) from Glen Canyon Dam for December 4 through December 29, 1992.

Date (Dec. 1992)	Peak	Trough
4	14050	9060
5	14170	7970
6	13050	7170
7	14260	8340
8	14290	8170
9	14870	8400
10	14240	8710
11	14860	8430
12	14390	7650
13	12490	8270
14	14450	8410
15	15040	9080
16	14790	9340
17	14460	8530
18	13930	8280
19	13990	7970
20	12370	6440
21	14340	8620
22	14200	8180
23	13930	8150
24	14040	7340
25	12800	7930
26	13350	7930
27	12200	7180
28	13800	7800
29	13860	6930

From Plant Operations, Bureau of Reclamation, Glen Canyon Dam, Page, Arizona.

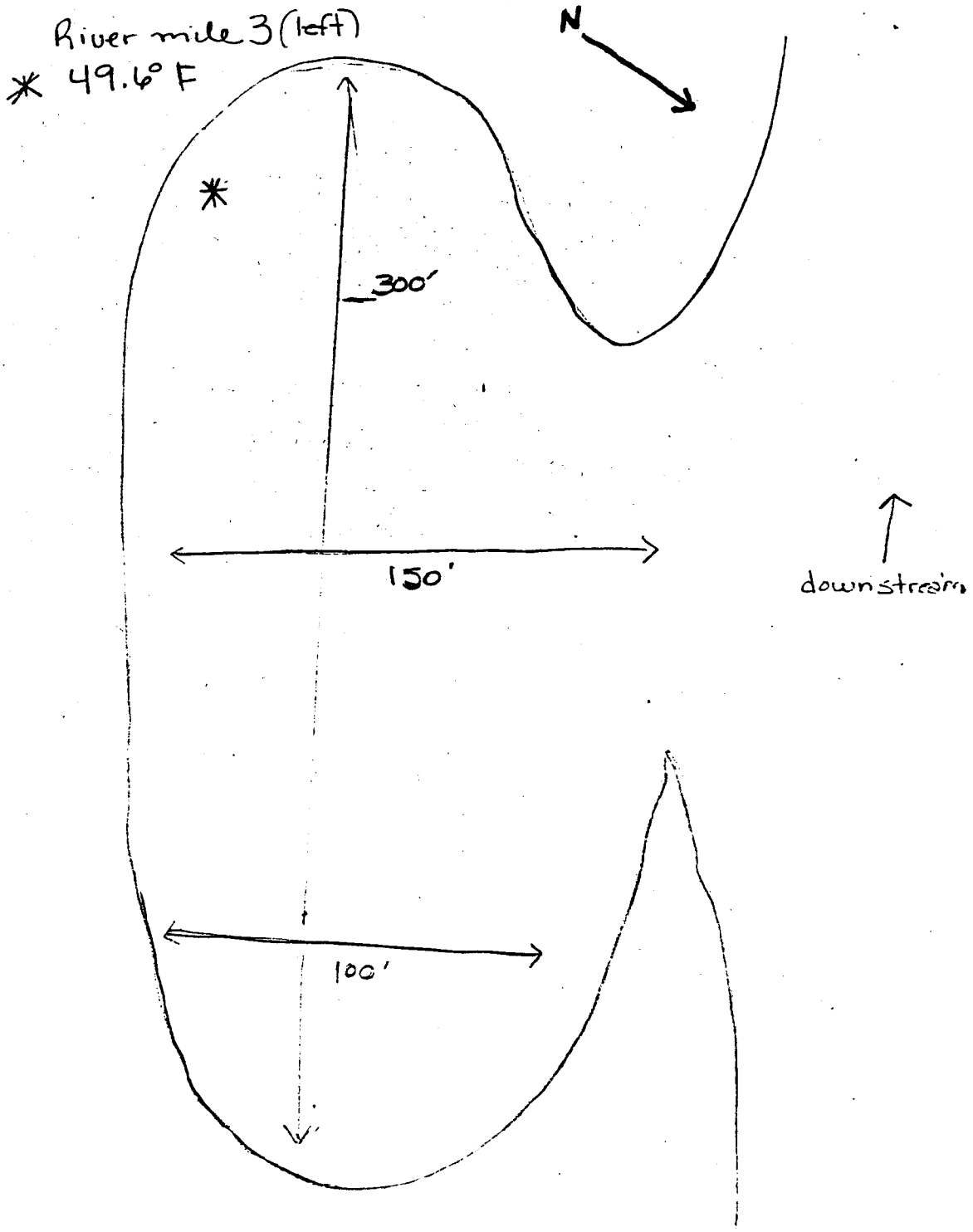
APPENDIX B
The 12 geomorphic reaches of the Colorado River through the Grand Canyon and their distinguishing characteristics.

Reach (river mile)	Local name of reach	Major geologic units of reach	Description of reach width
0-11.0	Permian Section	Kaibab Limestone Toroweap Formation Coconino Sandstone Hermit Shale	Wide
11.0-22.5	Supai Gorge	Supai Group	Narrow
22.6-40.0	Redwall Gorge	Redwall Limestone	Narrow
40.0-61.5	Lower Marble Canyon	Muav Limestone Bright Angel Shale Tapeats Sandstone	Wide
61.6-77.4	Furnace Flats	Tapeats Sandstone Unkar Group	Wide
77.5-117.8	Upper Granite Gorge	Zoroaster Plutonic Complex Trinity & Elves Chasm Gneisses	Narrow
117.9-125.5	Aisles	Tapeats Sandstone	Narrow
125.6-139.9	Middle Granite Gorge	Tapeats Sandstone Unkar Group Vishnu Schist	Narrow
140.0-159.9	Muav Gorge	Muav Limestone	Narrow
160.0-213.8	Lower Canyon	Basalt Muav Limestone Bright Angel Shale	Wide
213.9-240.0	Lower Granite Gorge	Vishnu Schist	Narrow
240.0-276	Lake Mead	Lake Sediments	-

After Schmidt and Graf, 1990. Modifications made by this study were to extend Lower Granite Gorge reach to mile 240 and to add Lake Mead reach from mile 240.0 to mile 276.

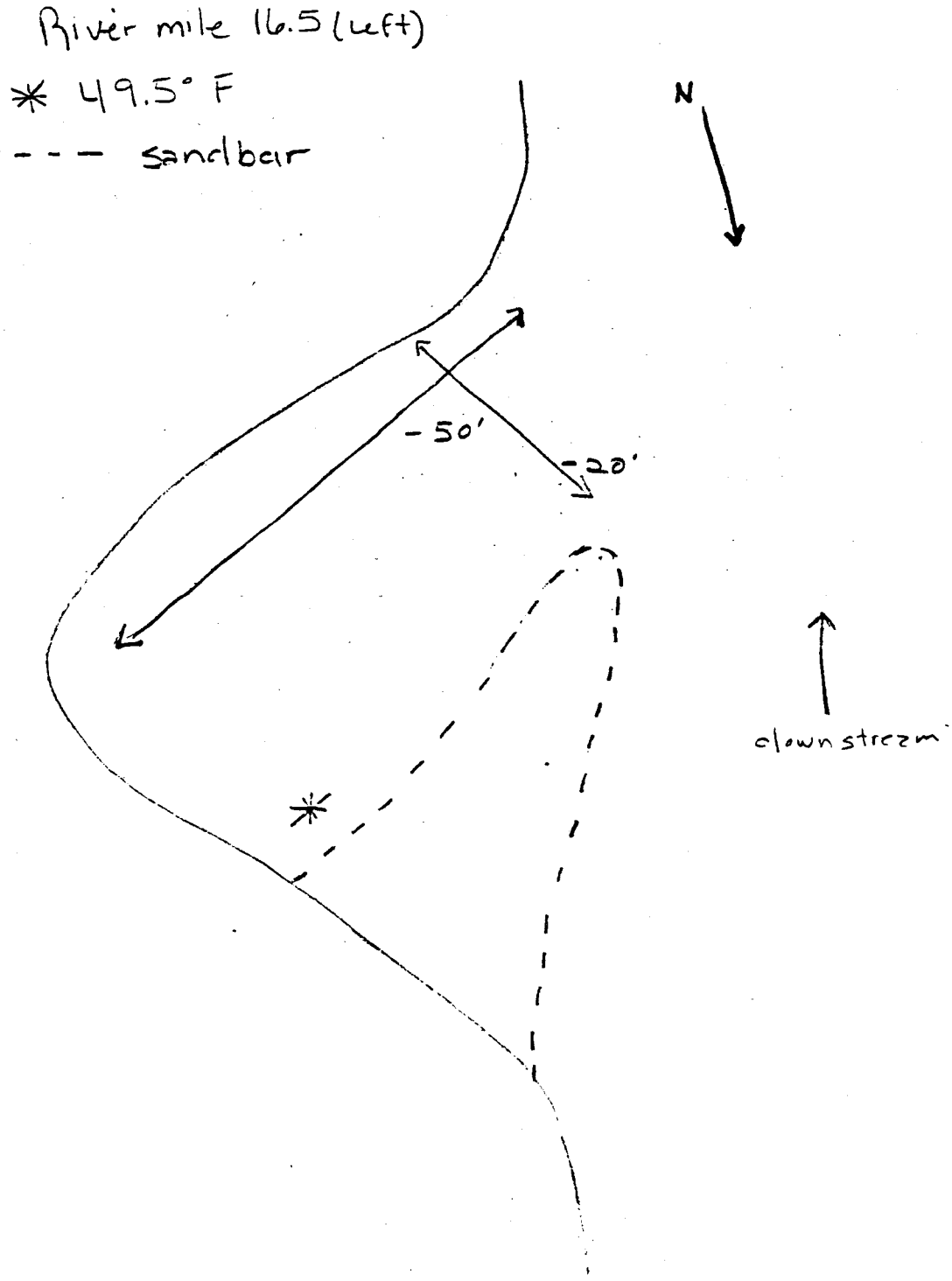
APPENDIX C
Maps of backwaters

MAP #1



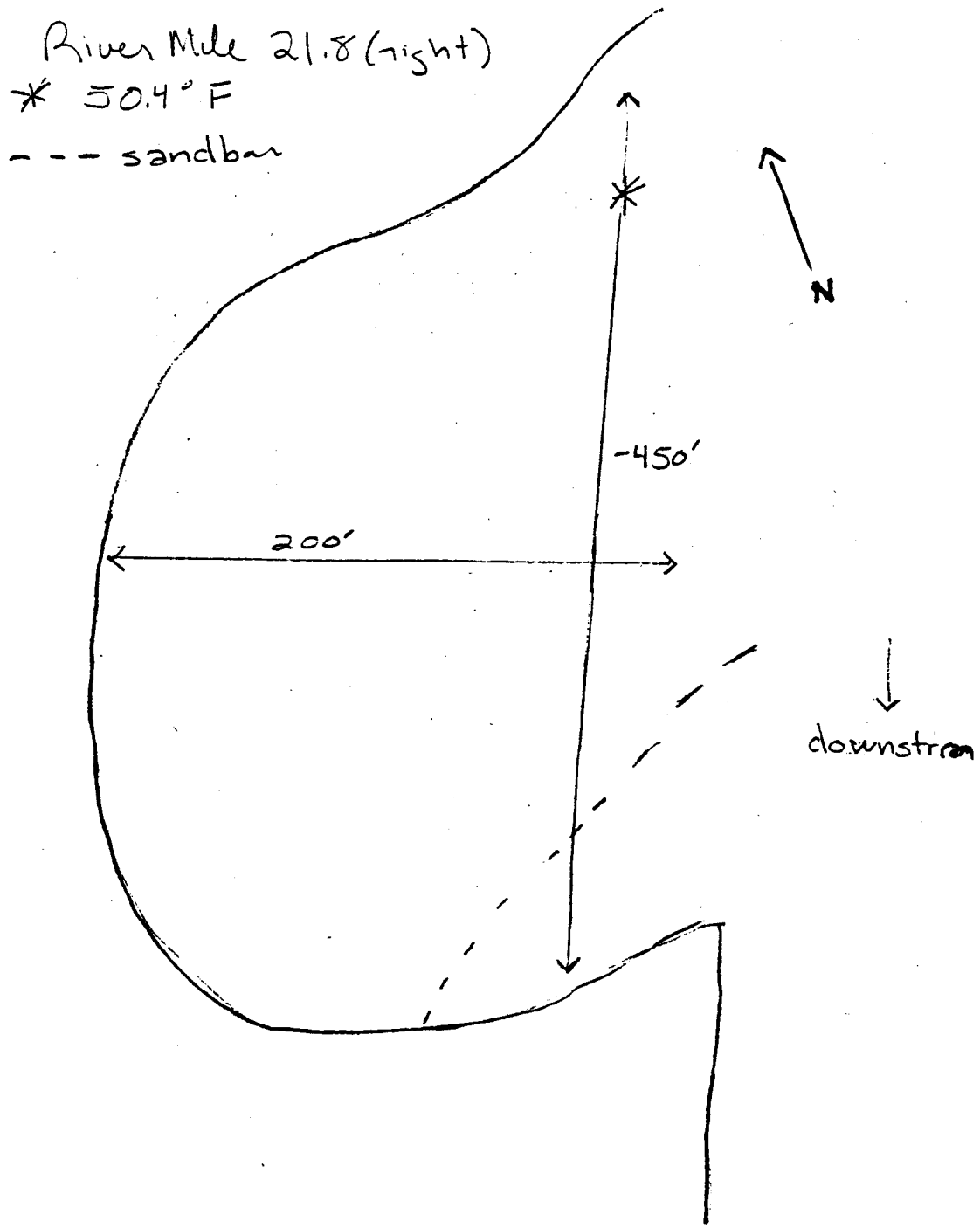
FRENCH & MUNSELL

MAP #2



FRENCH & MUNSELL

MAP #3



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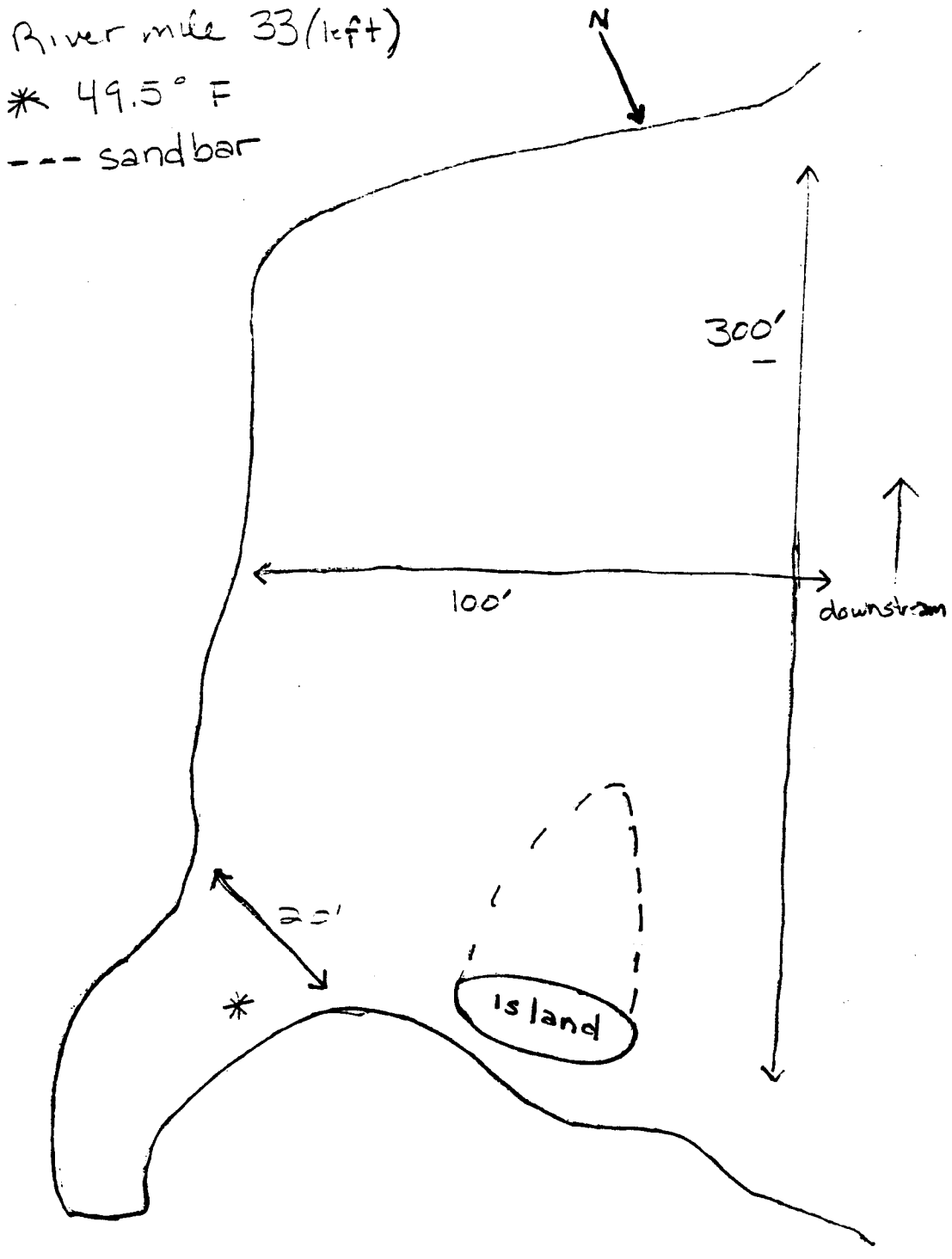
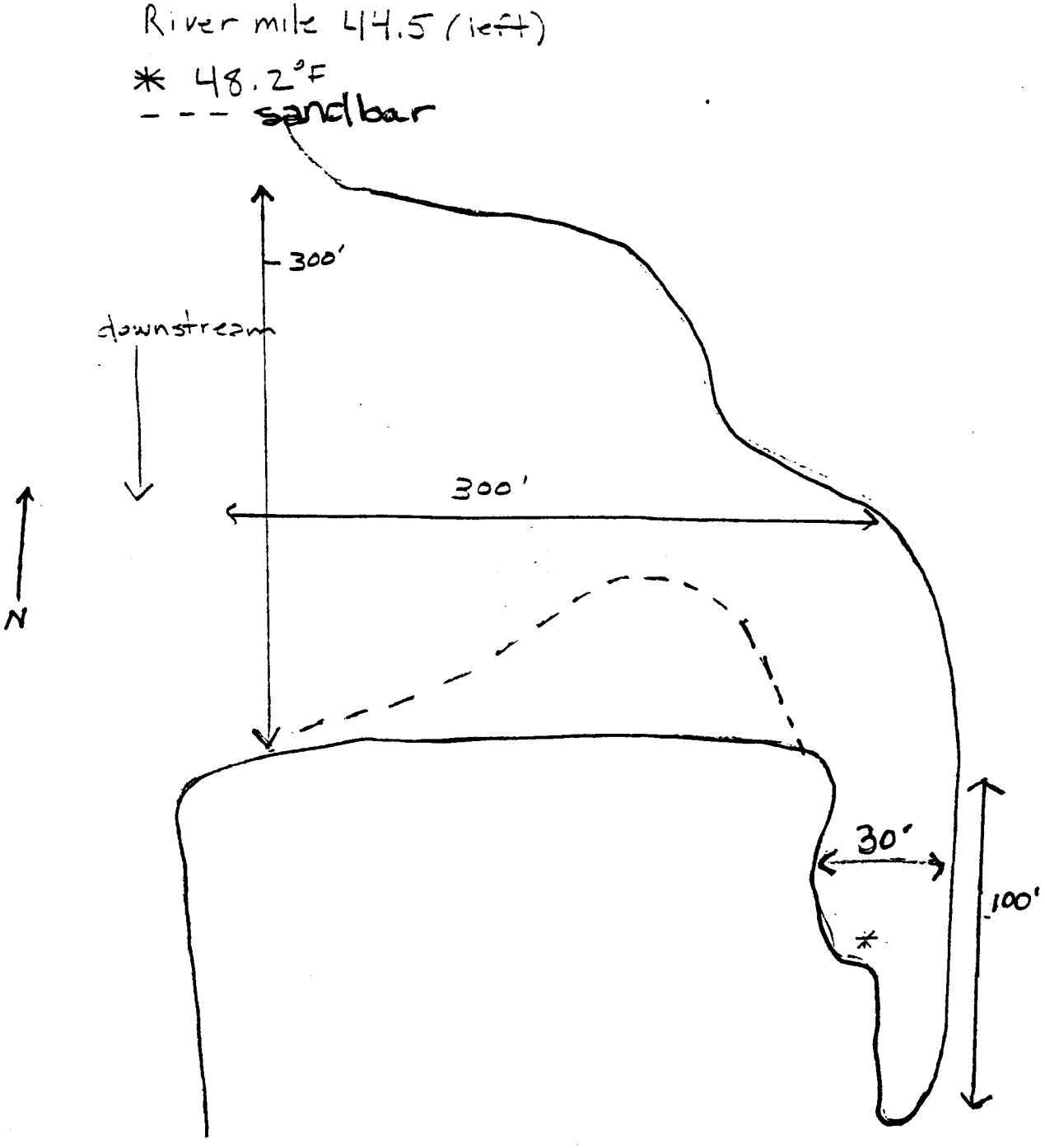
MAP #4



FRENCH & MUNSELL

MAP #5



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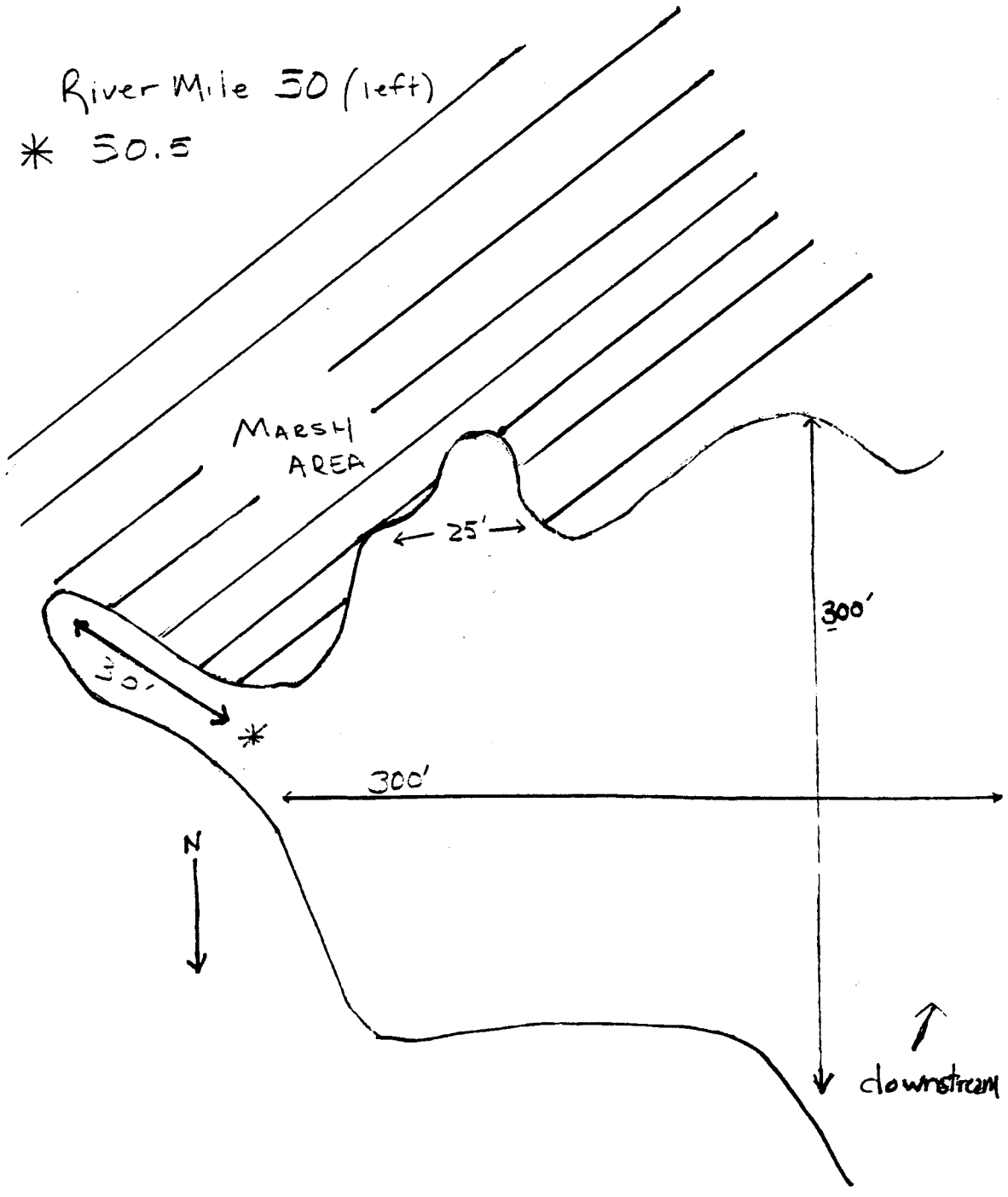
MAP #6



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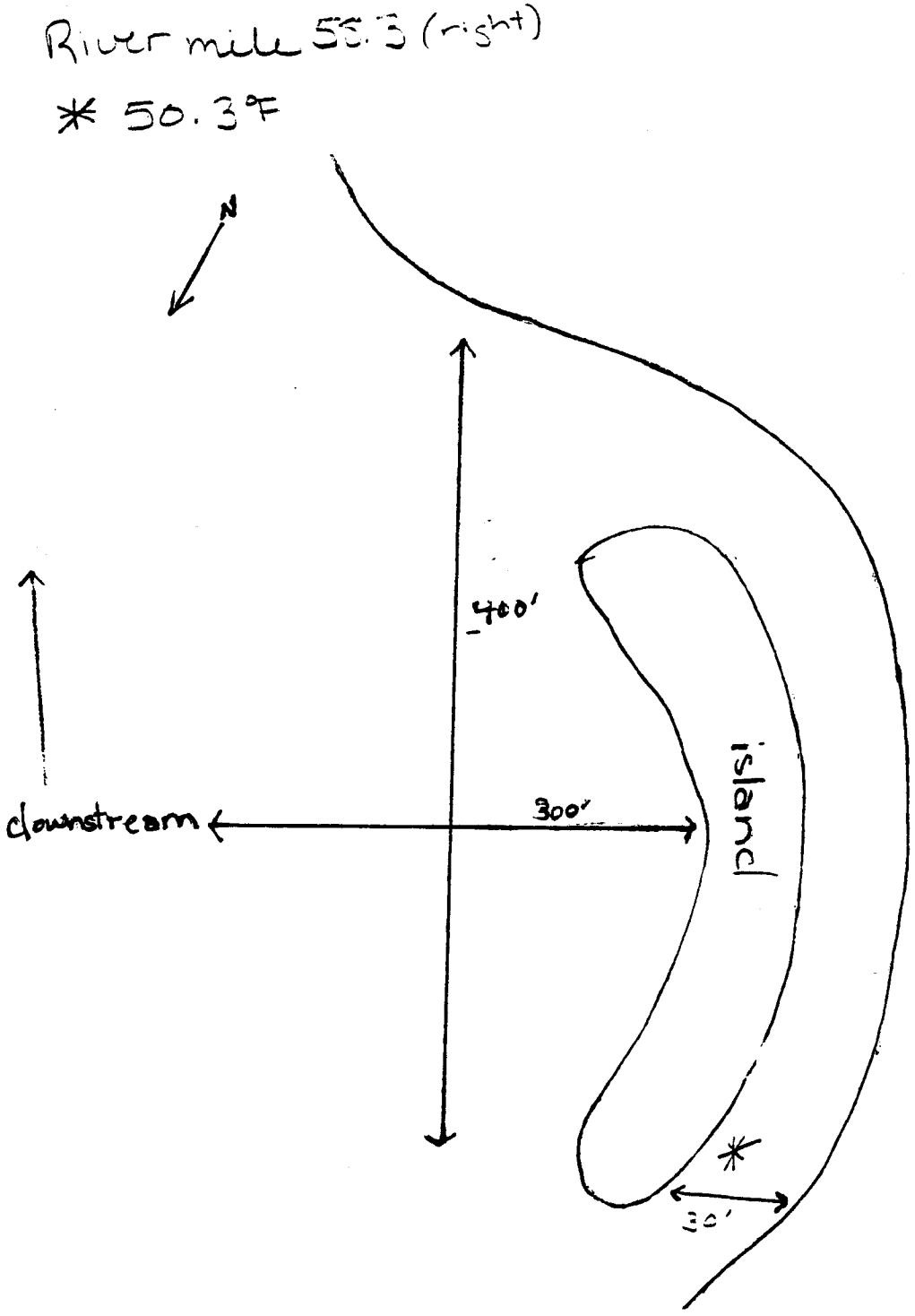
MAP #7



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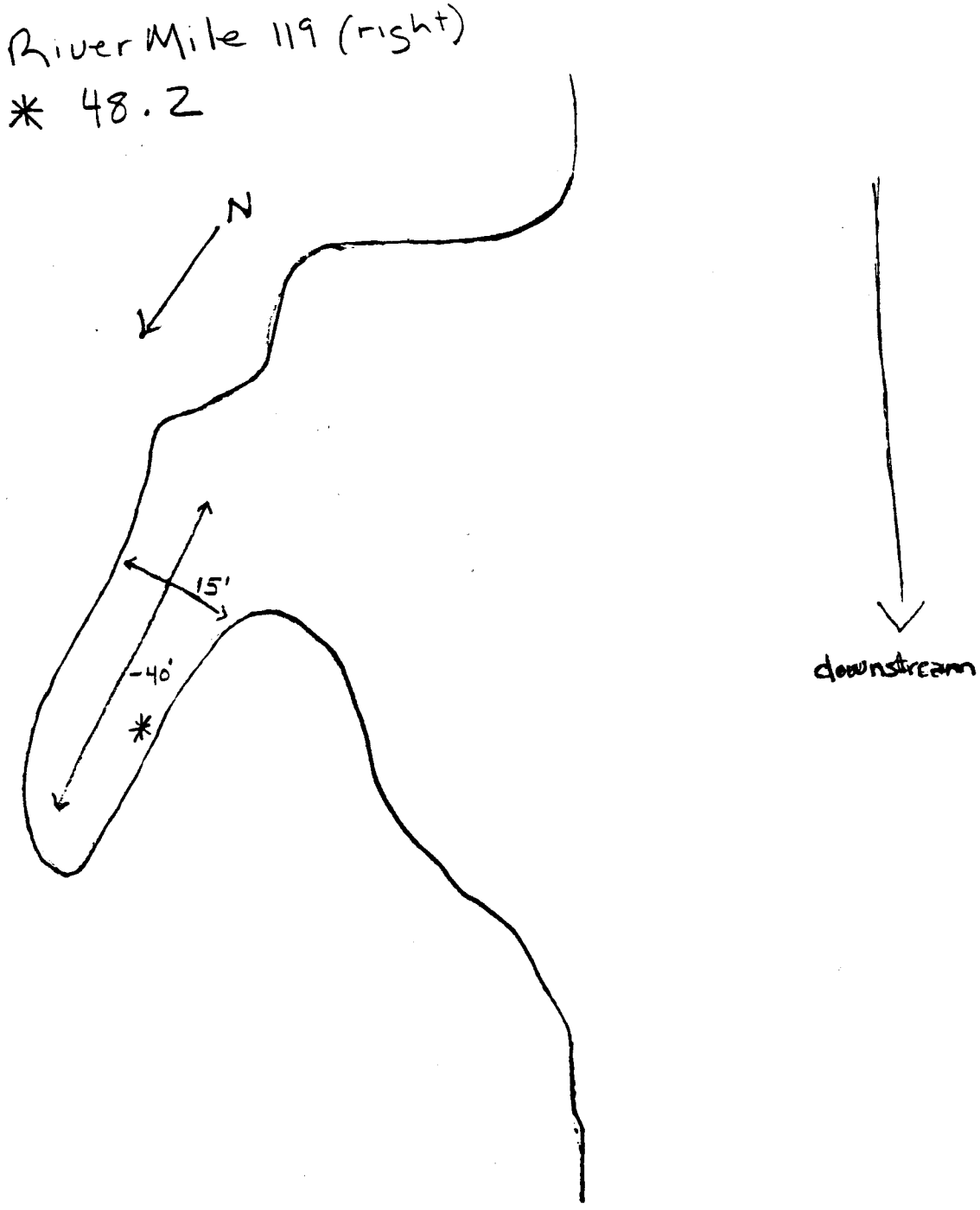
MAP #8

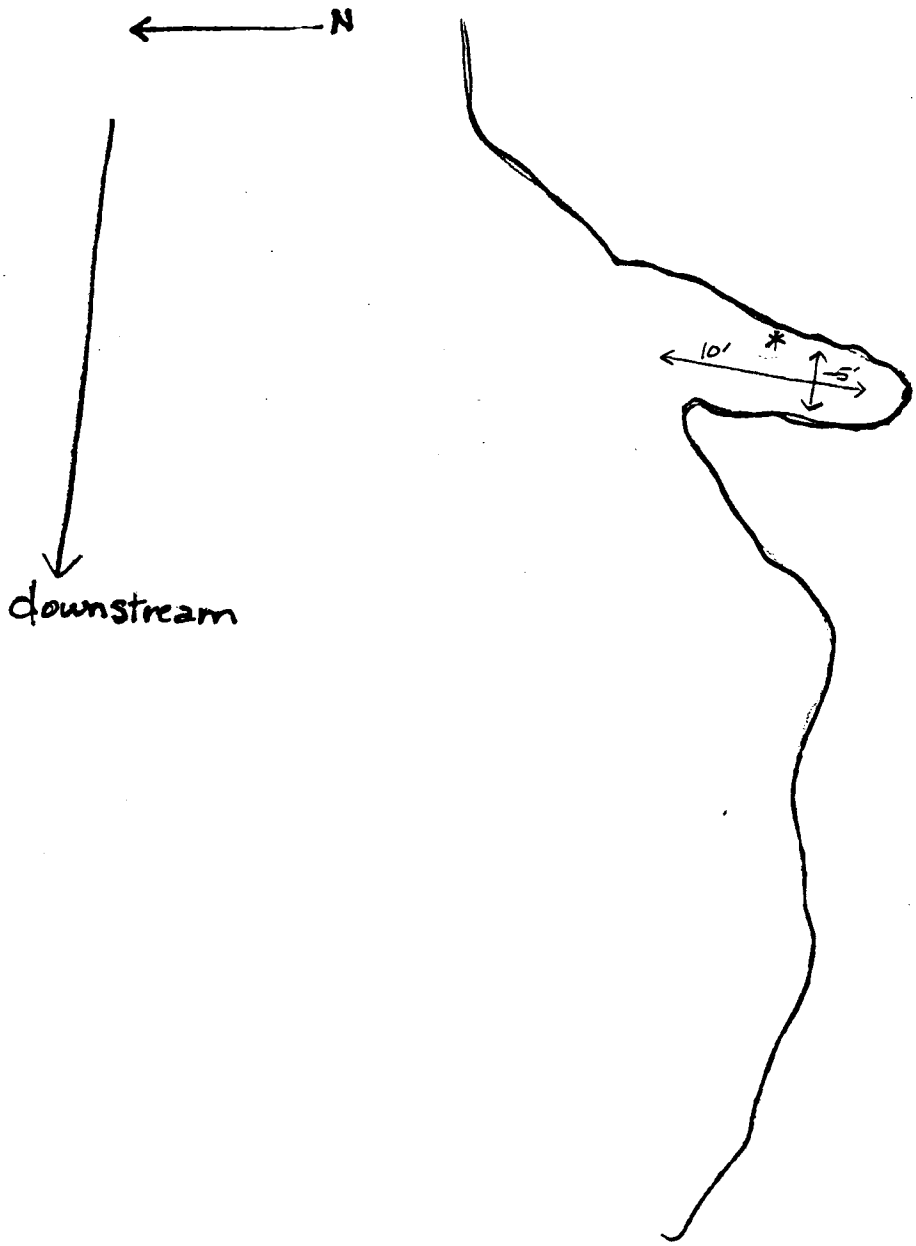


FRENCH & MUNSELL

MAP #9

River Mile 137 (left)

* 44 °F

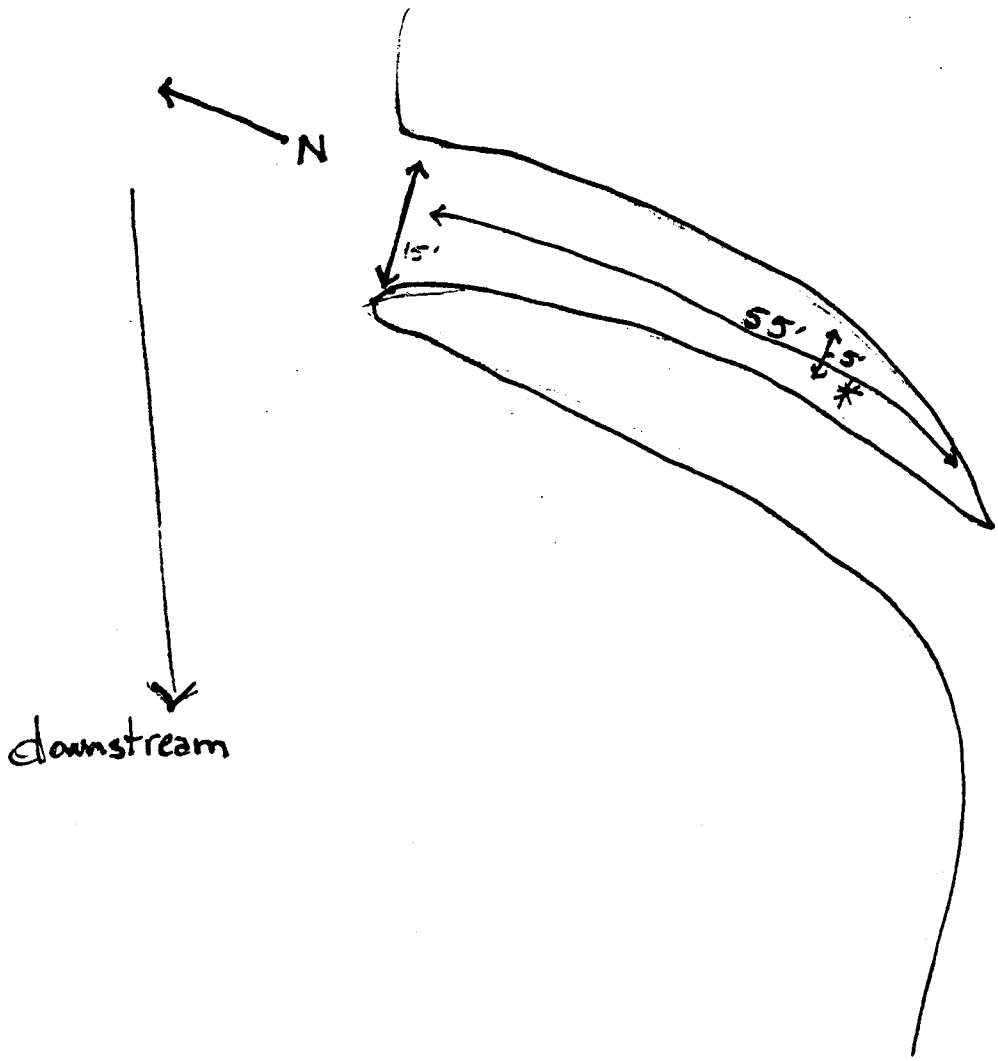


FRENCH & MUNSELL

MAP #10

Rivermile 172 (left)

* 40° F



WEATHER ALONG THE COLORADO RIVER IN THE GRAND CANYON DECEMBER, 1992

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ABSTRACT

Weather data was collected from 4 December to 28 December, 1992 along the Colorado River in the Grand Canyon. Numerous frontal boundaries entered the region producing a wide range of temperature extremes. Temperature readings for the month ranged from a minimum 28.0° F to a maximum of 59.0° F, with a mean ambient air temperature of 42.0° F. Precipitation was moderate and wind speeds were generally light throughout the month.

INTRODUCTION

The purpose of this study was to provide weather information to Glen Canyon Environmental Studies (GCES) so that it may be used by GCES for future research along the Colorado River in the Grand Canyon. The study was conducted by eleven Prescott college students and three faculty members from December 4th to December 29th, 1992. Weather information collected while on the river was time and river mile, percentage of cloud cover, wind speed/direction, ambient air temperatures (°F), precipitation amounts, cloud types and remarks.

METHODS

All readings are from river mile (RM) 0, Lees Ferry to RM 279, Pierce Ferry. River mile information is from Stevens (1987). Ambient air temperatures were taken in four time windows during the day: 0700 to 0900; 1100 to 1300; 1600 to 1800; and 2000 to 2100 hours. A digital thermometer (Micronta) was used =/- 0.1° F until December 12th. Thereafter temperatures were taken with an analog thermometer (alcohol based) +/- 0.5° F. All temperatures were read on shore and in shaded localities, unless otherwise indicated. All temperature readings were taken 6-7 feet above river level to avoid moderating influences of the river.

Additional data collected were percentage of cloud cover, wind speed/direction, and precipitation from last reading. These data are estimates based upon visual observations. Cloud types were identified with the aid of Schafer & Day (1991). All tables and figures were compiled from data listed in appendix A.

RESULTS

Monthly maximums and minimums only represent temperature extremes for the established timewindows. They do not necessarily represent temperature minimums and maximums for the day or month.

Ambient air temperatures between 0700 to 0900 were 44.3° F at Lees Ferry and 38.0° F at Pierce Ferry (figure 1). The maximum temperature reached was 44.5° F on December 4th. The minimum temperature reached was 28.0° F on December 14th. The mean ambient air temperature during this time window was 36.2° F.

Figure 2 illustrates temperature data taken between 1100 and 1300 hours. Ambient air temperatures were 49.1° F at Lees Ferry and 59.0° F at Pierce Ferry. The maximum temperature reached was 59.0° F on December 28th. The minimum temperature reached was 36.0° F on December 20th. The mean ambient air temperature during this time window was 47.9°F.

Between 1600 and 1800 hours ambient air temperatures were 42.4° F at Lees Ferry and 50.0° F at Pierce Ferry (figure 3). The maximum temperature reached was 53.0° F on December 18th. The minimum temperature reached was 35.1° F on December 6th. The mean ambient air temperature during this time window was 43.7° F.

Ambient air temperatures between 2000 to 2200 hours were 32.6° F at Lees Ferry and 45.0° F at Pierce Ferry (figure 4). The maximum temperature reached was 48.8° F on December 24th. The minimum temperature reached was 32.6° F on December 6th. The mean ambient air temperature during this time window was 40.3° F.

The following weather summary is based upon estimates derived from visual observations. All pertinent data surrounding this weather summary is available in appendix A.

From the 4th of December to the 8th of December (RM 0 to 44) a frontal boundary entered the region. Nimbostratus and stratus clouds along the river corridor indicated the frontal boundary's presence. An estimated 0.2 inches of precipitation fell in the form of snow between the evening of December 4th and the morning of December 5th. Winds were light and generally out of the southwest. An estimated .2 inches of precipitaiton in the form of rain fell between the evening of December 7th and the morning of December 8th. Gradual clearing occurred after the 8th and clear skies prevailed until the 9th of December (RM 44 to 52.5).

After the 9th of December another disturbance entered the region and lasted until the afternoon of the 11th of December (RM 52.5 to 64). Cloud types included cirrostratus, nimbostratus and stratus clouds. Southwesterly winds with an average of 2-3 mph prevailed during this time period, with no measurable precipitation. Partial clearing occurred from the morning of December 11th to the morning of December 12th (RM 64 to 69).

From the morning of December 12th to the morning of December 13th (RM 69) clouds increased, resulting in an estimated 0.2 inches of rainfall. Winds were calm.

From the morning of December 13th to the morning of December 15th (RM 69 to 81) stable conditions prevailed. Winds were generally from the east, with moderate winds occurring within the first three days of this time period. Altostratus clouds began moving in from the northwest on the evening of December 14th.

Throughout the day of December 15th (RM 81 to 93) overcast skies prevailed. Cloud cover in the form of altocumulus and stratocumulus reached below the upper rim of the canyon. Precipitation in the form of snow fell above the Tonto Platform, none of which reached river level. Clouds began exiting the region that evening. On the morning of the 16th (RM 93 104) clear weather prevailed. Winds were calm. Cirrus, altostratus and altocumulus clouds entered the region on December 17th (RM 104 to 120). These cloud types entered the region from the southwest and exited to the northeast and by the evening of the 17th clear skies prevailed.

On the morning of December 18th (RM 128 to 137) nimbostratus clouds returned to the area. An estimated 0.3 inches of rain had fallen during the night. Light winds issued from the southwest. During the day clouds decreased and by late evening all clouds had exited the region.

From December 19th to December 26th (RM 137 to 209) clear weather predominated over the region. On December 20th (RM 152), December 24th and December 26th (RM 209) high cirrus and cirrostratus clouds entered the region from the southwest. Winds during this time period entered from both the northwest and southwest, and were relatively calm over the specified duration.

The heaviest precipitation fell at night on December 27th and the morning of December 28th (RM 236). Cirrostratus and altocumulus clouds began entering the region on December 27th and by 1736 hours nimbostratus clouds covered the sky. Rain began falling by 2126 hours and continued through the night till the morning of December 28th. An estimated 1.0 inch of rain fell during this time period. Mid to high-level clouds decreased throughout the day and by evening (RM 263) a thick blanket of low-level stratus clouds covered most of the skyline.

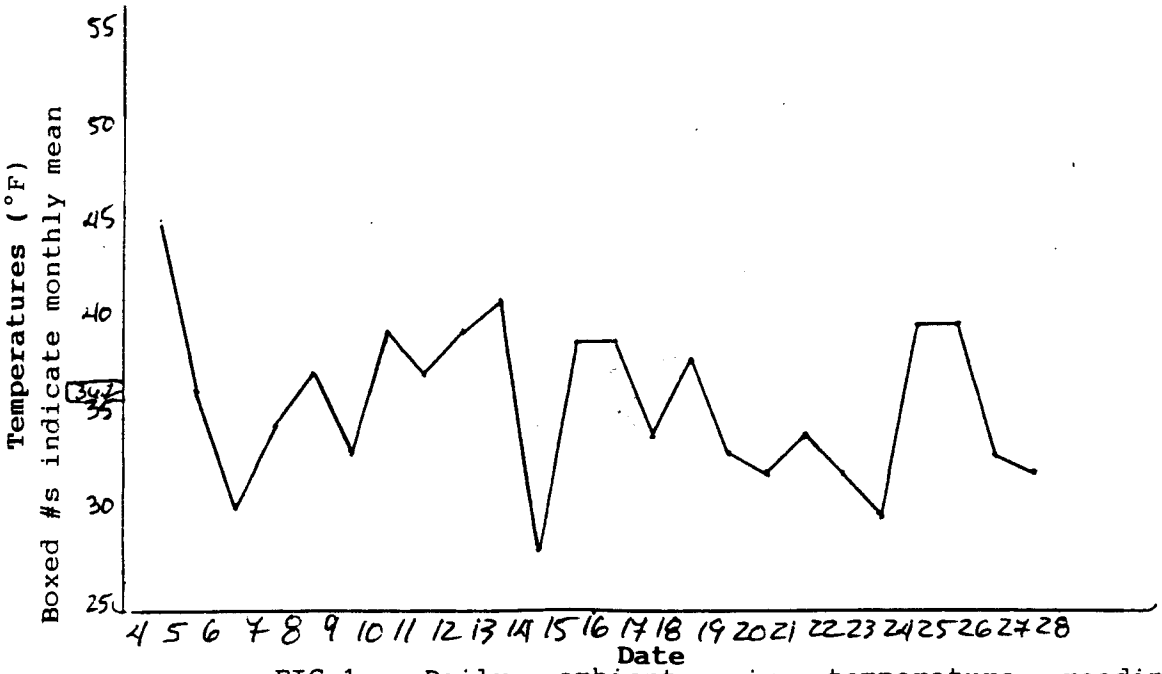

FIG.1. Daily ambient air temperature readings occurring between 0700 to 0900 hours along the Colorado River in the Grand Canyon. December, 1992.

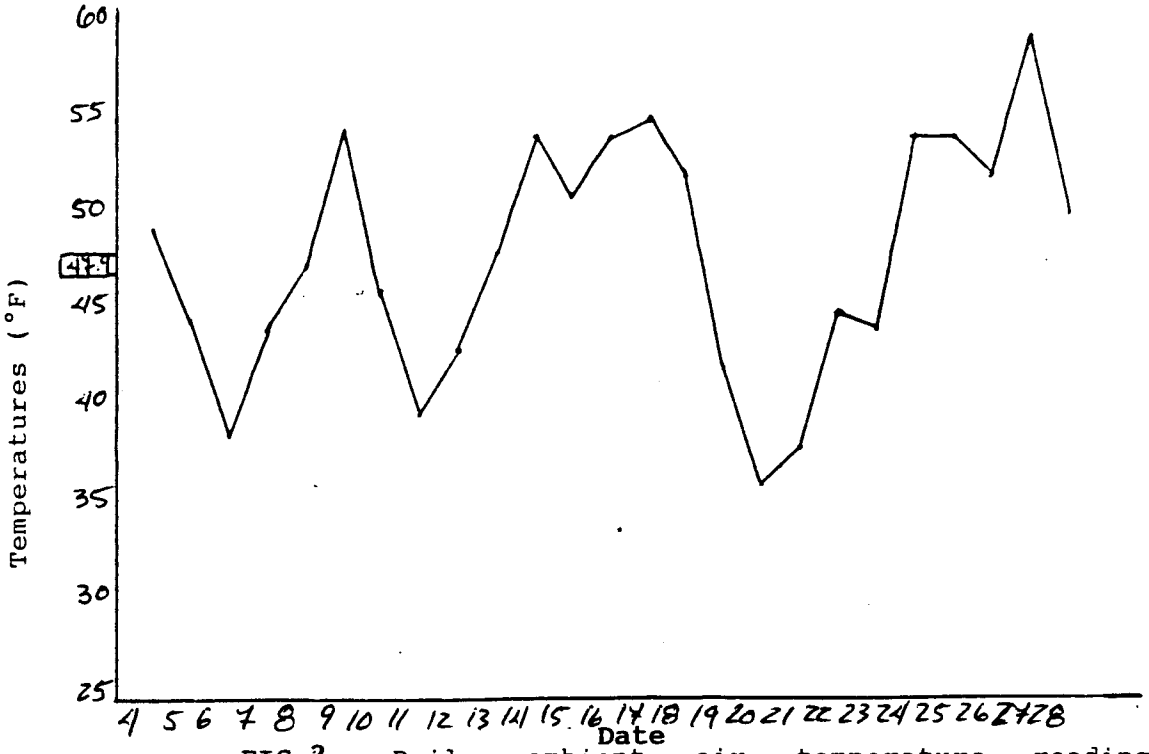

FIG.2. Daily ambient air temperature readings occurring between 1100 to 1300 hours along the Colorado River in the Grand Canyon. December, 1992.

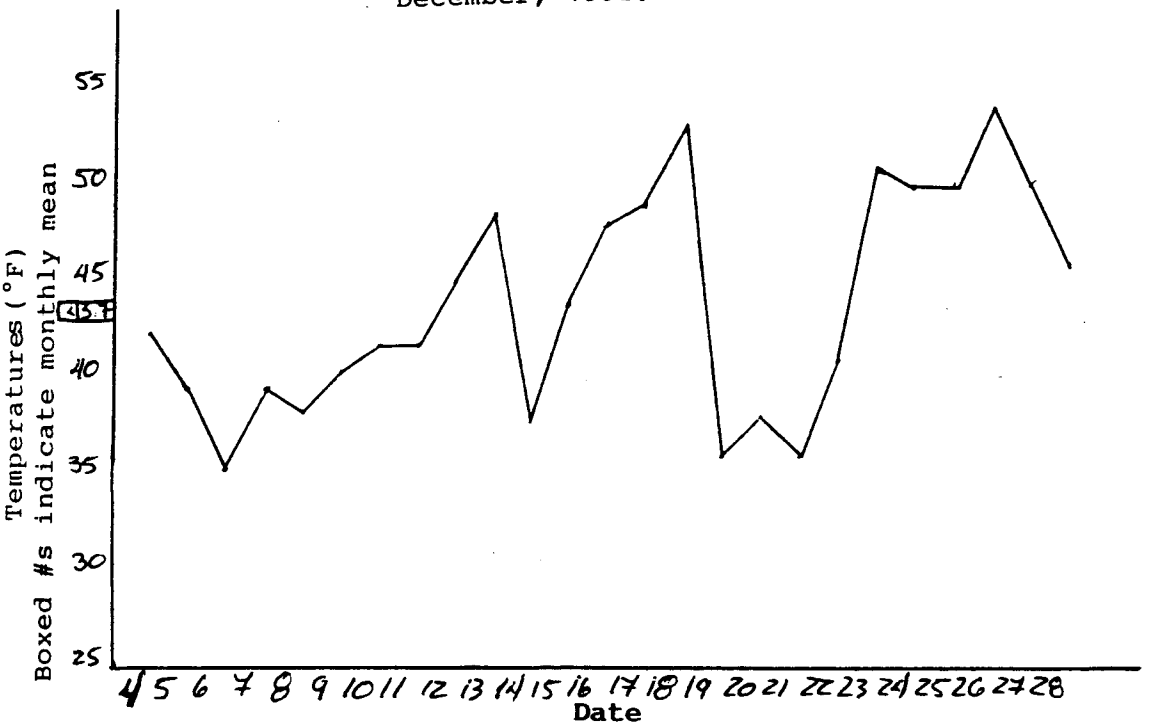

FIG.3. Daily ambient air temperature readings occurring between 1600 to 1800 hours along the Colorado River in the Grand Canyon. December, 1992.

FIG.4. Daily ambient air temperature readings occurring between 2000 to 2200 hours along the Colorado River in the Grand Canyon. December, 1992.

DISCUSSION

The 12 geomorphic reaches of the Colorado River corridor may aid the reader in correlating collected data (appendix B).

Daily ambient air temperatures illustrated in figures 1-4 fluctuated throughout the entire month of December, 1992. It would be difficult to determine any trends or patterns in the temperatures during this study due to the number of variables that may be affecting those temperatures. Those variables include atmospheric disturbances (cold fronts, warm fronts), distinctive canyon morphologies, cold air drainage, slope aspect, solar incidence, time of year, latitude and elevation. All contribute to daily and monthly temperature variations. All variables listed above affect temperatures directly or indirectly, in unison or individually.

Atmospheric disturbances may be a useful example of how a single variable in conjunction with many others may affect daily temperature fluctuations. One may hypothesize that a low pressure system might have had some effect towards the drop in temperatures during the first four days of the research. Those first four days do show a distinctive trend in temperature drops, but whether a frontal boundary independently

influenced those temperature drops would be difficult to determine. As well, there are some temperature drops which do occur after the exiting of frontal boundaries (possible cold fronts). Those drops occurred on the 6th, 11th and 19th of December (figure.1). Yet these were also places where canyon narrowing became more pronounced. Alternately, temperatures also rose during December 26th and 27th with the entrance and exiting of a frontal boundary. This may indicate a possible subtropical low pressure center entering from the southwest. Thus, frontal boundaries do have some control over temperature fluctuations, though, how much of an affect would be difficult to ascertain with the information collected.

Due to our continual movements down river, weather data did not represent one locality. Correlating long-term weather data from numerous localities made for difficult weather analysis. Also, the span of the study was short. Weather patterns are generally deduced by long-term studies. It may be helpful, if this type of study is to occur again, to establish specified weather sites along the river corridor. Specific sites along the river corridor may help reduce the number of variables affecting temperature changes. These sites may aid future researchers in understanding overall weather patterns on the Colorado River in the Grand Canyon.

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Schmidt, J.C. and J. B. Graf. 1990. Aggradation and degradation of alluvial sand deposits, 1965 to 1986, Colorado River, Grand Canyon National Park, Arizona. U.S. Geol. Surv. Prof. Paper 1493.

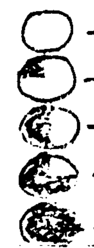
Stevens, Larry. 1987. The Colorado River through the Grand Canyon: A Guide. Red Lake Books, Flagstaff, Arizona.

TURNER

APPENDIX A
Field notes and data charts

Weather for the month of December 1992
Recorded from Lees Ferry to Pierce Ferry [illegible]
Key to Columns

<u>% of cloud cover</u>:

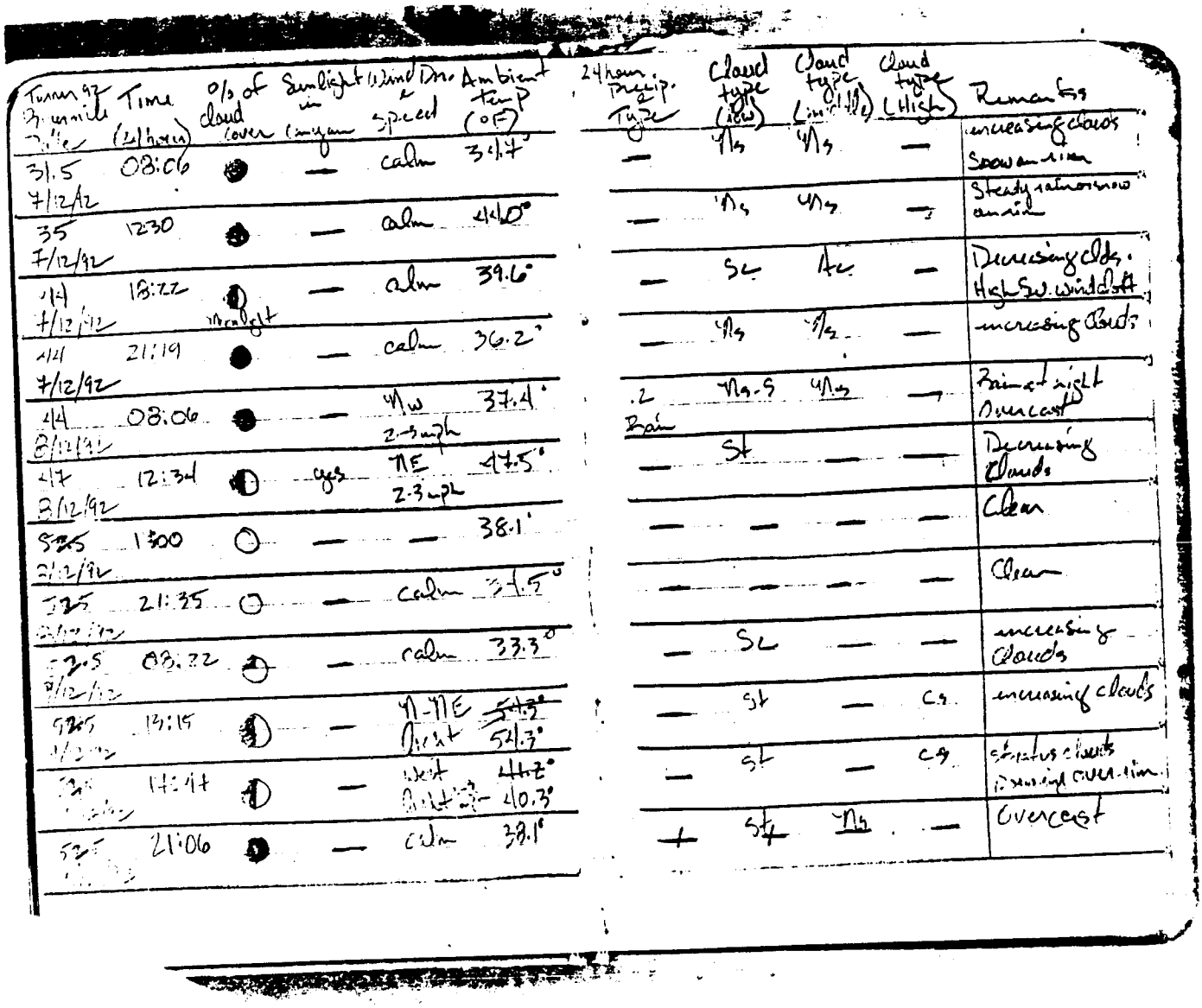


- none
- 1/4 cloud cover
- 1/2 cloud cover
- 3/4 cloud cover
- full cloud cover

<u>Cloud types</u>: <u>Low</u> 0-10,000 feet
St - Stratus
Cu - Cumulus
Sc - Strato Cumulus
Ns - Nimbo stratus
<u>Middle</u> 10,000-20,000 feet
Ns - Nimbostratus
Ast - Altostratus
Ac - Altocumulus
Cc - Cirrocumulus
Ci - Cirrus

<u>High</u> 25,000-50,000 feet
Cc - Cirrocumulus
Ci - Cirrus
Cs - Cirrostratus

Turner '92 river mile / Date	Time 24 hour	% of Cloud Cover	Sunlight	Wind direction & speed	Ambient Temp. (°F)	24 Precip. Type	Cloud type (low)	Cloud type (middle)	Cloud type (high)	Remarks
0 4/12/92	0834	●	—	calm	45.3°F	—	Ns	Ns	—	snow to south Cloud base [illegible]
3.5 4/12/92	12:33	◕	—	N-NW light	49.1°F	—	Ns	Ns	—	Strong gusts
8 4/12/92	16:46	●	—	NW 2-5 mph	42.1°F	trace Graupel	Ns	Ns	—	Increasing clouds
8 4/12/92	~~2~~ 2009	●	—	NW light	41.9°F	trace snow	Ns	Ns	—	Snow at river level (sticking)
8 5/12/92	08:00	●	—	N-NW light	36.5°F	.3 inches snow	St	Ns	[illegible]	Decreasing Clouds
11.5 5/12/92	12:31	◕	Partial	calm	41.6°F	—	St	Ns	cc	Decreasing Clouds
20.5 5/12/92	18:13	◐	—	calm	39.5°F	trace Snow	Sc-Ns	Ns	—	Clearing
20.5 5/12/92	20 21:00	○	—	Nw light	37.4°	—	—	—	—	Clear + cold
20.5 6/13/92	07:55	○	—	N 4-5 mph	30.5°	—	—	Ac +	—	Ac to S.
[illegible] 6/13/92	12:33	○	yes	calm	35.3	—	—	—	Cs	Cs to Sw.
31.5 6/13/92	~~31.5~~ 17:10	○	—	NE 2-3 mph	35.1°	—	~~cc~~	cc	Ci	Various mid to high level clouds seen
31.5 6/13/92	20:58	○	—	NE 5 mph	32.6°	—	—	—	—	Clear ~~[illegible]~~ [illegible]



Turner 97 Transmissometer File	Time (24 hour)	% of cloud cover	Sunlight in langleys	Wind Dir. & speed	Ambient temp (°F)	24 hour Precip. Type	Cloud type (low)	Cloud type (Middle)	Cloud type (High)	Remarks
31.5 7/12/92	08:06	●	—	calm	34.7°	—	Ns	Ns	—	increasing clouds Snow and rain
35 7/12/92	1230	●	—	calm	44.0°	—	Ns	Ns	—	Steady rain or snow and rain
44 7/12/92	18:22	● moonlight	—	calm	39.6°	—	Sc	Ac	—	Decreasing clds. High SW. winds aft
44 7/12/92	21:19	●	—	calm	36.2°	—	Ns	Ns	—	increasing clouds
44 8/12/92	08:06	●	—	NW 2-3 mph	37.4°	.2 Rain	Ns-S	Ns	—	Rain at night Overcast
47 8/12/92	12:34	◐	yes	NE 2-3 mph	47.5°	—	St	—	—	Decreasing clouds
525 8/12/92	1500	○	—	—	38.1°	—	—	—	—	Clear
525 8/12/92	21:35	○	—	calm	34.5°	—	—	—	—	Clear
525 9/12/92	03:32	◐	—	calm	33.3°	—	Sc	—	—	increasing clouds
525 9/12/92	13:15	◑	—	NNE light	~~54.2°~~ 54.3°	—	St	—	Cs	increasing clouds
525 9/12/92	17:47	◑	—	West light	44.2° 40.3°	—	St	—	Cs	stratus clouds increasing overcast
525 9/12/92	21:06	●	—	calm	38.1°	+	St	Ns	—	Overcast

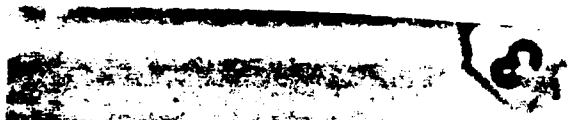
Turner 12 River mile [illegible]	Time (24 hours)	% of Cloud Cover	Sunlight in Canyon	Wind Dir & Speed	Ambient temp (°F)	24 hour Precip type	Cloud type (Low)	Cloud type (Middle)	Cloud type (High)	Remarks
52.5 R 10/12/92	07:52	●	—	calm	31.7°	—	—	St	Ns	Cloud base below canyon rim
56.8 R 10/12/92	12:36	●	—	SW 2-3 mph	46.0°	—	St-Ns	Ns	—	Full cloudcover
61 10/12/92	16:58	●	—	SW 2-3mph	41.9°	—	St-Ns	Ns	—	Overcast Snow on rim
61 10/12/92	21:13	●	—	calm	36.7°	—	St-Ns	Ns	—	Cloudy
61 11/12/92	07:41	●	—	SW 6-8mph	37.2°	—	St	—	—	stratus clouds atop of rim
64 11/12/92	10:40	◐	—	calm	39.9	—	St	—	—	Decreasing clouds
68 R 11/12/92	14:08	●	—	NE 5-10 mph	41.9°	—	St	As	Cc	increasing clouds
67 11/12/92	20:01	○	—	calm	40.1	—	—	—	—	Clear
69 R 12/12/92	08:36	◐	—	SW 2-3mph	39.6°	.2 Sleet	Ns	Ns	—	Rain between [illegible] Clouds
69 R 12/12/92	12:15	●	—	SW 2-3mph	43.3	—	St-Ns	Ns	—	Increasing clouds
69 R 12/12/92	16:30	●	—	calm	45.0°	—	St-Ns	Ns	—	light rain
69 R 12/12/92	—	—	—	—	—	—	—	—		No Reading

Turner 92 mile / Date	Time (24 hour)	% of Cloud Cover	Wind Dir & Speed	Ambient Temp (°F)	Precip. from last reading Type	Clouds (Low)	Clouds (Middle)	Clouds (High)	Remarks
19 [illegible] [illegible]/12/92	03:36	◐	East 1-6 mph	41.1°	—	—	Sc	ASt	increasing clouds from Northeast
[illegible] 13/12/92	11:56	○	East 1-6 mph	48.1	—	—	—	—	Clear
63 [illegible] 13/12/92	16:31	◐	East 3-4 mph	48.4	—	—	Stc	—	stratocumulus forming over [illegible] Plateau
6[illegible] 13/12/92	21:24	○	calm	39.6°	—	—	—	—	Clear
69 14/12/92	08:15	○	calm	28°	—	—	—	—	Clear
74 14/12/92	12:15	○ Sun	Calm	54° 60° in Sun	—	—	—	—	Clear
81 14/12/92	17:13	●	west light	38.0°	—	—	Ast	—	High cloud moving in from N-NW
81 14/12/92	21:21	○	calm	37.0°	—	—	—	—	Clear
81 [illegible]	07:43	◐	SW light	39.0°	—	Sc	Ac	—	Mixed cloud cover moving in from N-NW
87.5 [illegible]/12/92	1204	◐	Calm	51.0°	—	Sc	—	—	partly Cloudy
93 [illegible]	1[illegible]:[illegible]3	●	Calm	44.0	—	—	Ac		Overcast
93 [illegible]	20:[illegible]	●	calm	42.8	—	—	Ac	—	overcast

Turner 92 Riverside Site	Time (24 hr)	% of sky cover	Wind speed & Dir	Ambient temp (°F)	Precip. from last reading time	Clouds ([illegible])	Clouds (Cm)	Clouds (H)	Remarks
93 16/12/92	08:09	○	calm	39.0°	—	—	—	—	Clear
99 16/12/92	13:11	○	calm	51.0°	—	—	—	—	Calm/Clear
104 16/12/92	17:17	○	calm	38.0°	—	—	—	—	Clear
101 16/12/92	21:45	○	calm	35.0	—	—	—	—	Clear
101 17/12/92	07:52	◕	calm	34.0°	—	—	—	Ast	Ast entering from Southwest
114 17/12/92	13:43	◔	calm	55.0° Sun	—	—	—	ci	Decreasing Clouds
120 17/12/92	17:45	◑	NW light	49.0°	—	—	ac	ci	Ac entering from S.W. increasing clouds
120 17/12/92	20:32	○	NE 3-5 mph	45.0°	—	—	—	—	Clear, Winds lowering temps 6-10°F
120 18/12/92	08:19	●	calm	38.0°	.3 inches Rain	Ns	Ns	—	Overcast, Snow at base of Redwall [illegible]
128 18/12/92	13:53	◕	SW light	52.0°	showers	Ns	Ns		Decreasing clouds
134 18/12/92	16:[illegible]	●	calm	53.0°	showers	Ns	Ns	—	Increasing Clouds
137 [illegible]/12/92	20:43	○	calm	40.0°	—	—	—	—	Clear

Tuanda Biaramile Site	Time (24 hour)	% of Cloud Cover	Wind Sp & Dir	Ambient Temp (°C)	Precip from last reading	Clouds (L)	Clouds (M)	Clouds (H)	Remarks
137 19/12/92	0813	○	SW. 2-3 mph	33.0°	—	—	—	—	clear
137 19/12/92	1257	○	S.W. light	<12.0°	—	—	—	—	Clear
137 19/12/92	1734	○	Calm	36.8	—	—	—	—	Clear
137 19/12/92	2045	○	calm	34.0°	—	—	—	—	Clear
137 20/12/92	0724	○	Sw lt.	32.0°	—	—	—	—	Clear
143.5 20/12/92	1211	○	calm	36.0°	—	—	—	ci	increasing clouds from SW
152 20/12/92	1718	◔	SW lt.	38.0°	—	—	cc	cc	increasing clouds
152 20/12/92	2102	◔	calm	35.0	—	—	cc	cc	slight increase in cld. cover
151 21/12/92	0751	○	calm	34.0°	—	—	—	—	clear
168 21/12/92	1237	○	Calm	38.0°	—	—	—	—	clear
171.4 21/12/92	1722	○	Calm	36.0°	—	—	—	—	clear
171.4 21/12/92	2123	○	Calm	34.0°	—	—	—	—	Clear

Turan '92 Bicycle Mile Date	Time (24 hour)	% of Cloud Cover	Wind Speed & Dir	Ambient Temp	Precip. Frequency Reading type	Clouds (L)	Clouds (M)	Clouds (H)	Remarks
171.1 22/12/92	0810	0	Calm	32.0°	—	—	—	—	Clear
176 22/12/92	1245	0	Calm	45.0°	—	—	—	—	Clear
188 22/12/92	1656	0	Calm	41.0°	—	—	—	—	Clear
188 22/12/92	—	—	—	—	—	—	—	—	Not reading
188 23/12/92	0759	0	Calm	30.0°	—	—	? —	—	Clear ~~Clear~~
197 23/12/92	1245	0 Sun	Calm	44.0°	—	—	—	—	Clear
208 23/12/92	1658	0	NW 3-5mph	51.0°	—	—	—	—	Clear
208 23/12/92	2043	0	NW 3-5	49.0	—	—	—	—	Clear
208 24/12/92	0814	0	Calm	40.0°	—	—	—	CS	Cirrostratus entering from Southwest
208 24/12/92	1206	0 Sun	SW light	54.0°	—	—	—	—	Clear
208 24/12/92	1640	0	Calm	50.0°	—	—	—	—	Clear
208 24/12/92	2040	0	Calm	43.3°	—	—	—	—	Clear



Turning Time (Eastern Standard Time) Date		% of Cloud Cover	Wind Speed & Dir.	Ambient Temp (°F)	Precip. from last reading	Clouds (Lo)	Clouds (Mi)	Clouds (Hi)	Remarks
208 25/12/92	0821	0	calm	40.0°F	—	—	—	—	clear
208 25/12/92	1206	0 5km	SW light	54.1.0° 60.0 5km	—	—	—	—	clear
208 25/12/92	1610	0	calm	50.8	—	—	—	Cu	Cirrus to South
208 25/12/92	2010	0	calm	48.0°	—	—	—	—	clear
208 26/12/92	0840	0	calm	33.0°	—	—	—	—	clear
208 26/12/92	1210	0	SW lt.	52.0°	—	—	—	—	Cirro Stratus entering from SW
208 26/12/92	1620	0	calm	54.1.0°	—	—	—	—	clear
208 26/12/92	2044	0	calm	38.0°	—	—	—	—	clear
208 27/12/92	0806	0	calm	32.0°	—	—	—	CS	increasing clouds
220 27/12/92	1218	1	SW light	54.0°	—	—	HC	LS	increasing clouds
220 27/12/92	1456	8	calm	50.8°	—	Ns	—	—	Full Cloud Cover Rain on South Rim
220 27/12/92	2110	8	calm	15.0	—	Ns	—	—	Rain

Turner 92 Binnamite & Date	Time (24 hrs.)	% of cloud cover	Wind speed & Direction	Ambient Temp (°F)	Precip from last reading	Clouds (h)	Clouds (Km.)	Clouds (ft)	Remarks
28/12/92	0332	●	calm	45.0°	1 inch	Ns-St	—	—	Rain through night Some clearing
28/12/92	1214	●	Calm	50.0°	Shwrs.	Ns-St	—	—	Stratus clouds below rim
28/12/92	1436	●	calm	46.0°	—	Ns-St	—	—	Decreasing Clouds
28/12/92	1943	●	Calm	52.0°	—	—	—	—	Decreasing Clouds
29/12/92									
29/12/92									
29/12/92									
29/12/92									
30/12/92									
30/12/92									
30/12/92									
30/12/92									

APPENDIX B.

THE 12 GEOMORPHIC REACHES OF THE COLORADO RIVER THROUGH THE GRAND CANYON AND THEIR DISTINGUISHING CHARACTERISTICS

Reach (river mile)	Local name of reach	Major geologic units of reach	Description of reach width
0-11.0	Permian Section	Kaibab Limestone Toroweap Formation Coconino Sandstone Hermit Shale	Wide
11.0-22.5	Supai Gorge	Supai Group	Narrow
22.6-40.0	Redwall Gorge	Redwall Limestone	Narrow
40.0-61.5	Lower Marble Canyon	Muav Limestone Bright Angel Shale Tapeats Sandstone	Wide
61.6-77.4	Furnace Flats	Tapeats Sandstone Unkar Group	Wide
77.5-117.8	Upper Granite Gorge	Zoroaster Plutonic Complex Trinity & Elves Chasm Gneisses	Narrow
117.9-125.5	Aisles	Tapeats Sandstone	Narrow
125.6-139.9	Middle Granite Gorge	Tapeats Sandstone Unkar Group Vishnu Schist	Narrow
140.0-159.9	Muav Gorge	Muav Limestone	Narrow
160.0-213.8	Lower Canyon	Basalt Muav Limestone Bright Angel Shale	Wide
213.9-240.0	Lower Granite Gorge	Vishnu Schist	Narrow
240.0-276	Lake Mead	Lake Sediments	-

After Schmidt and Graf, 1990. Modifications made by this study were to extend Lower Granite Gorge reach to mile 240 and to add Lake Mead reach from mile 240.0 to mile 276.

PHOTOGRAPHIC BEACH SURVEY ALONG THE COLORADO RIVER IN GRAND CANYON, DECEMBER, 1992

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INTRODUCTION

The beaches along the Colorado River in the Grand Canyon have been a specific interest for the Glen Canyon Environmental Studies (GCES) since 1982. Erosion of beach habitat is due both to lack of sediment in water released by Glen Canyon Dam and the rates of which the water has been raised and lowered. Documentation of this erosion is important in order to determine the manner in which water should be released from the dam. As part of a monitoring study, Prescott College students documented beach morphology during the month of December 1992. Photographs were taken during this survey in order to document any specific erosional features in addition to general morphology of beaches within the Colorado River corridor of the Grand Canyon. The main objective of this survey is to provide GCES with photographs which can be used in comparison with other surveys.

Beach survey photographs for GCES were taken at a total of 42 sites, 29 of these sites were established survey beaches, 8 were campsites used by the Prescott College research party, the remaining sites were thought to have been survey sites used previously by the GCES. The primary sites were selected from a list of survey beaches provided by GCES, included in table 1. Photographs were taken beginning 12/4/92 and ending 12/27/92, between Lees Ferry (river mile 0) and Spencer Canyon (river mile 246). Mileages were taken from Stevens (1987).

Table 1. List of 42 beach sites photographed during December 1992, by name and river mile (Stevens, 1987) (* denotes camp photographs).

BEACH NAME	RIVER MILE & SIDE
Cathedral Wash	3 Left
Jackass	8 Left
Hot Na Na	16.5 Left
North Canyon*	20.6 Right
Beach	21.8 Right
Fence Fault	30 Right
South Canyon	31 Right
Redwall Cavern	33 Left
Anasazi Bridge	43 Left
Eminence Break	45 Left
Saddle Canyon	47 Right
Beach	50 Left
Beach	51 Left
Nankoweap*	53 Right
LCR research camp*	61 Right
Tanner Canyon	68 Right

Table 1 (Cont.)

Basalt Canyon*	69.8 Right
Grapevine	81 Left
Cremation	87 Left
Trinity Creek	91 Right
Monument	93 Left
Little Ruby	104 Right
Beach	119 Right
Blacktail*	120 Right
Beach	122 Right
Forster	123 Left
Pancho's	136 Left
Fishtail	139 Right
Beach	145 Left
Mohawk Canyon*	171 Left
Beach	172 Left
Beach	183 Right
Whitmore Wash*	188 Right
Beach	194 Left
Beach	202 Right
Granite Park*	209 Left
Pumpkin Springs	213 Left
Gorilla	220 Right
Diamond Creek	225 Right
Gneiss Canyon*	236 Right
Separation Canyon	239.5 Right
Spencer Canyon	246 Left

METHODS

A number of considerations were taken into account when photographing any specific site. First and foremost was establishing a key vantage point, from which the entire beach profile could be seen, as well as any significant erosional features. Vegetational features, sand distribution, waterlines, and back waters were also factors in establishing this point. This vantage point was generallychosen in an attempt to minimize the number of photographs taken. Occasionally, the best vantage point was on the opposite side of the river. In addition, many of these points had been marked previously, indicating that these sites had been pre-established, probably by GCES.

The use of a tripod was preferred, although many of the photographs were taken with a hand-held camera. This was due to limited time as well as the location from which the photograph needed to be taken.

Due to low winter light, Fujichrome 100 ASA 35mm slide film was used. This provided a workable range of shutter speeds and a fairly fine grained film for clarity. A 28mm to 85mm Nikkor zoom lens was used. This gave wide angle capability for whole beach profile as well as zoom capability for close up feature photographs.

RESULTS

A total of 42 beaches were photographed throughout the survey. Of these beaches, 29 were established survey beaches, 8 were campsites used by the Prescott College research party, the remaining sites were thought to have been survey sites used previous by GCES. Twenty six rolls of film were taken. The number of photographs taken per beach varied, depending on the size of the beach and the location of the vantage point from which the beach was to be photographed. Beach photographs and backwater photographs were taken. The number of photographs of either can be found in photo survey field book.

DISCUSSION

The use of photographs is an integral method used to study the evolution of beaches within the Grand Canyon. It provides a permanent record of this evolution throughout time and allows scientists to compare these changes over time. The survey beach photographs provided to GCES from this survey will help them in their long-term monitoring of the Colorado River in the Grand Canyon. These photographs may allow GCES to draw conclusions based on comparisons with earlier photographs.

To improve this study, pre-established vantage points would be of great value. Accurate topographical maps of these sites should be provided to surveyors in future studies.

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Who We Are:
Journal Entry

We are 14 people traveling the Green and Colorado Rivers by raft. We call our trip "Re-Exploring Powell's Journey". We vary in age from 20 to 41. There are 11 students and 3 instructors, by title, we are all students. We have a lot to learn. We base our trip on the travels of a bearded, self-taught, one-armed major--a geologist, an ethnologist, an explorer known as John Wesley Powell. Our guru of sorts. He started his trip on the Green River in Green River, Wyoming and made his way down through the Grand Canyon on the Colorado River in 1869. He filled in the blank spot on the map by naming the canyons, rapids, buttes and falls. His thoughts explained the topography, geography, natural history and geology. (If only we could accomplish that much! I think we can.)

We are traveling his trail - partially. We start below Flaming Gorge Dam under the eye of a federal employee who runs his mouth as fast as the turbines 150 feet away. The red walls of Flaming Gorge, which awed and inspired Powell on his third day, thrill us on our first. We rig and forget about the background noise of the dam and that man.

We push off not knowing what lies ahead. How could we? For most of us this is a first voyage. We see eye to eye with Powell. "Self-taught" rings a bell for all of us. We represent an alternative college where experiential education is a tool for learning. Seeing, touching, feeling, inspiration and involvement are some of the elements of our learning process. Motivation stems from a desire to learn about the world around us. We want to experience the areas we explore. We may not discover a new bird species or solve a geologic mystery but we will uncover something new in ourselves, discover new things about our environment and each other.

The regulated flow of water will change the nature of our course, so will the rubber boats and the absence of Indians. We will look at ruins, petroglyphs and pictographs in wonder, touched by their existence, left to speculate on their creator's religions, lifestyles and cultures. We will examine our own artifacts; beer cans on the bottom of the Uinta Basin, the

river register at Bow Knot Bend and the dams of the Bureau of Reclamation.

We will travel 735 miles down two rivers that are part of the river system that the West relies upon for water, food, power and recreation. During that time a president will be elected
and two babies will be born into the families of expedition members. This we know. This is our future. We hope for a president who has a vision that includes innovative environmental policy, a commitment to education and whose politics reflect that the people of the world are one.

COMPARATIVE HISTORY OF THREE SCIENTIFIC EXPLORATIONS ON THE GREEN AND COLORADO RIVERS

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In 1869, John Wesley Powell journeyed by wooden boat down the previously unexplored Green and Colorado Rivers. He was successful in his explorations and went back again for a second trip. One hundred and twenty-three years later, eleven students and three instructors from Prescott College set out on a seventy- two day, 735 mile journey re-exploring the journeys of Powell. Their trip was an academic endeavor, the first of its kind for the college. Their goals were to familiarize themselves with the geology and ecosystems of the region and to collect data for the Glen Canyon Environmental Studies (GCES) in the Grand Canyon portion of their trip. Experiential education, the nature of their educational style, allowed them to learn by "doing". To get a closer understanding of Powell's explorations they immersed themselves in the environment that Powell traveled through. They slept by the rivers, drank from them, washed in them, and traveled on them. The group learned to respect the rivers as they were directly dependent on them. The channels and flows became a part of their existence and in one way or another the rivers became metaphors for life. Through challenge, adventure, exploration, and experience the spirit of education was inspired, emerged and grew.

The trip was not true to Powell's itinerary as some notable features block the free flow of the rivers. The group started below Flaming Gorge Dam and floated down 465 miles to Lake Powell. The only major task of river travel was one long and laborious portage around Glen Canyon Dam, a feature Powell would not believe. From practically the base of that dam, at Lees Ferry, the journey went on 281 miles to the slack waters of Lake Mead. In rubber boats nonetheless.

In the process of this journey the group experienced the evolution of the rivers. There were day-to-day changes with flows and sediment. There was evidence of historic change like remnants of floods and introduced

vegetation. The evidence of human impact was endless from diversion dams, abandoned ranches, scars from abandoned dam sites, power lines and styrofoam bait cups whirling in eddies. Many, many people were here before and many would follow.

The first European to see the Grand Canyon was Lieutenant Garcia Lopez de Cardenas in 1540. Cardenas was a member of the party of the Spanish conquistador Francisco Vasquez de Coronado. His men attempted to cross it and failed. It went almost unnoticed until 1857 when the first official American explorer, Lieutenant Joseph C. Ives came to the Grand Canyon with a U.S. Army survey. He had this to say about the Grand Canyon:

> "The region is altogether valueless. It can only be approached from the South, and after entering it there is nothing to do but leave."[1]

and the Colorado River:

> "It seems intended by nature that the Colorado River along the greater part with its lonely and majestic way, shall be forever unvisited and undisturbed."[2]

For anyone familiar with the arid West today, these early impressions seem ludicrous. But in the age of discovery and exploration these opinions accurately represent the true feelings of those men who traveled in this region during a time when the land was wild and uninhabited. Had John Wesley Powell, or any of the other explorers who followed closely behind him, read and believed Ives's words, the shape of history in the West may have been very different. Powell was ambitious in his quest for knowledge and discovery.

Today the Grand Canyon receives about 4.3 million visitors annually and the Colorado River System is the lifeline to the West, with its water as the most valued and valuable resource. Ives' opinions could not have been farther from the reality of the development of the West.

During the past 200 years, the shaping of the West reflects the government's pursuit of finding value in the land. In the name of science and progress we have explored, expanded and exploited. Now, in the

name of conservation and education we are exploring to maintain the land and its resources. Government sponsored scientific exploration of the Green and Colorado Rivers has reflected the focus of the government during these processes. Three of these explorations were: the 1869 and 1871 explorations of John Wesley Powell, the 1923 USGS Birdseye Survey, and Glen Canyon Environmental Studies that began in 1982 and continue to this day. The specific purposes of these explorations vary as time passes. Powell set out to explore, Birdseye surveyed, GCES researches and monitors.

The Colorado River System is the premier watercourse in the Southwest. It begins in the Rocky Mountains and flows 1,400 miles to Mexico and the Gulf of California. The entire drainage basin is comprised of 244,000 square miles. Over 108,000 square miles make up the Upper Basin above Lees Ferry and 136,000 square miles make up the Lower Basin. Colorado, Utah, New Mexico and Wyoming make up the Upper Basin; California, Arizona and Nevada make up the Lower Basin.

The Green River begins on the west slope of the Wind River Mountains in Wyoming. The source is Little Dale Lake. The river runs for 730 miles with a drainage basin of almost 45,000 square miles. The annual run-off is 5.7 million acre feet. A tributary to the Green River is the Colorado River. It is 1,400 miles in length, 320 miles between Glen Canyon Dam and Hoover Dam. It has a drainage basin of 26,000 square miles and more annual run-off than the Green River.

These rivers have been a focal point for Western development. Science and technology have been employed with the vision of controlling and taming the rivers in order to: support human life, livestock, and agriculture; control flooding and water flow; and provide power. The views of Ives, Powell and Birdseye were not the same. Their visions for the use and value of the land and water vary considerably, however, these visions were centered around conquering the land and taming the water. Today people are concerned with the impact of past reclamation projects on the environment and the quality of life. Today conservation and preservation are two ideals that need to be in balance with the systems that we are dependant on for survival. Science and technology are being used to find and maintain this balance. A commitment to education and concern for the

environment will carry on the visions, ideals and hopes for harmony and balance between the natural world and the human controlled world.

In the 19th century, applied science and basic science were developing. Applied science was the primary application of science to develop technology and assist invention. Second to the application of technology and invention was collection and observation for the purpose of theory and experimentation - basic science. The tradition of American scientists included the opportunity for amateur endeavors, especially in the early part of the century. The West was opening up and there was much exploration and discovery of what the West had to offer. Most people became specialists in either natural or physical sciences.[3]

The government supported mostly applied science. The railroad, telegraph, power from machinery and steamships are some of the tools that enabled people to explore. The application of science through agriculture, war and navigation was a significant aim of the government. Geological surveys were initially conducted for research, "contrary to the intent of the legislatures involved."[4] The lawmakers were interested in locating resources and mapping routes so that the settlers would move West. Later, in the 1840's, science was linked to exploration to meet these needs.

Exploration was used by the government as a tool for progress. Their interest was to put a map of the country together, especially in the West. The government wanted to know what kind of land and resources were available. In the spirit of the times, science was conducted with the intention of gathering a broad base of knowledge. This was especially true in the West where there was an unexplored mass of land with large amounts of new flora and fauna, and topographical and geological features, that needed to be discovered, collected, catalogued and studied.

In the 19th century, the West was being invaded by various groups who sought resources. It began with the trappers, mountain men and traders who were in search of furs. They were the first settlers and discovers of the West. Their journals included the explorations of rivers and mountains of the West. The miners followed in the middle of the century. An increase in population created new towns, increased agriculture and livestock raising, and aided the progress of railroads. Cattlemen followed the miners. The Great Plains and open ranges were ideal for cattle raising.

Agriculture came last. During a critical time in American history. The West, which was known as "the Great American Desert", became the "Great American Garden."

The first federal exploration was Lewis and Clark's from 1804 to 1806. Their purpose was to find a Northwest passage. Lieutenant Zebulon Montgomery Pike followed in 1806 with a federally funded geographical exploration. Pike was the first American to enter the South West (then Spanish territory) and return to the United States to publish his findings.[5] In his journal, which was published four years after his exploration, Pike pointed to the value he saw in the arid West between Missouri and the Rockies. "From these immense prairies," he wrote, "may arise one great advantage to the United States, viz: the restriction of our population to certain limits, and thereby a continuation of the union."[6] The West was thought of as valueless mainly because of the lack of water.

America's first systematic scientific expedition was led by Major Stephen H. Long in 1819. He travelled along the Platte River to the Rocky Mountains in search of the source of the Red River.[7] In the name of science, Long validated the theory that the arid West was worthless. Explorers who followed Long supported the idea by saying that the soil was incapable of growing crops because it was sterile.[8] He coined the term the "Great American Desert".[9] This area encompassed the part of the West between the 98th meridian and the Rocky Mountains. Later, it became known as the Great Plains.[10] Today it applies to the mountain west which has an area of 900,000 square miles. It is divided into three sections: the East is the high plains, the middle is the mountains and the West is the intermountain province of the Great Basin.[11]

After the war of 1812, the government realized the need for topographical engineers and surveys for determining the lay of the land in the West. In 1817, the Topographical Corps of Engineers was established. The men who made up the Corps were "professionally trained soldier-engineer(s) whose purpose it was to explore the American West scientifically." [12] In 1838, the Army Corps of Topographical Engineers did a survey of the West with economic and scientific goals in mind. There were resources to be located and catalogued and maps for travel created.

The Topographical Bureau created a relief map in 1850. It was "the first accurate map of the West's physiographic features." [13] It was put

together from the former explorations of the Topographical Corps of Engineers, as they dominated land surveys. The settlers who would be moving West would need to know what resources they could develop and extract, the climate, the topography and the route to get there. The West was forming with power, politics and economics as the triangular base with development balanced on top.

The "Great American Garden" idea was pushed by speculators and railroad developers. Their goal was to entice people to settle in the West. Their propaganda was based on the idea that if people came, so would the rain. In 1844, an article in Josiah Gregg's Commerce of the Prairies was the first publication of the idea. Gregg wrote, "the extreme cultivation of the earth might contribute to the multiplication of showers, as it certainly does to the fountains." [14] Gregg and others believed that if a large number of people settled in the West, there would surely be rain. A well known Nebraskan scientist, Dr. Samuel Aughey, created the maxim "Rain Follows the Plow". He claimed that the prairie sod prevented the rain from being absorbed. Once the sod was plowed, the earth would absorb water like a sponge. [15] These theories were mainly spread through newspapers in the East. The word got around and the people did move West. Ironically, the rainfall in the 1860's and 1870's did increase.[16] The farmers were able to conquer the prairies and began spreading westward towards the desert. The Great American Desert became an "Eden" or the "Great American Garden" in the mind of the developers and farmers, though not for very long.

The droughts of the 1880's led to crop failure, loss of livestock and bankruptcy. The trend of little or no rain continued until 1897. By then, science and technology had come up with plans to protect the West against the effects of drought.

Civil War veteran Maj. John Wesley Powell, a self-taught generalist, set out to collect an endless accumulation of facts. Through this process he believed he could answer questions and generate information for new theories. His personal aims were to challenge himself and explore the last unexplored territory in the West. He wanted to pursue his belief that solutions to problems could be found by science. Powell, the first science-oriented explorer of the region, followed the trappers, mountain men,

traders and the Indians, the first people to run parts of the Green and Colorado Rivers.

Powell was an advocate of Basic Science. His scientific studies were comprised of general observations. Observation sufficed as he was an amateur scientist and natural historian.

> "The Canyon of Lodore is 20 3/4 miles in length. It starts abruptly at what we have called the Gates of Lodore, with walls nearly 2,000 feet high, and they are never lower than this until we reach Alcove Brook, about three miles above the foot. They are very irregular, standing in vertical or overhanging cliffs in places, terraced in others, or receding in steep slopes, and are broken by many side gulches and canyons."[17]

The observations are in flowery words, however, their content is important and for the most part accurate.

Powell started his exploration ten years after Darwin published Origin of Species. The Suez Canal had been built. Electricity, telegraph and steamships were making communication and travel easier and more accessible. By the 1870's when Powell started his second exploration, civilian surveys were replacing military expeditions. The government was no longer interested in catalogued resources but in solving the problems related to development in the West. They were interested in answering questions like: where can minerals be found, what crops would be best for the land, where should the routes for the railroad go, and how should the land be divided and developed. Government and business needed to cooperate in order to solve the problems and answer the questions.

Powell's first trip down the Green and Colorado Rivers took place between May 24 and September 4, 1869. He was 35 years old at the time. Powell's crew consisted of: Jack Sumner(leader), age 29, former owner of an Indian trading post; Oramel Howland (assistant to Sumner), outdoorsman and part-time painter; Seneca Howland, 25; Billy Hawkins, 20's; Frank Goodman, 20's; Andy Hall; and Walter Powell. None of these men were scientists or held college degrees. They were mainly hunters, trappers and outdoorsmen. The one thing they shared was that they were enlisted in the army at one time.

The Powell expedition was sponsored by the Smithsonian, Union Pacific Railroad and numerous Illinois organizations. The only government

sponsorship they received was bacon and bean provisions from an army post.

Their boating equipment consisted of three double ribbed, rounded bottom oak boats weighing almost one-half ton each. They were 21 feet long, 29 inches deep and carried 2,000 pounds of cargo. Their fourth boat was a 16 foot pine boat named the Emma Dean, after Powell's wife. Their scientific equipment included sextants, chronometers and barometers.

The first trip did not amount to much in a scientific sense. The group was faced with survival as they lost most of their rations, and towards the end of the trip three members left at Separation Rapid. However, the trip spurred Powell's interests and intrigued him to further explore the region. He also gained experience, public notoriety and recognition, which lead to the sponsorship of his second trip.

Powell's second survey began in 1870 and lasted until 1874. He was granted $10,000 in 1870 by Congress and had one year in which to use it. He was able to prepare for the trip during that year and to use his funds beyond that year's deadline.

The survey staff for his second expedition again were amateurs. The group consisted of: Almon Thompson, Powell's brother-in-law; his two assistants, Walter Graves, cousin of the Howlands and F.M. Bishop, a recent graduate of Normal University; S.V. Jones, third topographical assistant, principal of Washburn, Illinois Schools; Frederick Dellenbaugh, a 17 year old self- taught artist; Clement Powell, assistant photographer; Andy Hattan, cook and handyman; Jack Hiller, who started as second handyman and later became assistant photographer and finally photographer; E.O. Beaman, photographer; and J.F. Steward, geologist. Powell's assistants, G.K. Gilbert and Clarence Dutton became the best team of geologists at that time. Together they came up with the first comprehensive work on the Plateau Province. Powell himself had three major works come out of the survey. His first scientific report was written as an adventure story, combining and exaggerating incidents from both trips. His second book was Report On the Lands of the Arid Region, and the third was Report Of the Eastern Portion Of the Uinta Mountains.

Powell's major contributions to science were in structural geology and the general relation of people to the arid lands of the West. He virtually

created the science physiography. It was originally a description of natural features and later became synonymous with physical geography.[18]

Powell was primarily concerned with the Plateau Province, one of three physiographic divisions he created. The Plateau Province is made up of all eastern and southern Utah, part of western Colorado, part of northern New Mexico and northern Arizona. Great Basin and Park Province are the other two regions. [19] He mapped the Plateau Province, gave it boundaries, worked out some of the geological history and named many of the features. In 1872, Powell's men discovered and named the last unknown river, the Escalante, and explored the last unknown mountain range, the Henrys, in the United States. His team recorded the entire Plateau Province in photos, maps and drawings. Topographical maps were key to his success on the second trip because the visual perspective showed his physiographical conclusions in the sequences in which they appeared.

Powell's ethnographic studies were extensive. Much of his interests revolved around the Indians and their language and culture. His contact with the Mormons inspired dry land agriculture studies. The Mormons had been irrigating the land and had created cooperative water distribution and development. Powell latched onto these ideas and used them as part of hisreclamation ideas in his study Report On the Lands of the Arid Region.

Report On the Lands of the Arid Region was perhaps the most important document that came out of his second survey. It was a break-through in land policy, land tenure, irrigation, and politics. Powell's intention was to instigate change in the laws pertaining to land and water. For Powell, the development of the West needed to be comprehensive. It was not possible for theWestern system of land division to be based on the Eastern model. If humans were to adapt their lifestyles to the land and vice versa, the system of development needed to be practical and logical. Powell thought that the government needed to be in control of the water rights and to assume the responsibility of developing the land in a methodical, logical and practical manner.

Powell described the arid land region as:

> "the Great Rocky Mountain Region of the United States ...it embraces something more than four tenths of the whole country excluding Alaska."[20]

In this region Powell recognized the fact that droughts and unpredictable rainfall would affect agriculture and settlement. He determined that the land was worthless without water. The average yearly rainfall was 20 inches, a minimum to sustain agriculture. Those tracts of land which had sufficient water would be suitable for agriculture. However, such tracts were scarce or nonexistent in some areas of the region. There were also threats of floods. Powell was battling the myth that West was an "Eden". Developers pushed the ideas that "rain would follow the plow", that there was endless amounts of water for irrigation, and that all of the arid lands could be irrigated.

Land division in the West posed a large problem for Powell. It was based on the system of the Eastern United States, a relatively flat region. The climates, altitudes, and water supplies of the two regions did not remotely resemble one another. In the Eastern system, the land was divided into rectangles in a grid-like pattern, a useless system for the arid West where much of the land is without water.

The Homestead Act of 1862, gave 160 acres of land to anyone who could settle and live there for five years. According to Powell's Report On the Lands of the Arid Region, this allotment, unirrigated, was not enough land for a homesteading family. However, 80 acres of irrigated land was more than enough. The Desert Land Act of 1877 gave settlers 640 acres of grazing land. Powell recommended 2,560 acres. Powell sought to challenge these policies in his book. He suggested that land be divided by its topographical features, especially pasture land which needed the greatest number of waterfronts.

Powell acknowledged that water and water rights were vital to the individual farmer and cattleman. It was Powell's idea that the land in the arid West is worthless without water. Knowing that, the government should control the rights and fund development programs. Powell foresaw the impracticalities of development without water. At the time, the water system in the United States was based on English Common Law, which was not realistic considering England is a rainy country. The English system granted water rights to the person who owned the river bank. The water they did not use flowed downstream, making it available to others. With irrigation, usually there is no water return and there is a greater chance that the person upstream uses all the water, leaving those downstream without.

Powell predicted "all the waters of all the arid lands will eventually be taken away from their natural channels, and they can be utilized only to the extent to which they are thus removed, and water rights must, of necessity, be severed from the natural channels." [21] Thus he believed that the government should organize water development, obtain all water rights and fund water development and distribution projects.

Water was going to have to be rechanneled in order to irrigate the land. Diverting streams and rivers, ponding and dams were some of the methods that were being employed or would be used in the near future to give value to the land.

Government involvement, especially in financing irrigation projects, would help to protect the small farmer. No small-scale farmer could afford irrigation projects. Powell encouraged creating watershed divisions and cooperative irrigation projects.

Report On the Lands of the Arid Region made significant points about the development of the West. Powell was determined and radical enough to include two sample bills to instigate changes in the laws. One was for organizing water districts and the other was for organizing cooperative pastures. For Powell, practical development of the land was important to the development of the West. Powell foresaw the possibility of overgrazing, so he suggested that public lands were not to be fenced in and he recommended cooperative land use.

Despite his novel ideas, Powell's attempt at land system reform and water development failed. In the votes of 1879, one year after his report was published, land laws and survey systems were not altered. A public land commission was created to study the problems on public land. Under the Civil Sundry Bill, the United States Geological Survey (USGS) was created, Powell's survey was turned into the Bureau of Ethnology, with him as director.

The settlers rejected Powell's report because like the senators and congressmen, they felt that it restricted Western growth. The settlers did not want the government controlling them or determining the size of their land holdings. They thought Powell's intentions were to serve the large-scale cattlemen and not the small farmer. The stock companies who controlled water rights did not want to give up their monopoly. Speculators feared that

they would lose the opportunity to make money off the acquisition and sale of land. Powell was defeated.

In 1881, Powell took over as director of the USGS. He was in an extremely powerful position and exercised his opinion about Western development, which Western congressmen saw as restrictive and limiting. In 1888, while Powell was still director of the USGS, the West was in an extreme drought that lasted through 1889.[22] Western law-makers were concerned with conducting surveys for water projects. Since Powell held the power to decide dam site locations, law-makers organized to take away his appropriations and power. Men in government like William E. Smythe saw irrigation as the answer to the problem facing Western settlement and development between the Pacific Ocean and Missouri River. It was Powell's accurate opinion that there was not enough water supply available to irrigate the land in this area.[23] People like Smythe were passionate about the endless possibilities in conquering the arid West. These hopes and ideals were heard by settlers and developers and taken as truth. The impact of these ideas would be felt through the next century. Powell's two journeys provided him with his own visions and ideals which he carried with him throughout the rest of his political career.

The irony of Powell's pursuits in the development and reclamation of the West was that it ultimately led to the destruction of the Indian culture. The Bureau of Ethnology studied the evolution of tribal cultures and language, along with social, political and religious customs. The government's interest included surveying the land for resources and development possibilities. This would lead to the eventual displacement of the Indians to make room for the white man and his culture and customs.

In 1902, Powell's influence was reflected in the Newlands (Reclamation) Act. Representative Francis G. Newlands of Nevada was responsible for introducing the legislation into Congress. His idea was that small family farms were the best parcel size in developing the West due to limited water supply and the cost of irrigation. He, like Powell, thought that no person should have water rights to more than 80 acres.[24] The Reclamation Service was created under the Department of the Interior. The Reclamation Service was to select dam sites, build dams, and establish water distribution systems. The purpose of the act was to explore the management and development of the Colorado River. This law called for a

series of dams to be built in seventeen Western states for irrigation. The funds for this project came from the sale of public lands (the government had stopped giving away public domain at the turn of the century) and the sale of water. Later, the sale of power was included.[25] This act enabled the government to control projects that harnessed the Colorado River, an idea that Powell supported.

In 1921 the Colorado River Commission was authorized by two separate acts; one from Congress and the other by legislatures of seven Colorado River Basin states. Herbert Hoover, Secretary of Commerce, was chair. The purpose of the commission was to determine how the waters of the Colorado River were to be divided among the seven states. The USGS began topographical surveys with the intention of finding ways to control the Colorado River. These surveys were supported by Southern California Edison Company and Utah Power and Light. The canyons of the San Juan, Lodore, Desolation and Cataract were explored.

In November 1922, an important one day rafting trip took place beginning at Hall's Crossing through Glen Canyon. The final meeting of the Colorado River Commission was to take place on the 24th of that month. E.C. La Rue, chief hydrologist of the USGS, arranged the float. Members on board were; Arthur Powell Davis, Director of the Bureau of Reclamation, Colonel Claude Birdseye, chief engineer of the Topographical Branch of the USGS, officials of various power and railroad companies and a representative for Hoover.[26]

La Rue had been conducting hydrology surveys since 1911. He wrote the first comprehensive water use plan for the Colorado River in 1916. The Commission was interested in the future site of a high dam. Engineers believed that the site should be in either Boulder or Black Canyons. La Rue thought differently. The site he chose was four miles above Lees Ferry. On this float he pointed out the past reclamation projects and the sites for future ones, including his own.

The Colorado River Compact came out of the November 24th meeting. The Compact was the first interstate agreement of its kind. It put the Department of the Interior in charge of managing the river. It also divided the water of the Colorado River equally between the Upper and Lower Basins. Each basin was given 7.5 million acre feet of water annually. The Lower Basin was given a 1.0 million acre feet increase in

any given year. There was a delivery requirement of 1.5 million acre feet for Mexico. The dividing line was Lees Ferry, mile zero, located one mile above the mouth of the Paria River. A gauging station was placed there to measure stream flow to keep track of the water delivery requirements set forth by the Compact.

From the Colorado River Compact came the authorization for the 1923 USGS Birdseye Survey. The purpose of the survey was to investigate and report the natural resources of the country through geological survey. These resources included the development of water power, sources for irrigation and water storage. The government was interested in classifying their land in terms of natural resources in value and magnitude. This information would lead to development that was "safe and sane".[27] Hubert Workt, Secretary of the Interior named the vision for the future of the Colorado River when he said, the "Colorado River, (which) constitutes perhaps the greatest undeveloped asset of several states."[28] The Colorado River was targeted for development because the size of its drainage basin constitutes one thirteenth of the area of the United States. The Colorado River was perfect for irrigation and power generation due to the massive quantity of water concentration and gradient. In "Surveying the Grand Canyon of the Colorado: An Account of the 1923 Boating Expedition of the USGS", Lewis Freeman shared the vision of taming the river because its water was going to waste.

> "The control of the flood waters of this mighty river and theutilization of the power which now goes to waste in its drop of nearly two vertical miles, as well as the vast irrigation projects which have been and are yet to be developed along its course, directly concerns the citizens of Wyoming, Colorado, Utah, New Mexico, Arizona, Nevada, California and our neighboring Republic of Mexico."[29]

Since the population was increasing, the demand for water, power and agriculture wasincreasing as well. The Colorado River, if controlled, could support the influx of people. Dams would also create slack water for recreational use. The flows at that time were not conducive for recreation due to the river's turbulent nature. Prior to 1923, only 27 men had traversed the Colorado River. Powell and Stanton were the only men who had any scientific backgrounds.[30]

The Birdseye Survey came at a time when the government was publishing topographic maps of canyons, rapids and reservoir sites for the purpose of development. This information was to be used primarily for flood control, but also power and storage.

The Birdseye Survey compiled a report for the Department of the Interior. The purpose of the report was to "present the facts regarding available water supply and all known dam sites on Colorado River between Cataract Canyon, Utah and Parker, Arizona, and to show the relative value of these dams sites to determine the relative value of the dam sites."[31] Unlike Powell, the Birdseye Survey had specific goals named by the government. The Department of the Interior had a specific agenda to map the Green, San Juan and Colorado Rivers as quickly as possible.

The Birdseye survey consisted of one geologist, five surveyors, four principal boatmen and one cook. Colonel Claude H. Birdseye was the head of the survey. His background included a survey of Mount Rainier and the crater of Kilauea in Hawaii.[32] Upon completion of the trip, Birdseye would have surveyed the only remaining unsurveyed stretch of the Colorado River System through this region. E.C. La Rue, chief hydrologist, had made numerous survey trips between 1914 and 1924 for reservoir sites, diversion dams, water storage projects and power plants. His responsibilities on the trip included selecting dam sites, supervising surveys of sites and photo surveys.[33] R.C. Moore, geologist, had previously completed geological work in the middle Colorado Canyon. Emery Kolb who was a photographer was hired as a boatman. He was familiar with boating the Grand Canyon having had boated it between 1911 and 1912 with his brother Ellsworth.

The gear they brought was extensive. It was mainly surveying equipment. They introduced waterproof bags and boxes which were made of plastic rubber bags, covered with canvas. They stored their food and beds in these. They had four white pine boats. They also had a folding canvas boat for the rodman. Birdseye was thorough in his planning. They also had a radio for the news and pleasure. The radio was broken for a short time, during which a flood was filling the river from the Little Colorado River. The flows were estimated at 100,000 cubic feet per second.

Unfortunately, they were at mile 179 and unaware of the danger. Although they ran the rapid (Lava Falls) at night, no one was injured.

In his report "Water, Power and Flood Control"[34], La Rue fulfilled the task the Department of the Interior set out for him and the survey. The survey named twelve reservoir and dam sites above Lees Ferry. Between Lees Ferry and where the Grand Canyon began at mile 60, they named four dam sites. In the Grand Canyon the survey named ten dam sites "where a total head of 2,523 feet may be utilized for power."[35] His conclusion was "without storage the total power of these ten dam sites is 1,758,000 horsepower. With storage, the power capacity would increase to 4,345,000 horse power."[36] Between Grand Canyon and Parker, Arizona, they named four power sites, three dam sites and eleven alternative dam sites.

Part of the vision of conquering the land included making expedient travel routes. Natural obstacles were no longer a concern as they could be conquered with the technology of the times. Even the Grand Canyon could not stop development. The future sight for Navajo Bridge was no exception. The Birdseye survey camped at the site.

> "...camped at a so-called bridge site a mile further down the river-a narrow section with abrupt walls nearly 500 feet in height on either side.
>
> The bridge plan is an Arizona project for linking the two sections of that state now almost inseparably divided by the Grand Canyon. If the structure is ever built it will have no rival in height for a long time."[37]

The survey was gruelling, time-consuming work. It was done in August and September when the temperature soared to 109 degrees. Birdseye estimated that the water temperature reached 90 degrees. Each survey point had to have the previous marker spot in view, so stopping every few hundred yards was necessary. The survey also measured the flow of the Colorado River and its tributaries, took elevation readings, measured rapids, and took temperatures. Most of their travel was less than five miles per day. The accuracy was quite good.

> "Birdseye tied his survey in with a benchmark at the mouth of Diamond Creek at elevation 1,362.166, which he listed as 163.8 miles below the mouth of the Little Colorado River (222.3

miles from the mouth of the Paria River) where they had begun their survey. It checked out with an error of -8.9 feet in the line from the tie-point at Bass Trail Crossing, which amounted to 0.07 feet per mile."[39]

After the Birdseye Survey of 1923, which was the last major survey of the Colorado River, the Bureau of Reclamation set out to tame the Colorado River. In December of 1928, after five years of congressional negotiation, the Boulder Canyon Project Act passed. This was the authorization for the construction of a dam "bigger than any yet built anywhere in the world,"[40] and the start of the dam building era that would last until the completion of Glen Canyon Dam in 1963.

The biggest dam in the world was Hoover Dam, then called Boulder Dam. President Franklin D. Roosevelt dedicated the largest publicly funded project of that time. Hoover Dam created Lake Mead, the largest man-made reservoir. The purposes of the dam were flood control, irrigation, cheap electricity and recreation area.

The Bureau of Reclamation had the goal of taming the Colorado River. They stated, "tomorrow the Colorado River will be utilized to the very last drop."[41] By 1946, there were 100 possible water projects in the Upper Basin and 34 in the Lower Basin. The purpose was to generate more power in Arizona and Utah, and for irrigation in Uinta Basin and the Grand Valley of Colorado. As predicted, the waters of the Colorado River System would be utilized to the last drop and beyond. There was not enough water to satisfy the wants of the seven basin states.

In October of 1956, Colorado River Storage Project Act was passed. It was a water development plan for the Upper Basin. Their aim also included a long-term plan to meet the commitments of the Colorado River Compact. This storage project would regulate the flow of Colorado River, store water, reclaim arid lands, flood control and power generation. It initially included ten dams and reservoirs in the Upper Basin. Six of these dams were authorized to be constructed. There was a dam on the Green River in Dinosaur National Monument, one in Flaming Gorge and one on the San Juan.

Opposition to the dam on the Green River in Dinosaur National Monument signified the beginning of the modern conservation movement. People were concerned with losing natural and wild places. The

movement represents a change in the vision of the country. A legal battle was launched and the dam was never built.

In 1964, after eleven years of negotiation, the Supreme Court allotted Arizona their 2.8 million acre feet of Colorado River water and all the water in the Lower Basin tributaries. In 1968, the Colorado River Basin Project Act was signed authorizing the Central Arizona Project (CAP) to be constructed. This project would enable Arizona to get their share of the water. The estimated cost of the project was $832 million in 1968, the amount tripled in 1982, and upon completion in 1991, the 300 mile long canal had cost $3.6 billion. It is no wonder that in 1987 the Bureau of Reclamation has had a change in focus. Due to the high costs of water projects they presently concern themselves with conservation, not reclamation. The environmentalists too were influential. Their voices were heard and their presence felt. There is the possibility of future reclamation projects, though the chances seem slim. The Bureau of Reclamation is working onmaintaining their facilities. Possibly, future reclamation projects will include finding a solution to the problem of the silt and sediment that is filling Lake Mead and Lake Powell.

As one of five dams in Colorado River Storage Project, Glen Canyon Dam is the most important regulatory operation on the Colorado River. It determines the release of water to the Lower Basin and Mexico. The operation of the dam must meet the requirements of the Colorado River Compact and satisfy the treaty with Mexico. The dam release is limited to 8.23 million acre feet per year.

Construction of the dam began in 1956. The gates closed in March of 1963. It has created Lake Powell, 186 miles long with 1,800 miles of shoreline. The full reservoir capacity is 27 million acre feet with an elevation of 3,700 feet. The dam was originally designed to be 3,900 feet in elevation, however due to pressures from environmentalists to save Rainbow Bridge and portions of side canyons, the design was altered.

Glen Canyon Dam affects the economy and the lives of the people of the seven basin states and Northern Mexico who are dependent on the dam for water and power. It generates 4.4 billion kilowatts of electricity which totals $80 million in gross power revenues. Over 20 million people depend on it for drinking water.[42] Since it is inextricably linked to the

economy, the legal battles over the water of Colorado River have been numerous.

One battle with environmentalists, recreationists, government agencies, and the public against the Bureau of Reclamation over the operations of Glen Canyon Dam and its impact on the environment has created GCES. When Glen Canyon Dam was constructed there were no environmental laws to enforce environmental impact studies of the dam. On December 8, 1982, Secretary of the Interior, James Watt authorized the initiation of a multi-agency to appease the concerns of the people concerned with the impact of dam operations. The studies are both short-term and long-term. They aimed at answering two questions. One is: Are the flows of the dam adversely affecting the environment and recreational resources of Glen Canyon and Grand Canyon? The second question is: Are there ways to operate the dam in a manner that would improve or protect the environment while fulfilling the water delivery requirements?[43]

The responsibilities of GCES are data collection, analysis and education. It is made of numerous agencies under the Bureau of Reclamation including the National Park Service, USGS, and Arizona Game and Fish Department. The impact of the dam has created numerous studies including the effect of changing water temperatures, flows, beach erosion, sediment deposition, plant life, reduction of habitat, loss of vegetation and loss of native fish species.

The GCES celebrated its tenth anniversary on December 8, 1992. The first group of undergraduate student researchers were in the field at that time. The GCES has three goals: research, monitoring and education. In fulfilling their committment to education, the GCES gave Prescott College students the opportunity for hands-on experience in scientific work and field methods.

The style of learning at Prescott College, experiential education, is alternative. Students learn through the work they do. It is their motivation and inspiration that drives the learning process. By living on the Green and Colorado Rivers, the students were actively involved with their surroundings. The water, vegetation, birds and mammals were as much a part of their education and experience as their books, lectures, and research.

The philosophy of the College recognizes a commitment to the environment with education as the key to understanding the responsibilities of the individual as a steward of the land. The experiences on the rivers offered opportunities to reflect on human impact, personal ethics and the responsibilities of a generation that will be part of the working world in the near future.

A trip to Glen Canyon Dam and a tour of the facility was the first stop at the start of the Grand Canyon section. The students' attitudes and opinions about the dam ranged from awe to disgust to intrigue. It is a given that the dam stands and has an impact on practically every person in the West. This dam was the reason for the students studying in the Grand Canyon on a GCES permit.

The tour of the dam provided valuable information and gave the students the opportunity to be inside the structure that held back the waters they had just traveled down. It was also food for thought. The releases they would be traveling on were being controlled by the men they met in the control room. This contact brought the students closer to the human-controlled element of the environment that they were to soon experience.

The group conducted eight surveys. They included; a passerine bird survey, trout count, eagle count, wildlife count, waterfowl count, beach photo survey, weather survey and water temperatures. Each group member was involved in at least one survey. The goal of the group during the Grand Canyon section of the course was to collect accurate data and compile it into a technical report. During those 27 days, the rigors of winter rafting, the challenge of navigating the water and the extended period of time in the field enhanced the experiences of the group.

Through the study for the GCES the students were challenged by looking at their environment in a methodical, linear way. The signs of the dam's impact were obvious. The high and low water level, beach erosion and clear, green, sediment free-water on Christmas are examples of the reminders of the dam's presence upstream. At the same time, the students reflected on their role in the big picture. How did they impact the environment? Their role extended beyond just enjoying the river and the canyon. They were working to protect it. They used their skills in minimum impact camping and cleaned up after those before them. Active participation induced environmental awareness.

The ramifications of this study extend beyond the limits of the Grand Canyon, the Colorado River Basin and the boundaries of the Colorado Plateau because the students will make these experiences a part their education, careers, personal lives, views and ideals. These are some of the tools necessary to instigate change and make a difference. We are like the people before us as we look for solutions to problems and invite science to help us. But we are looking for ways to save our environment and ecosystems now that they have been conquered. In the biggest picture painted on this trip, geologic time, the rivers will flow freely again. That may be when the great-grandchildren of those babies born during the course of the trip are born. Our lives may be short, but we can plant the seeds that make a difference.

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