

Water-Based Recreation
Management in Grand Canyon

Physical and social considerations applicable to formulating
regulatory policy for Colorado River trips.

by

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National Park Service records indicate that 2.7 million people annually visit the Grand Canyon National Park, but few (40,000) ever view it from the Canyon floor, and even fewer (approximately 16,000) traverse the Canyon's 250-mile length "shooting the rapids" of the Colorado River (Figure 1).¹ Although the number of river trip participants is small relative to total park visitors, trip popularity has mushroomed in recent years. River use has increased as much as 60 to 70 percent annually during the late 1960's. In response, the U.S. Park Service adopted a new management philosophy in 1971, limiting the use of the river to help protect the resource amenity. The policy reflected their concern about environmental impact and the possible degradation of the trip experience.

Since 1971, additional management decisions have been made to further limit river use, group size, departure dates, and equipment used.² Environmentalists and river trip outfitters accept the Park Service's concern for the area and the need for a regulatory policy; however, considerable dissent focuses on the actual nature and scope of regulations necessary and desirable -- the environmentalists generally concur with the proposed regulations while the outfitters believe that the regulations are not supported by environmental evidence. A group of outfitters has brought litigation against the Park Service contending that the new limits were arbitrarily set. The suit was dismissed by the court but has been appealed.

Environmental and sociological information on which to base policy has been, and still is, severely limited. Decision-makers need a basic understanding of visitor expectations, perceptions, interactions, satisfactions and dissatisfactions, along with the necessary bio-chemical parameters to make informed decisions. This paper summarizes and integrates the results of two studies designed to provide some basic decision-making information.

The first study entitled, "Colorado River Trips Within the Grand Canyon National Park and Monument: A Socio-Economic Analysis,"³ investigates considerations of a

Figure 1. Grand Canyon Reach of the Colorado River

social carrying capacity for the recreational experience. The second study, "Chemical and Biological Problems in the Grand Canyon,"⁴ considers physical, chemical, and biological parameters of the area in relation to the increased river use.

METHODS OF STUDY

In order to study socio-economic parameters, a mail survey of past river users (1967 through 1970) was used to investigate the long-term effects of the experience. The National Park Service provided river trip rosters for 1967, 1968, 1969, and 1970. A random sample of 2,622 people was selected and a 65% response rate was realized.

The chemical and biological investigations of the Grand Canyon from Lee's Ferry to Diamond Creek were made during the summer of 1972. The locations of sampling stations were tabulated as river miles from Lee's Ferry (mile 0) to Diamond Creek (mile 226) (Figure 1). Samples from tributary streams were taken up-stream from the confluence to eliminate the influence of the Colorado River water. Three surveys were conducted during the summer of 1972 (referred to as the June, July, and August surveys).

Water samples for chemical and bacteriological investigations were collected simultaneously. Chemical analysis was performed by the Soil and Water Testing Laboratory of the University of Arizona using the techniques outlined by the American Public Health Association.⁵ Coliform bacteria was used to indicate the presence of contamination.

THE TRIPS AS A PERSONAL EXPERIENCE

The study was directed to past users of the Colorado River in order to investigate the impact (on the people) of "running" the River. Policy-makers generally desire an understanding and awareness of the intensity of feelings toward the experience before management decisions are made that could upset the users or change the value of the experience.

The large response rate to the questionnaire illustrates the strong feelings toward river trips held by the participants. The river runners overwhelmingly enjoyed the trip; 67% responded that the trip was "super" and 27% considered it "very good." They agreed that the trip was a unique experience (95%) and was full of excitement and adventure (91%). Virtually all (94%) said that they found what they were looking for on the trip.

They felt that the trip was an environmental learning experience (93%), enabling one to observe the beauty of Nature (97%). Ninety-three percent said that the trip allowed them communion with Nature. Ninety-two percent felt that it was a wilderness experience.

CROWDING

The national recreation areas of the United States are experiencing increased crowding of available facilities and, according to some observers, the Colorado River from Lee's Ferry to Lake Mead is no exception. Of critical importance is the user's perception of a crowding problem and the relationship of this perception to regulatory actions.

One can distinguish and measure two distinct types of crowding, or potential crowding, conditions associated with river trips: (1) the size of each individual group or trip and (2) the interaction of different groups along the River at any one time. The size of an individual trip remains constant for the duration of the excursion. On the other hand, the second condition may only exist sporadically throughout the day, when one group overtakes another group. For example, two or more groups often stop at the same scenic or historic place for hiking, and on occasion more than one group will share a camping site at night.⁶

Individuals were asked to indicate approximately how many people were on the river trip they took and to evaluate this as too few, too many, or about right. Table 1 reports the results of these questions. Virtually no one indicated "too few" regardless of the trip size. The percentage of those answering "too many" seems to increase as the size of the group increases. When considering these data together, one sees that the percentages answering "about right" are greater than those for answers of "too many" until trip sizes of 41 to 50 people. This indicates that in general, for trip sizes less than 40 people, the majority of users were satisfied, but when trips become larger than 40 people, the majority felt the size was too large. Based on these results, group size has been limited to fewer than 40 passengers.⁷

The second type of crowding that can occur on the River is also important to river managers, outfitters, and users, as it concerns the total number and

Table 1. Individual Reactions to Different Size River Trips

Size	% of Sample on Trip	Too Few	About Right	Too Many
1-5	0.31%	40%	60%	--
6-10	3.86%	3%	93%	3%
11-20	21.03%	---	83%	16%
21-30	35.74%	---	79%	21%
31-40	21.79%	---	62%	38%
41-50	7.98%	1%	40%	57%
over 50	9.06%	1%	36%	62%

spatial distribution of groups on the water at a given time. Respondents were asked several questions to determine if they had seen other parties, what the effect of seeing other parties was, and what their opinions were about future management policies. More than 90% of the sample responded that they had seen other parties on the River, and their reactions are shown in Table 2. Notably, more people thought that the other groups were "reassuring" rather than "very annoying." The largest number (36%) thought that the other trips were "not annoying" while nearly equal numbers thought that they were "tolerable" and "enjoyable." The significance of the large number who felt that the other groups were "enjoyable" and "not annoying" should not be overlooked by the decision-makers. Only about 12% of the respondents were annoyed or very annoyed at seeing other groups on the River. All other users were not especially upset by the other groups, and in fact the majority found them at least tolerable.

There was a difference in the number of people who saw other groups when the yearly tabulations were compared to the aggregate results. In 1967, 75% of the sample saw other groups, compared to 85%, 89%, and 96% for 1968, 1969, and 1970, respectively, reflecting the increased user intensities per year. Thus, in 1970, it was virtually impossible to make the journey without encountering another party, whereas in 1967 three out of every four trips saw other groups. However, when the reactions to seeing other groups on the River are compared to both the aggregate response and to other years, no difference is apparent (Table 2). Regardless of user-intensity, and thus the incidence of encountering other groups, the participants' reactions to the other groups is consistent. However, the population of river trippers may have changed over time such that present populations have a greater tolerance of crowding than previous populations.

Management agencies should know their clientele's perceptions of policy needs prior to making new policy. Thus, it was felt that the participants should be

Table 2. Reactions to Seeing Other Groups on the River

	Total	1967	1968	1969	1970
Very annoying	3%	3%	3%	2%	3%
Annoying	9%	11%	8%	7%	10%
Tolerable	25%	21%	21%	28%	26%
Not annoying	36%	34%	43%	36%	34%
Reassuring	4%	4%	3%	2%	4%
Enjoyable	22%	25%	19%	23%	22%

questioned about future regulatory practices. Because the sample represents only 1967 through 1970 users, this offered the opportunity to question people who made river trips before the user limits were instituted by the Park Service. These people were not affected by the policy regulations, so it was possible to determine their perceptions of the need for such policy. They were asked "should the number of people taking river trips through the Grand Canyon be limited?" More than three-fourths (77%) believed that the number should be limited, but of that number, 70% would have been disappointed in having to postpone their trips because of user limits. Although these data support the policy of limiting river trips, respondents strongly agreed (90%) that people have the right to take more than one river trip, and over half (55%) said that people should be encouraged to take river trips.

Two-thirds of those who participated in the study said that they expected to make other Colorado River trips, and of this number half would take longer trips. Time appears to be more of a constraint than money because 77% said that they would make more river trips if they had more time, whereas 57% said that they would take more trips if they had more money. The time restraint is to be expected, because of the participants' high total family incomes.⁸ Hence, the number of "repeaters" taking river trips may be expected to increase in future years.

PUBLIC HEALTH INVESTIGATION

According to a recent report from the U.S. Public Health Service, between "May 23 and July 31, 1972, at least 115 persons on 13 Colorado River raft trips contacted gastroenteritis."⁹ The outbreak of illness during the summer of 1972 was unusual in its severity, but cannot be considered unique as similar outbreaks of gastroenteritis have been reported. Bio-chemical data on the Grand Canyon reach of the Colorado River suitable for management decisions was nonexistent. Thus, a need existed to determine the severity of the problem, the source of pollutants and contaminants, and the type of policies necessary to eliminate future epidemics.

Chemical Analysis

An examination of Table 3 shows that the chemical quality in the main river channel is relatively uniform with respect to both time and distance during the 1972 summer season. The general spatial pattern of salinity is relatively constant from Lee's Ferry (mile 0) to the confluence of the Colorado River and the Little Colorado River (mile 60). At this point, due to the inflow of the Little Colorado River, the salinity (TDS) increases by 50-70 mg/l. Sodium and chloride concentrations in the Little Colorado River are mainly responsible for this increase. There was also an increase in TDS of about 60 mg/l from June to August at Lee's Ferry (predominantly from variations in the chloride and sodium ion concentrations), reflecting the seasonal fluctuations in water quality in the Colorado River.

The chemical quality of the tributary streams (Table 4) can show more significant changes throughout the summer season. These changes stem from the cyclic patterns caused by the periodic storms in the side canyons. These rains have two effects on the water chemistries of the tributary streams. First, the dilution effect of the rainwater decreases the concentration of some ions. Most notable are changes in the concentrations of sodium (Na), chloride (Cl) and total dissolved solids (TDS). Secondly, the summer rains in tributary canyons increases the

Table 3. Summary of Chemical Water Quality Surveys of the Main Colorado River Channel, Summer, 1972.

Ion			TDS	Ca	Mg	Cl	SO ₄	F1	NO ₃	PO ₄
Permissible Level (mg/l)			500	75	50	200	200	1	2-4	-
Location ^a	River Mile	Survey								
Lee's Ferry	0	June	585	80	24	16	235	.2	1.8	-
		July	641	90	28	54	230	.21	2.3	0.0
		August	639	84	27	54	240	.23	2.6	0.02
Mile 41	41	July	654	92	28	54	240	<.2	2.6	0.0
Little Colorado	60	June	572	76	24	16	220	<.2	1.8	-
		August	645	94	24	56	230	<.2	2.4	0.01
Hance Rapid	78	July	629	78	28	28	240	.21	3.2	0.02
Bright Angel Cr.	89	August	683	84	27	80	230	.21	2.4	0.07
Elves Chasm	115	August	665	84	27	72	230	.20	2.4	0.05
Deer Creek	136	June	672	74	27	76	240	.20	1.8	-
Kanab Creek	140	August	675	88	26	64	250	.21	2.6	0.04
Lava Falls	180	June	677	78	28	80	235	.20	1.8	-
Diamond Cr.	226	June	611	78	26	34	230	.26	2.4	-
		July	655	78	22	64	240	.30	2.3	0.05

^a Samples were taken in the main channel upstream from the confluence.

Table 4. Comparison of Chemical Analysis of Selected Ions at Lee's Ferry and Main Tributaries in Grand Canyon, Summer, 1972.

Location	Survey	TDS (mg/l)	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)	SO ₄ (mg/l)	NO ₃ (mg/l)	PO ₄ (mg/l)
Lee's Ferry	June	585	80	24	16	235	1.8	-
	July	641	90	28	54	230	2.3	0.0
	August	639	84	27	54	240	2.6	0.02
Little Colorado River	June	2787	120	80	1214	180	3.8	-
	July	2731	154	41	1060	250	1.5	0.10
	August	2107	104	17	48	200	4.6	0.19
Bright Angel Creek	June	302	38	21	14	18	0.0	-
	July	315	40	21	14	12	0.1	0.01
	August	305	45	24	12	8	0.2	0.0
Elves Chasm	June	512	70	45	28	205	2.2	-
	July	545	76	40	28	200	2.8	0.06
	August	525	98	29	24	200	3.3	0.05
Tapeats Creek	June	247	19	22	12	15	0.2	-
	July	270	40	15	8	10	0.0	0.01
	August	341	59	19	8	40	0.4	0.06
Deer Creek	June	385	42	21	10	90	0.0	-
	July	335	44	22	12	20	0.1	0.01
	August	382	55	22	12	40	1.0	0.16
Kanab Creek	June	1123	176	80	28	680	0.2	-
	July	1142	196	69	40	650	0.5	0.01
	August	1007	228	45	20	570	3.2	0.05
Havasui Creek	June	528	38	44	52	60	0.6	-
	July	500	40	45	56	70	1.0	0.02
	August	500	50	49	52	55	0.8	0.01

runoff from the watershed and, thus, the rate of leaching. The effect is to increase the concentration of certain ions by increasing the salt load carried by the streams. Such increases are most notable in the concentration of nitrate (NO_3) and orthophosphate (PO_4) ions. These concentrations can be related to increases in bacteriological activity which have been noted during periods of flooding in the side streams.^{10,11,12,13} Flooding in the tributary basins would increase the organic matter content of the stream waters.

The recommended salinity (TDS) level of 500 mg/l¹⁴ for drinking water is exceeded at all river locations sampled as well as several tributary streams. These waters can have a natural laxative effect upon some people whose bodies are sensitive to changing drinking water quality. However, the concentrations found in the main channel are only slightly higher than the recommended standard and are commonly used for domestic purposes in the Lower Colorado River Basin. There is probably no health hazard to most river travelers caused by the salinity levels in the main river channel and most of the tributary streams; however, antidiarrheal agents should be included in first-aid kits. Extremely high TDS concentrations have been noted in the Little Colorado River, Kanab Creek, and several small streams and springs not listed in Table 4 (Crystal Creek (about 2000 mg/l), Pumpkin Bowl (about 7000 mg/l)). These locations pose potential health problems to river travelers, who should be warned against drinking from these sources.

In the main river channel and most of the tributary streams, concentrations of calcium (Ca), magnesium (Mg), chloride (Cl), and sulphate (SO_4) ions are generally below or slightly above U.S. Public Health Service recommended drinking water limits.¹⁴ It is difficult to determine the significance of those samples which showed concentrations slightly above the permissible level because different individuals show varying sensitivity to these ions. In general, these ions probably present no great danger to river travelers in most of the side streams and in the main river channel

within the Grand Canyon. Notable exceptions include the Little Colorado River (mile 60) with respect to chloride, calcium and possibly magnesium ion concentrations, Elves Chasm (mile 118) with respect to calcium ion concentration, and Kanab Creek (mile 140) with respect to calcium, magnesium, and sulphate ion concentrations. Drinking from these streams should be discouraged.

Fluoride (F1) ion concentrations were generally found to be at or below 0.25 mg/l in the main channel and tributary streams. Concentrations in excess of 2.0 mg/l were found in the Pumpkin Bowl Spring (mile 210) and concentrations of about 0.9 mg/l were noted in Diamond Creek (mile 226). Because of the limited exposure time, there is probably no danger to river travelers at these two locations.

Bacterial Analysis

The presence of coliform bacteria is commonly used as an indicator of pathogenic bacteria because the isolating and culturing of specific disease-causing organisms is expensive, time consuming, difficult and dangerous. Routine procedures have been developed for the culturing and enumeration of coliform bacteria.

Bacteriological analysis was undertaken using the membrane filtration techniques described by A.P.H.A.⁵ Bacteria were collected on 0.45 micron membrane filters. Because of the difficulty of culturing fecal coliforms in the field, during the June and July surveys, total coliform counts (i.e., including both fecal and soil groups) were made. Measured volumes of water samples were aspirated through the filters which were then placed on blotters containing 2 cubic centimeters of Difco-M-Endo MF media. The media contained a 95% ethanol solution to suppress the growth of non-coliform groups. The plates were then incubated at $35 \pm 1^\circ\text{C}$ for 48 hours.

The August samples were collected with the aid of a helicopter, kept cool, and driven the same day to Phoenix, Arizona. Here, at the U.S. Public Health Service Laboratories, the water samples were filtered (as above) and placed on specific media used to culture fecal coliforms and fecal streptococci. An effort

Table 5. Summary of Bacteriological Analysis for June and July Surveys.

Location	River Mile	Survey	Sample Size (ml)	Colony Count or Description
Lee's Ferry ^a	0	June	50	TNTC ^b
			25	190
			10	100
		July	10	428
			5	142
Little Colorado R.	60	June	25	49
			10	21
Bright Angel Cr.	89	June	20	TNTC
			10	Colonies spread by excess water
		July	5	Packed ^c
			10	Packed
Pipe Creek	90	June	10	TNTC
		July	10	Packed
Elves Chasm	118	June	25	Packed
			10	TNTC
		July	10	Packed
Deer Creek	136	June	20	Colonies spread by excess water
			10	120
		July	10	15
			5	36
Kanab Creek	140	June	20	226
			10	118
			5	49
		July	5	Packed
			10	Packed
Havasü Creek	155	June	20	Packed
			10	Packed
			5	Packed
		July	10	Packed
Diamond Creek	226	June	20	TNTC
			10	TNTC

a - Main Colorado River channel sample. Other samples taken in tributary streams.

b - TNTC $\equiv$ Too numerous to count.

c - Packed $\equiv$ Colonies overgrowing one another with no clear definition of colonies.

was also made to detect the presence of Shigella spp by first placing the filtered samples on GN (gram negative) broth to stimulate growth and then streak-plating these samples on differential growth media.

The results of the June and July surveys are summarized in Table 5. It should be noted that only one main channel sample location is listed in this table. As with the chemical quality, the bacteriological quality of the main Colorado River channel in the Grand Canyon was relatively uniform. The several other samples taken in the main channel during the June and July surveys yielded colony counts similar to or less than the Lee's Ferry samples.

The desired quality criteria for surface waters to be used for drinking is that there be less than 100 total coliforms (TC) per 100 ml (milliliter) and less than 20 fecal coliforms (FC) per 100 ml.¹⁵ The levels were set as the quality of surface waters that could be made potable using available technology.¹⁶ The Arizona water quality standard for primary contact (recreation) is a mean fecal coliform count of less than 200 per 100 ml with 10% of the samples not exceeding 400 per 100 ml sample. Nevada has set the upper limit at 100 fecal coliforms per 100 ml for recreational use. Using the rule-of-thumb ratio of 20 total coliforms per fecal coliform, the maximum permissible total coliforms for recreational waters in Arizona is 4,000/100 ml and in Nevada 2,000/100 ml.

In general the colony counts were less in the main Colorado River channel than in the side streams. It is in these tributary streams that most of the drinking and recreational activity of river travelers occurs. Thus, these sites are of pre-dominant importance in assessing the health hazards to the river runners.

The bacteriological contamination in the main river channel is normally at or below the criteria for primary contact and is below the maximum permissible level for drinking water. This does not preclude the necessity of treating water taken from the main channel for drinking purposes. Proper chlorination or other treatment should make the water quite safe for drinking.

Many of the side streams present quite another picture, at least with respect to primary contact. With the possible exception of Deer Creek (mile 136) the bacteriological contamination in most of the popular streams and swimming pools is in excess of the levels recommended for primary contact. Because of the failure to obtain countable plates with even 5 ml samples in some cases, a quantitative evaluation is difficult. The evidence, however, is strong enough to indicate the presence of a very real hazard.

It is also evident (Table 5) that great variations can occur in the bacteriological water quality of the tributary streams and the main river channel within the Grand Canyon. The variations in the side streams are related to summer storm and flooding cycles in the side canyons. The variations in the main channel may be related to the slight warming of the water observed as the summer progressed.

The results of the August bacteriological survey are shown in Table 6. Analysis of fecal coliforms in the main river channel showed much greater variability than had been observed for total coliforms in the earlier surveys. Some of this variability may be due to local effects as the samples were taken near the shoreline in all cases. From the main channel samples, only the Lee's Ferry sample showed a reasonable possibility of human fecal contamination. This possibility is shown by the fecal coliform (FC) to fecal streptococci (FS) ratio. Ratios less than unity indicate contamination from non-human sources. Ratios from 2 to 4 indicate human contamination. The FC/FS ratio is not an exact indication of the source of fecal contamination. Therefore, it is necessary to consider all fecal coliform organisms as indicative of serious contamination.

As was the case with the total coliform analysis of the June and July surveys, all of the tributary streams sampled except Deer Creek showed signs of contamination. The FC/FS ratios indicate the possibility of human fecal contamination in Kanab Creek and in Havasu Creek. The State of Utah requires that Kanab Creek have a total

TABLE 6. Fecal Coliform Counts from August Survey.

Location	River Mile	Fecal Coliforms per 100 ml	Fecal Coliform to Fecal Strep ratio
Lee's Ferry ¹	0	20	2
Above Little Colorado River ¹	60	60	0.5
Little Colorado River	60	30	0.2
Bright Angel Ck. ²	89	10	0.1
Bright Angel Ck. ³	89	40	0.1
Above Elves Chasm ¹	118	10	1
Elves Chasm	118	200	0.1
Deer Creek	136	0	0.0
Above Kanab Creek	136	60	1
Kanab Creek	140	1600	4
Havas	155	50	2

¹ Main Colorado River channel sample. Other samples were taken in tributary streams.

² Above Phantom Ranch.

³ Below Phantom Ranch.

coliform monthly arithmetic mean of 5000 per 100 ml sample "with exceptions." These "exceptions" are ill-defined but apparently August must be the one.

The July and August surveys were conducted after the commencement of the summer rains. Therefore, most of the tributary streams and the main channel below the Little Colorado River were carrying considerable amounts of sediment. Sediment hinders the membrane filter technique by masking the presence of growing colonies and clogging the filters. Sediment in the samples taken by the U.S. Public Health Service (in August) was allowed to settle out to some degree before the samples for analysis were extracted. Obviously there was opportunity for bacteria to settle out with the sediment. The general effect of sediment was to reduce the numbers of colonies observed and mitigate the level of contamination. Thus, where any fecal contamination was observed there is a real possibility of the actual presence of significantly greater levels of contamination.

In order to determine the cause of the 1972 gastroenteritis epidemic, an effort to culture and detect Shigella was made but yielded negative results. This fact by itself does not, however, eliminate water as the source of the 1972 epidemic. There are several reasons why Shigella may not have been found: 1) the samples may have been taken at a low point in the cyclic pattern of water quality in the side streams; 2) the initial source of contamination may have been transient with the ensuing epidemic being spread by person-to-person contact among river travelers and boatmen; and 3) the difficulties in analysis caused by large amounts of sediment in the water samples may have masked any Shigella present. Most of the tributary streams were flooding and filled with sediment when the August survey was made. Even though Shigella organisms could not be isolated in the water samples, Salmonella spp. were found at several sites: in the swimming pool at Elves Chasm, below Deer Creek falls, in Kanab Creek, in the Colorado River below Kanab Creek, and in Havasu Creek. Salmonella groups B, C, and D were detected. This is further evidence of potentially hazardous fecal pollution within the Grand Canyon.

GRCO 14-10

CONCLUSIONS AND MANAGEMENT CONSIDERATIONS

The river travelers sampled unanimously agreed that regulatory policies are necessary to protect the area for future generations although the large majority fail to perceive a crowding problem on the River. This suggests that proposed user limits may be too low. However, consideration should be given to the group of users who do perceive a crowding problem, even though they are a small minority. Policies could assure that a variety of river trips exist for participants to choose the type of experience they desire, e.g., a rowing trip with few people for those who want a "complete" wilderness experience.

The Park Service's current plan limiting the river use calls for the phasing-out of motor-powered craft during the next three years. In effect, individual trips will be longer for a given distance because oar-powered crafts travel much more slowly than motored ones. Thus, fewer people can move through the Canyon per given time period, fewer trips are possible with a fixed number of boats, and so fewer people can use the area during a season. Additional constraints are the proposed reduction of group size (40 passengers per trip in 1973 to 30 passengers per trip in 1974-1976) and the total number of miles traveled per day. The Park Service's basic argument for the elimination of motorized craft is stated in their January, 1971 Master Plan Draft: "The most desirable river experience is felt by some persons to be the slow, 10 - to 15 - day float trip, in small parties, without power -- a true wilderness experience."¹⁷

Although an oar-powered trip may represent more of a "wilderness experience" to some people, this does not appear to hold true for most of the people. The Park Service should note that 92% of the sample (of which nearly all took motorized trips) perceived their trip as a wilderness experience. This raises the question of whether one type of wilderness experience is better than another type. The Park Service may believe it desirable to encourage oar-powered trips and require that

a percentage of the year's total be rowing trips; however, there does not appear to be (or the Park Service has not made public) data supporting their belief that all trips should be oar-powered. The adoption of a policy prohibiting motorized craft has social implications that must be considered.

In general, the chemical and bacteriological quality of the main Colorado River channel is within acceptable limits although potential health hazards to river travelers have been noted in several tributary streams and springs within the Canyon. Total dissolved solids (TDS), calcium (Ca), magnesium (Mg), chloride (Cl), and sulfate (SO_4) ion concentrations in the main channel are generally below or slightly above recommended drinking water standards; however, high concentrations of these same ions are found in many of the tributaries. River travelers should be cautioned against drinking from any of the tributary streams, as high concentrations of these ions can have a laxative effect. If drinking water is limited to the main channel, any adverse effects should be limited to only those individuals sensitive to changes in chemical quality.

Similarly, the bacteriological quality of the main channel is normally at or below recommended levels for primary contact and within permissible levels for drinking water. Bacteriological contamination in tributary streams exceeds levels for primary contact. Again, river travelers should avoid unnecessary contact with tributary waters and only drink chlorinated, main-channel water until a complete inventory of tributary streams is completed.

A total inventory of all beaches used for camping by river trip parties, including size, riparian ecological considerations and maximum carrying capacity, is also needed. Many believe that much of the environmental degradation within the Canyon results from too many people using a small beach. Once the vegetation is disturbed, the beach rapidly erodes, upsetting the delicate balance between man and nature.

The environmental carrying capacity of the Colorado River from Glen Canyon Recreation Area to the Lake Mead Recreation Area needs to be defined. The environmental carrying capacity must include both bio-chemical and socio-economic parameters. From the previous discussion, it appears that the sociological considerations are not the rate determining step in river use; rather evidence indicates that the bio-chemical carrying capacity is the more constraining parameter. It is evident that the water quality in the Grand Canyon reach of the Colorado River is a function of both time and location, therefore making the determination of the environmental carrying capacity difficult.

When the carrying capacity for the River is determined, allocation models could be developed to schedule river trips and their daily progress.¹⁸ By scheduling trip departures, each group would experience little or no contact with other river expeditions. This would assure that both motorized and oar-powered trips would see few other groups and, thus, according to the Park Service's Master Plan, "improve the wilderness experience."

If the number of users per year is regulated and people are encouraged to make river trips without being limited to the total number of trips through the Grand Canyon in their lifetime, then the trips can become an experience for a small segment of the total population who continually repeat their trip. Since other people want to make river trips, decision-makers must consider this carefully when initiating regulatory policy. The question that must be answered is whether such regulations of users will further limit other prospective users.

Colorado River trips represent a complicated system to manage -- decisions are neither obvious nor easy. Currently, the major problem facing the Park Service is a lack of data. Bio-chemical and socio-economic research techniques are available to provide the necessary input data for management planning. The problem, however,

rests in the lack of resources available to investigate these decision variables. Until comprehensive research is completed, recreation management of the Grand Canyon reach of the Colorado River will continue to be a controversial subject.

REFERENCES AND NOTES

1. Colorado River trips generally begin at Lee's Ferry, Arizona, and end at Lake Mead, although people can elect shorter trips, joining or leaving at Phantom Ranch, on the canyon floor below the South Rim Village in the National Park.
2. River use limits are measured in passenger/days (P/D), i.e., a person making a ten day trip would count as 10 P/D. Nearly 66,000 P/D were reported in 1971, 89,000 P/D in 1972, and 87,000 P/D in 1973. Proposed limits would gradually reduce river use (commercial and private) to 55,000 P/D by the 1977 use season.
3. M. A. Boster, Colorado River Trips Within the Grand Canyon National Park and Monument: A Socio-Economic Analysis, (Natural Resource Systems Technical Report No. 10, Department of Hydrology and Water Resources, University of Arizona, Tucson, 1972).
4. G. C. Slawson, Jr. and L. G. Everett, "Chemical and Biological Problems in the Grand Canyon," Proceedings of the Arizona Section of the American Water Resources Association and the Hydrology Section of the Arizona Academy of Sciences Annual Meeting, Tucson (1973).
5. American Public Health Association, Standard Methods for the Examination of Water and Waste Water, (A.P.H.A., 13th ed., New York, 1971).
6. This situation is avoided whenever possible by all the outfitters operating on the river.
7. U. S. National Park Service, River Use Plan: Grand Canyon National Park Complex, Grand Canyon National Park, Grand Canyon, Arizona (1972).
8. Nearly half of the sample responded that their total family income exceeded \$20,000 annually, and almost two-thirds had incomes in excess of \$15,000 yearly.

9. U. S. Public Health Service - Center for Disease Control, "Morbidity and Morality," 21, 39, (Weekly Report for week ending Sept. 30, 1972).
10. G. C. Slawson, Jr. and L. G. Everett, Potential Health Problems in the Grand Canyon, Report submitted to the National Park Service (1972).
11. G. C. Slawson, Jr. and L. G. Everett, Potential Health Problems in the Grand Canyon: Evidence of Cyclic Patterns, Report II, Report submitted to the National Park Service (1972).
12. G. C. Slawson, Jr. and L. G. Everett, A Chemical Profile on the Lower Colorado River - Grand Canyon Reach, Report submitted to the U. S. Public Health Service - Center for Disease Control (1972).
13. L. G. Everett, R. D. Staker and H. K. Qashu, A Chemical and Biological Study of the Colorado River -- Grand Canyon Section, Report submitted to the National Park Service (1971).
14. U. S. Public Health Service, Drinking Water Standards, U. S. Department of Health, Education, and Welfare (1962).
15. J. W. Clark, W. Viessman, Jr. and M. J. Hammer, Water Supply and Pollution Control, (International Textbook Co., 2nd ed., Scranton, 1971).
16. Federal Water Pollution Control Agency, Raw Water Quality Criteria for Public Supplies, National Technical Advisory Committee Report, A report to the U. S. Secretary of the Interior (April 1, 1968).
17. U. S. National Park Service, Grand Canyon National Park Master Plan, Final draft (1971).
18. The Park Service is currently sponsoring research in this area, however, we believe that necessary data do not currently exist.