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THE WILDERNESS SIMULATION MODEL AS A MANAGEMENT TOOL FOR THE COLORADO RIVER IN GRAND CANYON NATIONAL PARK

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ABSTRACT

The Wilderness Simulation Model as a Management Tool for the Colorado River in Grand Canyon National Park

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White water rafting on the Colorado River in Grand Canyon National Park has increased since the closure of Glen Canyon Dam in 1963 from a few hundred to more than 15,000 visitors. In 1982 over 95,000 visitor days were spent on the river. The Park Service is monitoring the impact of this amount of use and seeks management programs to protect the canyon resources, enhance the visitor experience, and determine optimum use. This paper describes how the Shechter-Lucas Wilderness Use Simulation Model was modified to simulate current boat travel through Grand Canyon National Park. The model records the use of river segments, attraction sites, and campgrounds during the simulation period (one week). It also records encounters between different parties at each of these locations. The base model now reflects use and encounters as they occurred during the 1982 peak use period. Changes in management regulations, such as ratio of oars to motors, number of launches per day, size of parties, time of launch, closing certain campgrounds, etc., are fed into the model. How these change the use and encounter levels are then predicted by the model. This allows managers to evaluate the impact of management changes without the risky and often unpopular necessity of trying them out on the ground to see what happens. It is, of course, a management decision to decide the use and encounter levels that best meet Park Service management objectives.

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FOREWORD

The Shechter-Lucas wilderness simulation model is housed at the Forest Service Computer Center in Fort Collins, Colorado. Its language is GPSS and some modified FORTRAN. The main computer is a UniVac 1180. We accessed through the Coronado National Forest computer facility in Tucson, Arizona, where they have a Harris 1650 and tie lines to Fort Collins through Albuquerque. We are deeply indebted to the Forest Service--especially to Ace Crenshaw, the Coronado National Forest computer specialist, and to Martin Wefald, the computer specialist in the Forest Service San Francisco Regional Office. Without them we would have been helpless. Ace was always skillful in converting our information into useable computer input or output; he patiently helped work out "bugs" and was always cheerful and willing to devote extra time to our problems. Martin is the Forest Service expert on this as well as many other programs. He converted the original IBM model to its present form on the UniVac. When all our efforts to uncover "computer errors" failed, he always found the trouble and rescued us. We also want to thank Bob Lucas, Forest Service Wilderness Management Research Project Leader at Missoula, Montana, for his support and assistance.

Bo Shelby and his assistant, Richard Harris, were most cooperative and helpful, and both did a tremendous amount of work in the early conversion of the basic model to Colorado River conditions. We also gratefully acknowledge the help and support we received from various Park Service personnel including: Dick Marks, Dennis Fenn, Larry May, Steve Hodapp, John Thomas, Jennifer Burns, Sam West, Curt Sauer, and the list could go on. Special thanks also to Lupe Hendrickson who not only did our typing but also provided many needed editorial comments. Mike Duff at the University of Arizona worked with us last summer and helped develop the Apple program and generate river trips. Except for all the above, this is our project and our report.

Introduction

With the closing of Glen Canyon Dam in 1964, white water boating and rafting on the Colorado River through Grand Canyon became an attainable reality. Prior to that time the untamed river was traveled by only a few adventurers. Today, the National Park Service (NPS) permits approximately 15,000 persons a year to make the 240 mile trip from Lees Ferry to the upper reaches of Lake Mead. This increased use has created various management problems: human impacts on the already altered ecology of the canyon, beach erosion, crowding that detracts from the recreational experience, and visitor safety problems, to name a few.

In 1972 the NPS started a series of studies designed to culminate in a management plan for use and protection of the river through the canyon. A number of ecological and sociological studies were conducted to: 1. provide baseline data, 2. measure biological and physical impacts of Bureau of Reclamation releases at Glen Canyon Dam, 3. evaluate impacts of visitor use, and 4. measure user satisfactions (Colorado River Research Program, Report Series numbers 1-18, 1974-77). User satisfaction studies suggested that the number of contacts between parties on the river, at campgrounds, and at attraction sites was generally inversely proportional to user enjoyment of the trip.

All through the 1970's, and much earlier in certain cases, the Forest Service and others had been exploring this same theme in the management of wilderness and low use natural areas. These studies led to the idea of developing simulation models for solving wilderness management problems. There is no need here to go into the background and history of this development. It is well covered in Shechter and Lucas, Simulation of Recreational Use for Park and Wilderness Management (1979) which includes an introduction by John Kurtilla of Resources for the Future, the book's publisher. Kurtilla and his coauthor, V. Kerry Smith, published an earlier work on this subject, Structure and Properties of a Wilderness Travel Simulator (1976).

The Shelby-Nielsen studies (1976 a, b, c, d) in the Colorado River Research Program identified many of the differences between motor and oar trips, and between private and commercial trips. They also measured user reactions, expectations, and satisfactions with different types of trips. While their studies suggested that when commercial trip passengers understood the choices they favored oars over motors, Shelby and Nielsen found that users of both travel modes were well satisfied with their river experience. They also concluded that there were many other considerations that management should evaluate before deciding on the kind and level of use that the river plan should prescribe. They suggested that simulation models might be valuable management tools for the river. The decision was then made to try to adapt the Shechter-Lucas Wilderness Simulation Model to boat trips on the Colorado River through the canyon.

Unfortunately, before any of the Colorado River Research Program studies were initiated, the NPS had tentatively decided to phase out motors on the river. In 1971 a draft management plan was circulated to that effect. When controversy erupted over that and the proposed level of use, with opponents claiming there was no factual basis for such a move, a research program on the ecological and sociological aspects of river use was inaugurated. While these studies were going on, the phase-out was ordered, delayed, reordered, and canceled, as proponents and opponents marshaled various forces--mostly political. A "final" version of the phase-out plan was approved by former Park Service Director William Whalen and former Assistant Secretary of the Interior Robert Herbst in December 1979. Then, in November 1980, Congress intervened with the Hatch Amendment to the NPS Appropriation Bill prohibiting the use of appropriated funds to implement the phase-out. All of this has made any research conclusions that seem to favor oars over motors suspect in certain quarters.

In 1975, Dr. Bo Shelby, now of Oregon State University, commenced gathering data on river use and contacts as part of the above studies. He also developed techniques and a manual for use by the NPS River Patrol to monitor river use and party contacts. Between October 1980 and September 1981, Dr. Shelby commenced modifying the input section of the Shechter-Lucas model based on data and information collected in 1975. In Fiscal Year 1982 (1 October 1981 to 30 September 1982), the decision was made to turn the study over to the Cooperative National Park Resources Studies Unit at the University of Arizona where Dr. Underhill was a salaried Park Service employee, and graduate student and computer support were available. Shelby has reported on his earlier studies. This is the first report on the Colorado River adaptation of the Wilderness Model.

The Current Study

For the moment, we leave the controversy of what kind and level of use the NPS should permit on the Colorado through Grand Canyon National Park and will try to show how the Wilderness Use Simulation Model that we have modifed for the river can be helpful in making decisions.

In order to use this model it is necessary to collect and then enter into the computer a considerable amount of information on the area to be studied and the characteristics of the users. The basic model is set up to cover trails, attraction sites, and campgrounds used by horseback riders and hikers. It provides for one or more points of entry, or trailheads. Parties of both hikers and riders can be designated as small, medium, or large with the model user setting the average number of individuals in each. The ratio between riders and hikers and the ratios of small, medium, and large in each category can be put into the model. Trail segments, usually separated by junctions, attraction sites, or campgrounds, are each given a number. When all trail segments are numbered, the attraction sites continue the numbering, then the camp sites. Travel on trail segments can be in two directions; these are indicated by the numerals 1 or 2. Thus travel west on trail segment 10 would be indicated as 101, east on the same segment as 102. Campgrounds are always given the number 3 after the designation number. This numbering system can be used to lay out typical trips and enter them into the model. There is more, but it can be covered as we explain the river model.

Dr. Shelby turned over to us a model that had been modified to reflect the river situation. The river from Lees Ferry to Diamond Creek was the only trail except for those into and out of lunch stops or attraction sites. Lees Ferry was the only trailhead, and travel on the river was only in one direction. Instead of hikers and riders, we had oar trips and motor trips. Shelby divided the river into 199 segments, each separated by a lunch stop, attraction site, or campground. He had identified 110 lunch, rapid scouting, or attraction sites, and 141 campsites. Often an attraction site and a campground would be at the same location. A number of "typical" or potential trips can be constructed by stringing together the river segments, attractions, and campsites.

A comparison of the user input sections of Shelby's model (based on his 1975 observations) with 1979, '80, and '81 NPS launch information, user logs, and River Patrol reports showed that the model output differed considerably from the actual field records. Therefore, we decided to restructure the user input. We constructed 48 trips down the river, 24 oar and 24 motor trips. The actual potential trips were broken down into: nine 12-day oar trips (the usual length of commercial oar trips); eleven 18-day oar trips (the usual length of private oar trips); two 13-day, one 15-day, and one 16-day trips (the few exceptions to the above); twelve 7-day motor trips; nine 8-day motor trips (most commercial motor trips were in these categories); one 9-day and two 6-day motor trips (again, this covered the exceptions).

We worked in a new wrinkle for selecting these 48 trips. Using an Apple computer, we developed a program to print out each trip. The 199 river segments and the time required to travel each were entered into the computer (motor times were given a factor of 1.0; oar times, 1.75). We then entered attraction sites and their visit times (again 1.0 and 1.75 factors were used, because even here oar parties appeared to be much slower than motor). Each was given a frequency factor based on field observation as to how often it was visited. Campsites were then entered and again each was given a frequency factor based on popularity and use. We then developed a program capable of telling the computer the number of days for the trips (N), and of selecting campsites that divided the total river into N-1 segments ± 5 miles. It was then programed to figure travel time between these campsites and to "fill out" a 7-9 hour day with attraction site stops that added to the proper number of minutes. For example, if travel time between two campsites was 6 hours (360 minutes), it would add in attraction site stops that totaled approximately 60 to 180 minutes based on their frequencies of use. This gave us general trip outlines. We made corrections for each based on our knowledge of user behavior and logical trip composition. (See Appendix I for more details.)

While we were still testing certain combinations, we received a record of campsite use as reported by user logs for the 1982 season. In a number of cases use frequencies proved to be different than those our program had generated. The logs reported about 3,000 group overnight camps; our 48 trips have about 500 overnight group camps. Using this information, we determined total use for each campsite, divided each by 6 (approximately) to give a total use for our 500 camp nights. We then adjusted the model campgrounds to give us use totals that paralleled the log reports.

The rest of the model user input consisted of a number of different functions. They are described in the user manual compiled by Shechter and Lucas. We will only list them here:

1. Each of the 48 potential trips is given the number of days the party is on the river.

2. The attraction sites and campsites that we particularly wish to monitor are listed.

3. The number of parties to launch in a week is set. For our base model we used 29, the number the NPS was permitting during July and August.

4. The number of launches for each day of the week is set by percent.

5. The number of launches per hours of the day is set by percent (none before 9:00 AM or after 2:45 PM).

6. The percent of small (< 15), medium (15-30), and large (> 30) parties for both oars and motors is set by percent.

7. The oar/motor split is set (base model is 36% oars, 64% motors during peak summer season).

8. Each of the 48 routes is designated for oars or motors and for a morning or afternoon launch time, and each is given a frequency percentage. For example, if you want oar trips equally divided between commercial and private, you give 12-day trips (mostly commercial) frequencies that add up to 50% and 18-day trips (mostly private) frequencies that also add up to 50%.

9. Each of the 199 river segments is given a base travel time in minutes, then each of the 109 attraction sites is given a travel time, so many minutes in and so many out.

10. The factor differentiating oars and motor travel times is entered. We set motors at 1.0, oars at 1.75.

11. Camp departure time - motor parties are set to break camp at 8:30 AM ± 30 and oar parties at 9:00 AM ± 60.

12. Finally we set the simulation time, in this case 1 week.

All of these ratios, times, percentages, etc., are based on field data collected by Shelby, by NPS personnel, by the authors, or from user logs. It should be noted that we ran the model five times, twice to fill the river and then three 1-week repetitions. These three repetitions are averaged in the final summary tables.

Based on NPS launch records we decided that an average week's launch during the July-August high use period was 28-29 parties broken down as follows:

				Parties		People		
Sm.	oars	Private	18 day trips	2	7 Pvt.	16	people	10 oars
Med.	oars	Private	one 18 and four 12-day	5		130	"	
Med.	oars	Commercial	12-day trip	1	22 comm.	26	"	
Large	oars	Commercial	12-day trip	2		68	"	
Med.	motors	Commercial	7-day trips (one 6-day)	7		154	"	19 motors
Med.	motors	Commercial	8-day trips	2		44	"	
Large	motors	Commercial	7-day trips	4		140	"	
Large	motors	Commercial	8-day trips	6		210	"	
			Totals for week	29 parties		788	people	
			Average per day	4.14		112.6	people	

We based the size of parties on averages derived from launch information kept by NPS at Lee's Ferry: small oar parties 8, medium oar parties 26, large oar parties 34, small motor parties (this we didn't use, but 10 is about right if you have this category), medium motors 22, and large motors 35. Using these you can convert party use and encounter figures to people. The above constitutes our "Base Run."

As noted, we set the simulation for a 1-week period; ordered 3 replications, and first "filled the river" with 2-week launches of 29 parties each in the same ratio of oars, motors, trip lengths, and party sizes as we used for the three simulation runs. The model then printed 28 tables and 10 matrices for each of the simulation runs. It printed 8 tables consolidating each of the three simulations and then a total summary.

All of these matrices and tables can be useful in making management decisions, but for testing the validity of our base and the impact of various simulations, we found five to be most useful. These were:

Matrix 8 which tallied encounters and use levels for each river segment, attraction site, and campground,

Summary Table 2 which kept track of trail encounters by days of the week,

Summary Table 3 which tallied camp encounters by day of the week,

Across-run Summary Table 2 which gives by number and percentage the parties that had none, one, two, etc., encounters per day on the average. It also gives average number of encounters per party per day. (this is labeled average level of solitude or crowding), and

Across-run Summary Table 3 which is the same as Table 2 for camp as opposed to river or attraction site encounters.

Table 1. Parties encountered at selected attraction sites and average number of parties encountered per day.

N	Shelby 1975 41	Patrol 1980 5	Patrol 1981 10	Patrol 1982 10	Model (Base) 4 Jan. '83 87
Red Wall	.43	.60	1.10	.64	.55
Lit. Col.	.63	.80	1.30	1.64	1.26
Elves C.	.63	.60	1.90	1.91	.58
Deer Cr. F.	.67	1.00	1.70	1.90	1.09
Havasu	.67	1.00	2.10	2.22	2.35
Cont/day	3.40	3.20	2.74	2.45	2.54

After a considerable amount of adjusting of routes and ratios, the base model was conforming closely to the information we were getting from the field. Table 1 shows the daily average of party river encounters and parties met at five heavily used attraction sites for Shelby 1975, River Patrols of 1980, '81, and '82, and the average number on our base simulated run. Table 2 shows the same information for camp contacts. The model's contacts per day appear close to the figures from the actual river trips. As can be seen, there is considerable variation in the attraction site figures, but again the model is pretty much in line with the reported figures. While the model is lower than the reported camp contacts, it is close to the patrol figures for the comparable high use period.

Table 2. Camp contacts

Data Source	Camp nights	Alone	Percent
Shelby 1975	440	400	.91
NPS 1980	61	51	.84
NPS 1981	118	89	.75
NPS 1982	165	134	.81
Base Model	748	495	.66
NPS 81-82 6/15-9/15	129	81	.63*

*On 19 NPS patrols in 1981 and 1982, made during the high use period, 15 June - 15 September, they camped 129 nights. Of these 81 were alone. This gives a camped-alone ratio of .63.

Matrix 8 of the third replication accumulates information from all three replications. It records total use, oar use, motor use, total encounters, and total nights with encounters for each of the 199 river segments, the 110 attraction sites, and the 141 campsites. It is from this matrix we obtained the use and encounter information for the five heavily used attraction sites. From this matrix we have also taken use and nights with encounters information for 17 campsites where the NPS has been monitoring ecological impacts. Table 3 gives this information from the Base Model for a 3-week period and compares it with information provided by river runners' logs. Spearman's Rho test (Ranking Comparability Test) gives an r_s value of .87 showing a very high relationship between the two rankings. At this point we felt the base model was a reasonable replication of what actually takes place on the river, and we were ready for simulation runs. These were designed to show how different management strategies affected encounter and use levels in comparison to the base case.

Remember, with some modification for public relations and political considerations, the Park Service is in a position to control use of the river. All launches are at Lees Ferry where park rangers can check equipment, permits, size of party, safety precautions, etc. The number of parties, mix of parties, size of parties, commercial vs. private, etc., are and can be controlled. The assignment of campgrounds has, to date, been

Table 3. Campground Use. Three-week period during high use, July-August 1982 period.

Campground[1]	User Logs[2] Times Used	%	Rank	Base Model[3] Times Used	%	Rank
20 Mile	12	7.0	5	19	10.2	4
Saddle Canyon	10	5.8	8	18	9.7	5
Dinosaur L&M Nankoweap	11	6.4	6	20	10.8	3
Lower Nankoweap	9	5.2	10	5	2.7	12
Awatubi	6	3.5	13	6	3.2	11
Upper Unkar	8	4.7	12	14	7.5	7
Hance Rapid	1	.6	14	1	.5	14
Granite Falls	9	5.2	9	11	5.9	8
Hermit Creek	1	.6	15	0	0	16
Lower Bass	12	7.0	4	15	8.1	6
Forester	0	0	17	0	0	17
Stone Creek	9	5.2	11	4	2.2	13
Tapeats Creek	11	6.4	7	7	3.8	10
Deer Creek	14	8.1	3	10	5.4	9
Poncho, Eddy, Doris	37	21.5	1	33	17.7	1
National (2 camps)	21	12.22	2	22	11.8	2
River Mile 185.5	1	.6	16	1	.5	15
Total Group Camps	172			186		

[1]These are the river campgrounds that the NPS is monitoring to measure the impact of visitor use.

[2]User logs for the 10-week period 27 June-4 September were totaled. Since about 70% of users turned in logs, these totals were divided by .70 to give a total for the 10-week period. This figure was multiplied by .3 to give times used during a 3-week period.

[3]Use figures for each camp in the 3-week simulation of the Base Model were taken from the Matrix 8 printout of the third replication since Matrix 8 accumulates use and encounter figures from all previous replications.

vigorously opposed by all users. Most users, both commercial and private, know how many days they plan for their trip, but other than setting a minimum of 6 days and a maximum of 20 days to Diamond Creek, the Park Service has not told permit holders how long their trip should be. However, all of these and other management regulations are possible if they can be justified and generate sufficient support. With this in mind, we ran the following simulation runs:

1. All oars, 35 trips per week, average 114 people per day, 796 per week (9 small oars parties, 20 medium oars parties, 6 large oars parties). These further break down to 18-day trips: 9 private small, 6 private medium, 2 commercial medium; 12-day trips: 12 commercial medium and 6 commercial large. We wanted about the same number of people per week as now go down. This required 35 launches - 15 private and 20 commercial.

2. Mixed oars and motors, 42 trips per week, 132 people per day, 932 per week (14 private oar parties, small; 7 commercial oar parties - 4 medium, 3 large; 10 commercial medium motors, and 11 commercial large motors per week). This is the largest simulation we ran -- half oars and half motors, 14 private and 28 commercial. More launches can be simulated if desired.

3. All oars, 28 trips per week, average 102 people per day, 714 per week (7 private small oars, 7 commercial medium oars, 14 commercial large oars). We wanted approximately the number of launches as now occur, but all oars. Total people is less because the parties are smaller.

4. Mixed oar and motors, 35 trips per week, 127 people per day, 875 per week (7 private small oars, 3 commercial medium oars, 4 commercial large oars, 10 commercial medium motors, 11 commercial large motors). This is a compromise -- 40% oars, half private, half commercial; 60% motors, all commerical. That is about the current ratio, and this provides 7 more launches a week.

5. Same as No. 4, except launches are evened out to five each day of the week; there are no launches before 10:00 AM, between noon and 1:00 PM, and after 3:00 PM. In addition AM and PM launches are equal (i.e., 17 or 18 AM and PM launches per week). This is an attempt to measure the impact of specific changes in launch schedules.

See Table 4 for a summary of these simulations.

Table 4. Model Base, various simulations. Compared by encounters with other parties (see text for details on each simulation).

Location	Base Model 29 per wk. 19 motors 10 oars	#1. All Oars 35 per wk.	#2. 1/2 Oars, 1/2 Motor 42 per wk.	#3. All Oars 28 per wk.	#4. 14 Oars 21 Motor 35 per wk.	#5. Same as #4 but launches controlled
Red Wall	.55	1.06	1.07	.76	.85	.82
Little Colo. R.	1.26	1.25	1.53	.88	1.28	1.63
Elves Chasm	.58	2.00	1.54	1.31	1.30	1.10
Deer Cr. Falls	1.09	2.57	2.72	1.83	1.41	1.86
Havasu	2.35	3.34	3.59	2.11	2.96	2.67
Av. River encounters per day	2.54	3.85	4.30	2.97	3.51	3.35
% nights camped alone	.66	.41	.42	.44	.59	.53

Discussion

Our mission in this project was to modify the Shechter-Lucas Wilderness Travel Simulation Model to reflect as accurately as possible current river travel conditions on the Colorado River through Grand Canyon National Park. We were further asked to demonstrate how the user input section could be modified to measure the impact of various management changes such as ratios of oars to motors, number of launches, time of launches, length of trips, size of parties, etc.

No simulation model can duplicate exactly what takes place in the field. There are too many uncontrollable variables that cannot be anticipated and programed into a computer. We believe, however, that this model gives a good approximation of river use during the peak, summer 1982, season.

It can be seen that the model makes no judgments. It reports use and encounters based on the information you supply. We then ran five simulations as noted above and described in Appendix II. These runs were solely for the purpose of illustrating the kind of management changes that can be simulated. We believe that they reflect the changes in use and encounters that may be expected if such a management plan is initiated, but we hasten to point out that except as noted in Appendix II where we have changed frequencies, each simulation run uses the input of the Base Model and selects trips from the 48 we entered in the Base--24 oar (nine 12-day, eleven 18-day, two 13-day, one 15-day, and one 16-day) and 24 motor (twelve 7-day, nine 8-day, one 9-day, and two 6-day). For example, if only oars are launched, the model will select from the 24 oar trips and ignore the motor, but with only oars on the river, operators might have a different trip pattern than those presented. We believe, however, that the trends shown in Table 4 are valid.

There is no question about the need to regulate use and to protect the river environment as it now exists. The authors suggest, however, that the five simulation runs shown in Table 4 seem to indicate that little is gained with oars only, and simulation runs 2, 4, and 5 with 132, 127, and 127 people launched per day (6, 5, and 5 parties average per day) do not appear to be significantly different from the base or the oars only trips. Only #2 with 42 launches per week appears a bit higher, but again it becomes a management decision as to the level of use and encounters that is acceptable.

One interesting aspect of the encounter averages shown in Table 4 is the average number of river encounters per day, particularly the results of the oars only simulations, numbers 1 and 3. Oar trips take considerably longer than motor trips. The 2.54 average per day for the Base Model came from a total of 450 encounters during the simulation period. The 2.97 average per day for #3, same number of parties but all oars, came from a total of 908 encounters, over twice as many as are now occuring. Simulation run #1, oars only with 35 launches per week, had 1409 encounters during the simulation period, and run #2 half oars-half motors but 42 launches per week (the most we tried) had 1251 encounters. For these latter two the average encounters per day were 3.85 and 4.3.

Managers must decide on acceptable, desirable, optimum, etc., use and encounter levels. Some studies have been done on both crowding and on oars vs. motors. Shelby and Nielsen (1976) found some indications that commercial passengers exposed to both travel modes preferred oars, yet of the vast majority that traveled by either oars or motors (984 responses) "...only 1% rated their trips as 'fair,' 4% as 'good,' and 11% as 'very good.' Fifty-five percent said 'excellent, only minor problems,' and 29% said 'perfect.'" The same investigators found most river runners thought the river relatively uncrowded. Seventy percent said they did not meet too many people during the trip and 75% felt that the canyon was not being damaged by over use. Shelby and Nielsen also pointed out that managers must consider a number of other factors besides visitor perceptions--length of trip, cost, total visitor use (i.e., more people can experience the trip through the canyon by motors than oars for the same number of visitor days or nights), and, as has been demonstrated, political considerations.

It should also be noted that Grand Canyon National Park was established primarily to preserve for posterity the magnificent, unique geological phenomenon that is the Grand Canyon of the Colorado River. The construction and closing of Glen Canyon Dam completely altered the ecology of the river through the canyon. Scouring by raging torrents is almost eliminated; many native fish like the squawfish have disappeared to be replaced by salmonids; beaches are no longer nourished by sand and sediments except for small amounts from the Paria and Little Colorado; riparian vegetation, both native and exotic has become established. The 5,000-plus foot walls of the main and side canyons, however, remain unchanged. Their viewing from the river as opposed to from the rims has been made possible by the same man-made structure that changed the ecology, and thousands now make the trip annually where a few hundred at most did so before. While to most of these travellers it is the wildest and most wilderness-like experience of their lives, it is not a wilderness. It has been drastically altered by man, and they are traveling with propane gas stoves, refrigeration, sophisticated plastic, rubber rafts, and a host of other modern conveniences. This must be remembered when applying the wilderness encounter concept to this situation.

This model, however, can still be a useful tool for managers to test the impact of management changes. It can, for example, be adapted or modified to reflect the impact of changing Bureau of Reclamation releases at Glen Canyon Dam on recreational use of the river. In using it, managers must realize that use of areas and encounters with other parties are only two of many considerations that must shape management decisions.

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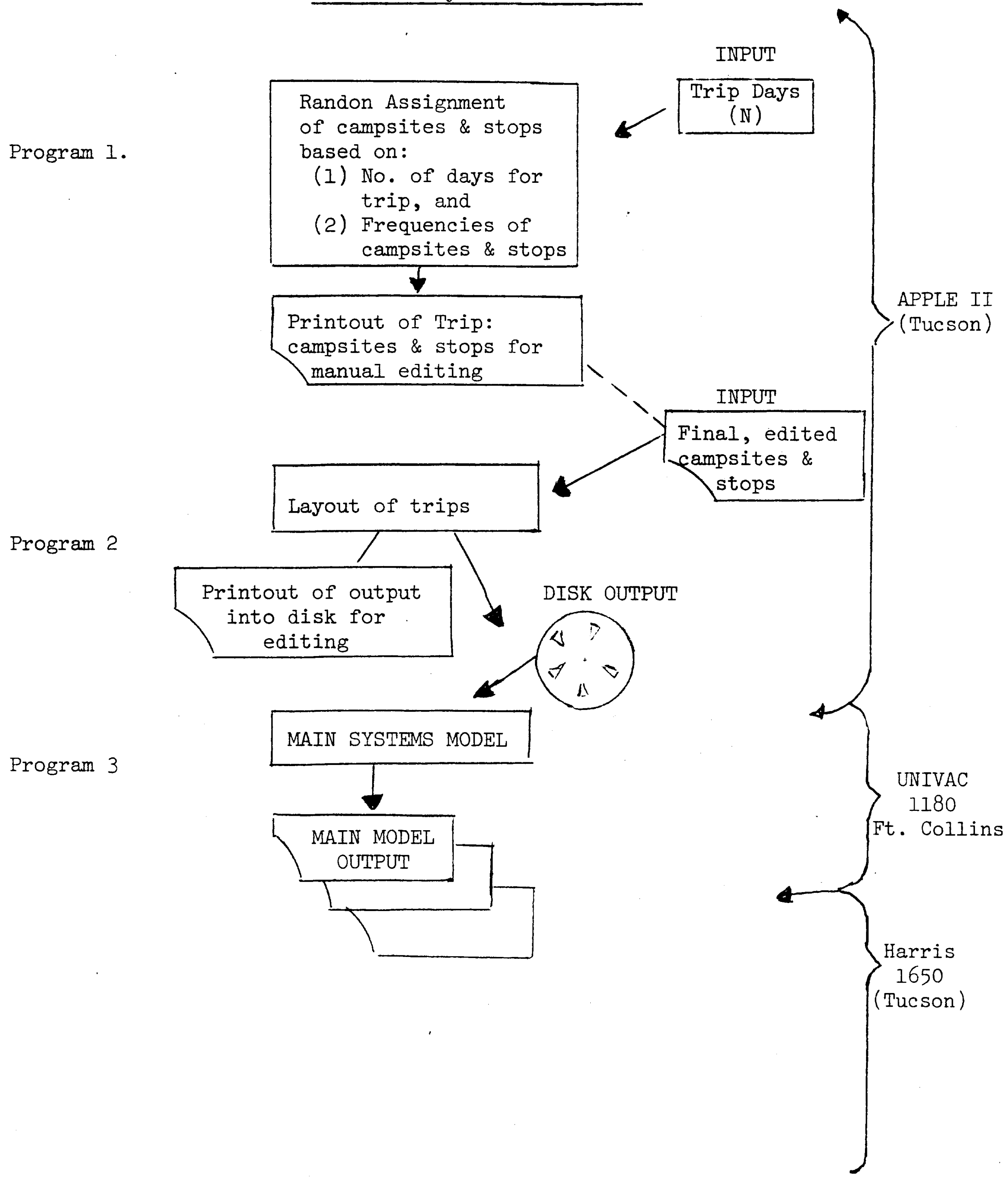
Appendix I

Schematic Systems Flowchart



Program 1: On the basis of the trip logs which the National Park Service normally collects from the various trips on the river, frequency tables were compiled and fed into this program. Trips were generated by the following procedure: From the logs, histograms were compiled for the camping trends of the campers per day per trip type. These histograms gave an indication of the popularity of each campsite per day per type. This information and the travel times established by Bo Shelby were fed into Program 1 to choose randomly the campsite for each day.

Second, between each two consecutive campsites were sightseeing stops with their respective frequencies. These stops were also picked randomly according to their frequencies and the observed times travelers normally spent at each site. The program looped around for each day picking out stops until the travel time plus the sightseeing time(s) added up to a 7-9 hour day. The program did this for each of the N days entered initially for the trip. It terminated as soon as the last campsite was processed.

The main advantage of this particular addition to the system is in savings of man-hours and money. Instead of physically sending monitors down the river to measure each trip type, the trip logs, which the river rangers and the travelers normally submit, are used. It also randomizes the assignment of the campsites and stops within each day.

It was, however, not possible to eliminate totally some subjective decisions in the generation of these trips. Since sightseeing stops and rapids are treated alike, the program would incorrectly allow several stops at a rapid just as it (correctly) did at a sightseeing stop. Other similar anomalies needed to be edited manually before the information was put into Program 2.

Program 2: The task of this program is to receive the final edited campsites and stops from Program 1 and lay out each trip according to a given sequence table. The output is a magnetic floppy disk. Each trip is output into the disk separately. This information on the disk can then be sent electronically to the main computer.

Appendix II

Make-up of Base and Five Simulation Models

Base Motors 65%; Oars 36%
29 launches per week; Av. of 5 runs, 19 motors, 10 oars

Small oars (private)	18-day trips	2	@ 8	16	people
Med. oars (private)	one 18-day, four 12-day	5	@26	130	"
Med. oars (commer)	12-day	1	@26	26	"
Large oars (commer)	12-day	2	@34	68	"
Med. motors (commer)	7-day(inc one 6-day)	7	@22	154	"
Med. motors(commer)	8-day	2	@22	44	"
Large motor (commer)	7-day	4	@35	140	"
Large motor (commer)	8-day	6	@35	210	"
		29		788	" per week
				113	" per day av.

Sim. #1 Motors 0%, Oars 100%
34 launces per week, av. of 5 runs, Sm. oars 8, Med. oars 29, lg oars 6

Sm. oars (private)	18-day trips	8	@ 8	64	people
Med oars(private)	18-day (one 16-day)	6	@26	156	"
Med oars(commer)	18-day	2	@26	52	"
Med. oars (commer)	12-day (one 15-day)	12	@26	312	"
Lg. oars (commer)	12-day (one 13-day)	6	@35	210	"
		34		794	" per wk.
				113	Av. per day

Sim. #2 Motors 50%, Oars 50%
Av. 41 launches per wk., Av. 5 runs, Sm. oars 14, MO 5, LO 2, MM 10, LM 11, 6 launches per day (2 Prvt. oars, 1 comm. oars, 3 comm. motors) 1 day only, 1 Prvt. oars

Sm oars (private)	18-day trips	9 per wk	@ 8	72	people
Med oars (Private)	12-day	4 per wk	@26	104	"
Sm. oars (commer)	12-day	4 per wk	@ 8	32	"
Med oars(commer)	12-day	1 per wk	@26	26	"
Lg. oars (commer)	12-day	2 per wk	@34	68	"
Med motor(commer)	7-day	5 per wk	@22	110	"
Lg. motor(commer)	7-day	5 per wk	@35	175	"
Med motor(commer)	8-day	5 per wk	@22	110	"
Lg. motor(commer)	8-day	6 per wk	@25	210	"
		41 per wk		906	" per wk.
				130	" per day

Sim. #3 Motors 0%, Oars 100%
29 launches per wk; Av. of 5 runs, Sm oars 7, Med oars 7, Lg oars 15

Sm oars (private)	18-day trips	7	@ 8	56	people per wk
Med oars (commer)	18-day	5	@26	130	" " "
Med oars (commer)	12-day	2	@26	52	" " "
Lg. oars (commer)	12-day	15	@34	510	" " "
		20		748	" " "
				107	" per day

Sim. #4 Motors 60%, Oars 40%
34 launches per wk; Av. 5 runs, Sm. oars 7, Med. oars 3, Lg. oars 5, Med. motor 12, Lg. motor 8

Sm oars (Private)	18-day trips	6	@ 8	48	people per wk
Sm oars (private)	12-day	1	@ 8	8	" " "
Med oars (commer)	12-day	2	@26	52	" " "
Lg. oars (commer)	12-day	5	@34	170	" " "
Med Motor (commer)	7-day	6	@22	132	" " "
Med motor (commer)	8-day	6	@22	132	" " "
Lg. motor(commer)	7-day	4	@35	140	" " "
Lg. motor (commer)	8-day	4	@35	140	" " "
		34		822	" " "
				117	" " day

Sim. #5 Motors 60T, Oars 40%
35 launches per wk; Av. 5 runs, Sm. oars 6, Med. oars 2, Lg. oars 5,

Sm oars (private)	18-day trip	6	@ 8	48	people per wk
Med oars (commer)	12-day	2	@26	52	" " "
Lg. oar (commer)	12-day	4	@34	136	" " "
Med motor (commer)	7-day	5	@22	110	" " "
Med motor (commer)	8-day	5	@22	110	" " "
Lg. motor (commer)	7-day	6	@35	210	" " "
Lg. motor (commer)	8-day	7	@35	245	" " "
		35		911	" " "
				130	" " day

Simulations numbers 4 and 5 were to be the same, except that for simulation number 5, we evened the launch schedule to 5 each day of the week (simulation number 4 launched 6, 5, 5, 5, 6, 3, and 4 for the seven days of the week), and we changed the frequency of launch times as noted below. There are, however, a number of random factors built into this program, and while we asked for 35 launches each time, the computer selected 34 for number 4, and 35 for number 5.

Also, as shown above, the actual size and type of parties differed between the two simulations, although they were very similar. On the basis of encounters shown in Table 4, the changes in launch schedules did not appear to make a significant difference.

For the base model and the first four simulations, launch frequencies were:

Sunday .168, Monday .133, Tuesday .149, Wednesday .149, Thursday .175, Friday .096, and Saturday .126. Actual launches in the printouts were:

Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.
5	4	4	4	5	3	4 for 20 a week
6	5	5	5	6	3	4 for 34 a week
7	6	6	6	7	4	5 for 42 a week
5	5	5	5	5	5	5 for sim. #5

For simulation number 5, we changed the frequencies to:

S .142, M .143, T .143, W .143, Th .143, F .143, S .143

For the base and the first four simulations, launch time frequencies were: no launches before 9 AM, 4% between 9 and 10:30 AM, 66% between 10:30 and noon, 23% between noon and 1:30 PM, and 7% between 1:30 and 2:45 PM, none later. For simulation number 5: no launches before 10:00 AM, 50% distributed evenly between 10:00 AM and noon, none between noon and 1:00 PM, and 50% distributed evenly between 1:00 and 3:00 PM.