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# BOATING ACCIDENTS AT LEES FERRY
# A BOATER SURVEY AND ANALYSIS OF ACCIDENT REPORTS

Glen Canyon Environmental Studies
Flagstaff, AZ

Apr 87



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# BOATING ACCIDENTS AT LEES FERRY

## A BOATER SURVEY AND ANALYSIS OF ACCIDENT REPORTS

FINAL REPORT

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National Park Service
Glen Canyon National Recreation Area

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16. Abstract (Limit: 200 words)
This study conducted an analysis of the accident rates of Glen Canyon National Recreation Area anglers and day-use rafters on the 15 mile stretch of river between Glen Canyon Dam and Lees Ferry. The study looked at 8 years (1977-84) of accident reports, examined additional accident factors recorded on the accident reports, used a factor analysis to examine accident occurrence in relation to flows, and examined river flow fluctuation prior to the accident to determine flow-related factors which may have contributed to accident occurrence. The accident rate for Lees Ferry appears to be comparable to the national average and does not appear to be skewed by river flows. The most frequent accident involves minor propeller damage as a result of hitting a gravel bar in the morning during a period of fluctuating flows and are not reported. About 5% of accidents are reported and the most common is the capsizing of 12-14 foot fishing boats cruising in strong current. The low number of accidents identified by both the survey and accident report analysis makes drawing conclusions difficult.

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# INTRODUCTION

## Location

Glen Canyon Dam is located in northern Arizona near the city of Page. It impounds the waters of the Colorado River for approximately 190 miles to form Lake Powell, the second largest reservoir in the United States. The dam was constructed as part of the Colorado River Storage Project by the Bureau of Reclamation to provide for long-term storage of water to meet the requirements of the Colorado River Compact. The pattern and variation of Colorado River flows have changed since the dam's construction. Before the closing of the flood gates river flows ranged seasonally between summer lows of less than 1,000 cubic feet per second (cfs) and highs during spring floods in excess in 80,000 cfs. Since impoundment, the flow regime is a product of distant hydroelectric energy demands and downstream water delivery obligations. From 1963 to 1984, Glen Canyon Dam releases ranged between 1,000 cfs and 28,000 cfs with large daily fluctuations in response to electrical demands for peak hydroelectric power. During 1983 high spring runoff in the upper Colorado River basin forced use of the spillways which produced river flows of up to 90,000 cfs.

The study area consists of approximately 15 miles of the Colorado River from Lees Ferry to Glen Canyon Dam. It is located within Glen Canyon National Recreation Area, which is administered by the National Park Service. Recreation opportunities include boating, fishing, camping, hunting and commercial float trips. Trout fishing is the most popular recreational activity. Boat types used on the river range from small, open, aluminum fishing boats with outboard engines to fiberglass runabouts with inboard engines. Hull sizes range between 9 and 24 feet with the 12-16 foot aluminum car top fishing boat predominating. Most boating occurs in the form of day trips between sunrise and sunset.

## Background

In 1982 the Bureau of Reclamation began the Glen Canyon Environmental Studies to investigate the impacts of dam releases on the Colorado River. The studies looked at sedimentation, biology and recreation with over 40 different projects. One important aspect of those studies is boating safety.

In April, 1986, a study by Underhill, Hoffman and Borkan of the Cooperative Park Studies Unit at the University of Arizona was initiated to determine if there is a significant correlation between reported boating accident occurrence and the river flows at the time and place of the accident.

The study looked at the eight accident variables; date, time, location, commercial or private operator, accident type, flow at time of accident, boat type and boat size. Flows were categorized into

four flow ranges of; Low = less than 9,000 CFS; Medium = 9,000-15,000 CFS; High = 16,000-31,500 CFS; and Flood = greater than 31,500 CFS. A total of 29 useable accident reports from the study period form the basis for the analysis. A mix of 14 National Park Service case incident and 15 National Park Service boating accident forms were used. Information on the forms varied greatly. They all supplied date, time and location of the boating accident.

A 24 hour boat-day converted to boat hours was compared to hourly flows for each of the four flow ranges. The 24 hour boat day was used because of the long length of Grand Canyon river trips and the inability to use the Bureau of Reclamation SSARR model (Streamflow Synthesis and Reservoir Regulation Colorado River flow model) to track flows to the location of the accident. The Chi Square statistical test was used to compare the percentage of reported accidents to expected accidents by flow range. Accident rates were determined for each of the three years analyzed but were not compared to any state or national average.

The analysis indicated that the accident distribution by flow range was non-random, with almost twice the expected number of accidents occuring during high range flows and less than a third of expected accidents occured during medium range flows. Twenty out of twenty-nine accidents occurred during the high flow range which accounted for only 40 percent of the boat-hours while only about 7 percent of the accidents in the medium flow range which accounted for 25 percent of the boat-hours. An overall accident rate of 0.104 accidents per hundred days was calculated. This translates into one accident for every 957 boat-days. This was considered low by the investigators.

The researchers concluded that although flow related trends appeared for boating accidents in Glen Canyon, the small number of reported accidents and the lack of sufficient information on other accident related variables made reaching any flow-related conclusions dangerous. However, they did note that although they felt the flow ranges used were reasonable, the use of different flow ranges might cause different and non-random distribution of accidents. The fact that 69 percent of all Glen Canyon boating accidents occurred in the high flow range which accounted for only 40 percent of the boat hours suggested some undetermined connection between flows and accident occurrence in the flow range between 16,000 and 31,500 CFS. They postulated one possible interpretation of the descriptive analysis of non-flow related factors and overall non-random distribution. Boaters were more likely to have problems which resulted in accidents during high flows and much less likely to get into accident situations during medium and low flows.

## Purpose of this Study

The Underhill study brought about several questions which needed to be answered. The findings seemed to indicate that more variables were involved than just a static flow level and the occurrence of an

accident at a specific location. What were those variables and how do they interact with flows, if at all? Are accident reports representative of the accidents that occur in the study area? The accident rate as computed appeared to be so small as to be insignificant. How does that compare to the national average and other locales with similar situations? The study looked at three representative years of data. The small sample size appeared to hamper the analysis. Would a larger sample size provide a better database? This study attempted to address these questions.

## METHODS

### Components and Data Analysis

The study was divided into two major components. The first was a survey of boaters at Lees Ferry to determine an accident rate and to compare actual accidents to reported accidents. This survey consisted of a short questionaire administered by HBRS, the USBR contractor conducting the recreation research for the Glen Canyon Environmental Studies. They administered this questionaire along with the Lees Ferry Fishermen Survey they were conducting, on the same days and to the same parties, although not to the same people.

The second component was an extension of the Underhill study by doing the following:

1. Extending the study period to cover eight years (1977-1984) of data by gathering all the accident reports during that period. This would cover all the useable accident reports on file at Glen Canyon National Recreation Area and would give a larger database from which to work.

2. Examine additional accident factors recorded on accident reports including all the data on the National Park Service boating accident report form.

3. Use a factor analysis to examine accident occurrence in relation to flows in order to determine if any "problem" flow ranges could be determined by the data.

4. Examine river flow fluctuation prior to the accident in a effort to determine what flow related factors, other than flows at the time of the accident, may have contributed to accident occurrence.

All boating accident reports in the files at Glen Canyon National Recreation Area were reviewed and those dating from 1977 to the present were found to be the most useful. Data gathered from the reports include date, time and location of the accident, type of accident, reported cause, wind, operator age and experience, size and type of boat, engine size in horsepower, boat operation at the time of

the accident, water and weather conditions, and finally if the accident occurred during the day or night. Bureau of Reclamation records on Glen Canyon Dam releases were used to get the flow at the time and location of the accident and hourly for the previous four hour period. All accident data was codified numerically and entered into a computer spreadsheet for subsequent statistical analysis. There were several reports for which some accident variables were unknown.

This report will be restricted to a descriptive analysis of the data due to the short time frames available and the lack of all the data necessary. It would be best to determine the exposure rate of all boaters to river flows and do a comparative analysis to determine the strength of the relationships, if any. Data collection for this would require a significant amount of time and resources beyond that available. Therefore, the statistical significance the relationships will not be determined.

## Definition of an Accident

Generally a vessel is considered to be involved in a boating accident whenever the occurrence results in damage by or to the vessel or its equipment,injury or loss of life to any person, or the disappearance of any person on board under circumstances which indicate the possibilty of death or injury. A boating accident includes but is not limited to, the capsizing, foundering, flooding, fire, explosion and disappearance other than by theft of a vessel.

The U.S. Coast Guard under the Code of Federal Regulations, Part 33, Section 173, paragraph 4 (33 CFR 173.4) files a report of an accident if the accident results in loss of life, personal injury which required medical treatment beyond first aid, damage to the vessel and other property exceeding $200, or complete loss of the vessel.

National Park Service regulations in 36 Code of Federal Regulations, Part 3 adopts U.S. Coast Guard regulations and applicable state laws and regulations. The National Park Service further requires all incidents involving an accident, collision, fire injury or other casualty to be reported to the Superintendent within 24 hours (36 CFR 3.4). It should be noted that the National Park Service accepted reports of accidents with damage below the $200 Coast Guard minimum.

## Accident Reports

It is the responsibility of the owner or operator to submit a written report to the appropriate state as required by state law. Glen Canyon National Recreation Area administered federally by the National Park Service (NPS) also requires the owner or operator to submit a report to the Superintendent. Individuals who fail to report an accident are subject to prosecution by the National Park Service. In practice all accidents reported to the National Park Service at Lees Ferry have accident reports filled out regardless of what the value of the loss

and only those serious accidents not reported which come to the attention of the Service are followed up on to get reports.

Incidents which met the criteria for classification as a boat accident were found on the following three NPS report forms:

1. Case Incident Record, Form #10-343.
2. Case Incident Record - Short Form, #10-343A.
3. Report of Boating Accident, Form #10-413 Boat.

The first two report forms are standard narrative reporting documents. These two forms were used by investigating rangers during the 1977-1980 period since the new boating accident form did not come into use until 1980. When data was retrieved from these records the information supplied by the investigators varied in its content. A suitable report was one which, at a minimum, provided the following details: date, time, location of accident and accident type.

The third report form, Report of Boating Accident, is a modified U.S. Coast Guard document. This report form requests the investigator to provide a detailed record of operator profile, boat data, accident scene description and several accident variables. A boating accident which was documented on this report form provided the minimum data and was used as long as it met the defined accident criteria, including accidents with damage less than $200. There were, however, several of these accident reports for which some information was unavailable to the investigators.

## Dam Release Records

Discharge figures for Glen Canyon Dam were available in one hour increments and were obtained from Bureau of Reclamation records maintained in Page, Arizona. Flow figures were collected for each accident occurrence and a four hour period preceding an accident. River flow at the accident was determined by identifying the accident location (in miles distant from the dam) then dividing that distance by the velocity of the discharge (approximately 5 mph). The resulting figure represents the time the accident site river flow was discharged from Glen Canyon Dam.

## Review of Pertinent Literature

A computerized search of relevant literature conducted by Computer Search Services, of Washington D.C., revealed no references of pertinent research on the subject of this study. However a check with the U.S. Coast Guard Statistical Branch revealed some useful studies. The first is the Coast Guard's annual Boating Statistics Report. The others are two boating safety surveys conducted by the Coast Guard in 1973 and 1976. Data from these surveys appears to be the best available for determining a nationwide boating accident rate. Rates determined in this study are therefore compared to these in an effort to determine their significance.

## FINDINGS

### Accident Survey

During the 64 days of data collection between April 29, 1984 and December 19, 1985, a total of 355 parties were surveyed of which 342 filled out questionaires for a response rate of 96 percent.

There were 21 reported accidents during the survey indicating that 6 percent of the respondents experienced a problem of some type during their boating trip at Lees Ferry. Of those reporting accidents 86 percent (n=18) reported damage to propellers only, 10 percent (n=2) reported running out of gas, and 5 percent (n=1) reported being swamped. One party reported damage to two different propellers on the same boat on one day. One was reported as destroyed and one as damaged. And was treated as one accident since only one location and a total value loss was reported. Another party reported damage to both the boat and the propeller. Since this occurred at the same location and time it was treated as one accident with propeller damage.

Accidents were reported on 11 of the 64 days surveyed. All but three of the days with accidents were in October, November and December of 1985. That period coincides with the fluctuating flow regime being operated by the dam for the Glen Canyon Environmental Studies. During that period river flows were fluctuating in the low range (0-9,000 cfs) for about 30 percent of the time. Flows were in the medium range (9,000-16,000 cfs) 47 percent of the time and in the high range (16,000-31,500 cfs) 23 percent of the time. Previous to that flows were high (+20,000 cfs) and constant with relatively no fluctuations. During the high-constant flow period there were two cases of people running out of gas and one incident of propeller damage. During the low-fluctuating flow period 86 percent of the accidents occurred including 15 damage to propeller, one damage to propeller and boat and one swamping. If only the accidents reported during the fluctuating flow period are related to those surveyed during that period (122 respondents) 15 percent of the sample had accidents.

Only 8 of the 21 respondents reported times for their accidents and only four of those indicated a specific time. All the others said that their accident occurred in the AM. Of those that indicated times two were in the morning, one was at noon and the other at 2:00 PM.

Ten repondents indicated a location of their accident with 70 percent (n=7) reporting Three-Mile Bar and one each at Four-Mile, Six-Mile and Ten-Mile respectively. Four-Mile could be a mislocation of Three-Mile Bar since mile zero at Lees Ferry has moved about one mile downstream from the original ferry site depending on the map used. Both Six-Mile and Ten-Mile are known to have wide, shallow portions of the channel due to bends in the river. Though direction of travel was not

indicated in the questionaire the preponderance of morning incidents seems to suggest that the direction of travel may be mostly upstream.

An estimate of damage cost was reported by 16 repondents. These ranged from 25 to 200 dollars with an average loss of 86 dollars. The loss estimates appear to be evenly spread throughout the range with 31 percent (n=5) reporting losses of 100-200 dollars, 31 percent (n=5) reporting losses of 25-50 dollars, and 38 percent (n=6) reporting losses of 60-70 dollars. The value of loss by accident type is 50 dollars for boat damage (n=1), 200 dollars for lost equipment from the swamped boat (n=1), and a range of 25-200 dollars for propeller damage with an average loss of 75 dollars (n=15).

A check of National Park Service records indicate that of the days surveyed two boating accidents were reported at Lees Ferry. On May 18 a boat flooded and capsized due to the operater dragging anchor while fishing and the rapid river current pulling the boat down. One occurred on May 20 when a boat engine lost power and drifted past Lees Ferry and into the riffles below. The boat and operater were rescued by NPS Rangers with no injury or damage. Those involved in both incidents were not surveyed, since data was not collected all day every day. Data from those accidents is not being used in this poprtion of the report. None of the recorded accidents reported by survey respondents were reported to the National Park Service.

## Boating Accident Report Data

The following analyses are from data compiled from National Park Service Lees Ferry boating accident reports. Several of the reports lacked data for all the accident factors and some accidents were reported with multiple response factors. A total of 56 accidents were evaluated. However, because of the multiple responses and the lack of available information in some reports, the number of accidents used in each portion of the analysis may total more or less than 56.

### Calculation of Accident Rate

During the analysis period a total of 96,965 boat days were recorded. A boat day consists of one boat on the water for an estimated 8 hours. Any boat on the water, regardless of trip duration, counts as one boat day. Passengers, or anglers on boats from Lee's Ferry are calculated by National Park Service standardized statistical methods developed for the Lee's Ferry area. Fisherman counts, for the study period, total 198,250. For purposes of comparison to U.S. Coast Guard statistics, fisherman and boat day counts were calculated and converted to "million passenger hours per year." Annual boat use and accident rates are provided in Tables 1, 2, and 3.

Table 1. TOTAL PASSENGER HOURS BY YEAR FOR THE PERIOD 1977 - 1984

| 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | Total |
|---|---|---|---|---|---|---|---|---|
| 49598 | 72662 | 142034 | 98049 | 250196 | 474385 | 271944 | 227131 | 1,535,998 |

Total passenger hours were converted to million passenger hours and presented by accident type in Table 2. The result for accidents which had $100 or more damage for the eight year period indicates a reported accident rate of 17.7 per million passenger hours. In 1978 the Coast Guard changed their qualifying requirements for reporting accidents to damage of $200 and greater.

Table 2. ACCIDENT RATES (Per Million Passenger Hours): 1977 - 1984

| | YEAR | | | | | | | Overall |
|---|---|---|---|---|---|---|---|---|
| TYPE | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | Rate |
| Grounding | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.1 | 0.0 | 4.4 | 1.3 |
| Capsizing | 0.0 | 27.5 | 14.1 | 0.0 | 4.0 | 10.5 | 0.0 | 8.8 | 8.2 |
| Flooding | 0.0 | 13.8 | 14.1 | 10.2 | 0.0 | 2.1 | 7.4 | 8.8 | 5.7 |
| Collision | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.1 | 0.0 | 0.0 | 1.3 |
| Sweptaway | 0.0 | 0.0 | 7.0 | 0.0 | 0.0 | 2.1 | 0.0 | 0.0 | 1.3 |
| Overall Rate | 0.0 | 41.3 | 35.2 | 10.2 | 4.0 | 19.0 | 11.0 | 26.4 | 17.7 |

The U.S. Coast Guard statistics stratify accident rates by boat type. No accurate record of boat days by boat type used on the Colorado River out of Lee's Ferry is maintained by the National Park Service. However, interviews of Lee's Ferry district rangers indicated the following distribution of boat types:

1. Open lightweight with motor.
2. Non-bowrider runabout.
3. Bow-rider runabout.
4. Johnboat.
5. Inflatible with motor.
6. Pontoon.
7. Canoe with motor.

Vessel types 1 through 4 were estimated to comprise approximately 90 percent of total boat use between Glen Canyon Dam and Lee's Ferry. This is further confirmed by the accident reports which indicate that runabouts, open motorboats, and fishing boats combined represent 91 percent of the accidents while canoes and inflatables represent 8 percent of the total. Reports of accidents by boat size indicate that 89 percent of boats involved are 18 feet or less.

The most recent statistics available from the Coast Guard revealed the first four boat types, when combined, produced an accident rate of 1.27 accidents per million passenger hours. When compared to the Lees Ferry boating accidents it appears that Lees Ferry has an accident rate almost 14 times the national average. However, Coast Guard figures represent reported accidents only. The Coast Guard (Traub, personal communication) estimates the reporting rate of non-fatality accidents to be only 5 to 10 percent. The National Park Service estimates a reporting rate of 90 percent for accidents under the U.S.

Coast Guard criteria and 5 to 10 percent for minor incidents. Assuming this to be the case then the adjusted national figures give a rate of from 25.4 to 12.7 per million passenger hours. The Lees Ferry accident rate of 17.7 is more in line with this adjusted national average. Use of a $200 minimum damage amount would further reduce the Lees Ferry rate closer to that of the Coast Guard.

## Types of Accidents

Table 3 figures represent the number of reported accidents over the eight year period by accident type with damage of $100 or greater. The damage figure was used as a cut off to coincide with Coast Guard statistics. Capsizing and flooding are the two most common types of accident accounting for 46 percent (n=13) and 32 percent (n=9) of all accident types with damage equal to $100 or more (n=28). The most common accidents reported to the Coast Guard is collision with another vehicle.

Table 1. ACCIDENT TYPE (Damage $100 or Greater): 1977 - 1984.

| | YEAR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| TYPE | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | Total |
| Grounding | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 2 |
| Capsizing | 0 | 2 | 2 | 0 | 1 | 5 | 1 | 2 | 13 |
| Flooding | 0 | 1 | 2 | 1 | 0 | 1 | 2 | 2 | 9 |
| Collision | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 2 |
| Sweptaway | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 2 |
| Total | 0 | 3 | 5 | 1 | 1 | 9 | 3 | 6 | 28 |

If all reported accidents are calculated the order remains the same but the percentages decrease slightly to capsizing 35 percent (n=22) and flooding 26 percent (n=16). Table 4 represents frequency by accident type for all accidents reported during the study period.

Table 4. FREQUENCY OF ALL REPORTED ACCIDENTS BY ACCIDENT TYPE

| TYPE | n | percent |
|---|---|---|
| Grounding | 10 | 16 |
| Capsized | 22 | 35 |
| Flooding | 16 | 26 |
| Collision | 2 | 3 |
| Sweptaway | 12 | 19 |
| Total | 62 | 100 |

Four of the five types of accidents may be associated with flows. Grounding can be associated with fluctuating flows and the shallow gravel bars common on this stretch of the river. With low flows even small boats must stay in the channel. If the water level decreases

while a boat is on the river a course which was adequate going upstream may be too shallow for navigation. The category labeled sweptaway could be two different types of incidents. Either a boat was beached and floated away as the river rose or there was a loss of power and the boat floated past the launch ramp at Lees Ferry into the riffles below. At least two fatalities in one accident may be attributed to the latter. Capsizing and flooding are frequently related to the same cause. Fishermen frequently fish the area by drifting with the current. In order to slow themselves down they drag an anchor. If located off the stern of a small boat the swift current or an increasing flow could pull the stern down flooding the boat and then capsizing it. Flooding is also caused when a boat is beached or moored tightly. When the water rises as a result of a fluctuating flow there is not enough line for the boat to float free and the boat floods. Collision with other boats has not been associated with flow and is an infrequent occurrence with only two cases in 8 years.

## Accident Locations

The most frequently reported accident location is the Lees Ferry launch ramp. Paria Rapid, Three-Mile Bar, and Nine-Mile Bar are the next most common locations of reported accidents respectively. Why the Lees Ferry launch ramp is the most frequent location may be explained because it is the location where reports are most often taken and it is easier to use that location, especially if the reporting party is unfamiliar with the river. The other locations appear to cluster around the gravel bars common in this stretch of the river. This is especially true if river miles are clustered to represent map error with the zero mile movement on local maps and boater familiarity with the area. Table 5 is a summary of reported accident locations.

Table 5. SUMMARY OF REPORTED ACCIDENT LOCATIONS

| Location | n | Percent |
|---|---|---|
| Paria Rapid | 8 | 14 |
| Lees Ferry Launch Ramp | 12 | 21 |
| River Mile 1-2 | 5 | 9 |
| 3-Mile Bar | 11 | 20 |
| River Mile 6-7 | 2 | 4 |
| 9-Mile Bar | 10 | 18 |
| River Mile 11-14 | 3 | 5 |
| Glen Canyon Dam | 5 | 9 |
| | -- | --- |
| Totals | 56 | 100 |

## Factors Relating to the Incidence of Boat Accidents

The investigating officer or those involved reported on their determination of what caused the accident in all of the reports. There may be more than one cause reported for a particular accident.

There were seven general categories of accident causes cited in the reports as the cause of the accident. These are loading, boat operation, equipment failure, wind, flooding, rapids/rocks, and river flow fluctuations. Loading was cited in 8 percent (n=5) of the cases and could be overloading, weight distribution or passenger movement. Boat operation could be speed, time and attention of the operator, high speed turns and collisions and represented 24 percent (n=16) of the cases. Flooding or taking water over the sides was reported in 14 percent (n=9) of the cases. River fluctuations were cited in 23 percent (n=15) of the cases. Flooding and fluctuations are the only two reported causes that can be related to river flows. However combined they represent over one third (37 percent) of the reported accident causes. Table 6 summarizes the reported cause of accidents.

Table 6. REPORTED CAUSE OF ACCIDENTS

| | n | Percent |
|---|---|---|
| Loading | 5 | 8 |
| Boat Operation | 16 | 24 |
| Equipment Failure | 11 | 17 |
| Rapids/Rocks | 5 | 8 |
| Wind | 4 | 6 |
| Flooding | 9 | 14 |
| Fluctuating Flows | 15 | 23 |

Boat operation at the time of the accident is also a separate category in the National Park Service boating accident report form. A summary of that data is presented here. Table 7 represents the frequency of boat operation at the time of the accident.

Table 7. BOAT OPERATION AT THE TIME OF THE ACCIDENT

| Operation Type | n | Percent |
|---|---|---|
| Cruising | 15 | 33 |
| Drifting | 9 | 20 |
| Dragging Anchor | 6 | 13 |
| Beached (tied) | 7 | 15 |
| Beached (not tied) | 6 | 13 |
| Docked | 1 | 2 |
| Being Towed | 2 | 4 |
| Totals | 46 | 100 |

Several other indirect factors can cause an accident including water condition, weather, wind, darkness, and operator experience. In an evaluation of these factors wind, weather, darkness, and operator experience do not appear to be significant. The wind was reported as none or calm for 69 percent (n=20) of the accidents where wind condition was reported. It was clear or cloudy in 84 percent of the

accidents reporting weather conditions. Storms were reported in only three accidents during the study period. It was daylight at the time of 77 percent (n=43) of the accidents. Operator experience is evenly distributed from less than 20 hours experience to over 500 hours experience for the accidents where it is reported. Boat operation and water conditions did appear to have a relationship to accidents.

Water condition is reported as calm, choppy, rough, very rough and strong current. At Lees Ferry boating accidents tended to occur in very rough (14 percent) and strong current (43 percent) water conditions, although 37 percent occurred during calm water conditions. If rough, very rough and strong current are combined they represent 60 percent (n=21) of those accidents where water conditions were reported. Rough and very rough water conditions could be related to wind conditions. There were 6 accidents reporting these water conditions while the same number of accidents reported wind conditions of greater than 25 miles per hour. However, of those reports citing accident causes, winds were reported as the cause in only 6 percent of the cases (n=4). Strong current is most likely related to flow and may be related to the high incidence of accidents reported during high flows and to fluctuating flows. Table 8 indicates the reported water condition at the time of the accident.

Table 8. REPORTED WATER CONDITIONS

| | n | percent |
|---|---|---|
| Calm | 13 | 37 |
| Choppy | 1 | 3 |
| Rough | 1 | 3 |
| Very Rough | 5 | 14 |
| Strong Current | 15 | 43 |
| | 35 | 100 |

River Flows and Releases from Glen Canyon Dam

When comparing accidents to flows a pattern similar to the one found by Underhill emerged. Using the same flow ranges, a disproportionate number of accidents appeared in the high flow range of 16,000-31,500 cfs with 57 percent (n=32) of all reported accidents in this range. The low range, 0-9,000 cfs, and the medium range, 9,000-16,000 cfs, were more evenly divided with 18 percent (n=10) and 23 percent (n=13), respectively. The very high range of all flows greater than 31,500 cfs represented only two percent of the reported accidents.

When broken by flows in 2,000 cfs increments no discernible pattern emerges. However, 21 percent (n=12) of all accidents occur at 26,000 cfs. The reason for the extremely large number of accidents at this flow has not been determined. A more detailed statistical analysis

should be done to explore this anomaly.

Table 9. FLOWS AT THE TIME AND LOCATION OF ACCIDENTS

| Flow Range | n | Percent |
|---|---|---|
| 0-9,000 cfs | 10 | 18 |
| 9,000-16,000 cfs | 13 | 23 |
| 16,000-31,500 cfs | 32 | 57 |
| >31,500 cfs | 1 | 2 |
| Totals | 56 | 100 |

A change in flows 1 to 3 hours before the accident occurred in 70 percent of all the cases. When considering the entire 4 hour period before all the accidents, 27 percent experienced no change in flows while 56 percent experienced an increase in flows and 17 percent experienced a decrease in flows. These percentages generally stay constant for each hour of the fours hours pervious to the reported accidents.

The change in flows for each hour ranges from a maximum decrease of 3,255 cfs to a maximum increase of 8,446 cfs over the four hour period. One hour before the accidents 25 percent experienced a 1,000 cfs increase in flows, 20 percent experienced a 2,000 cfs increase in flows, 7 percent experienced a 3-4,000 cfs increase in flows and one accident experienced a 7,000 cfs increase in flows. Conversely for the hour before the accident 11 percent had a 1000 cfs decrease in flows and 4 percent had a 2-3,000 cfs decrease in flows. These percentages stayed approximately the same for each of the four hours before the accidents.

Two hours before the accidents 29 percent experienced a 1000 cfs increase in flows, 5 percent had a 2,000 cfs increase, 4 percent had a 3-4,000 cfs increase and 9 percent had a 5-7,000 cfs increase. Moving out to three and four hours before the accidents the increase in flows moves toward the greater ranges. At three and four hours before the accident there is a 4-9000 cfs increase in 14 percent of the cases, for each hour, respectively.

Table 10. THE CFS CHANGE IN FLOW BY HOUR BEFORE REPORTED ACCIDENTS BY NUMBER OF ACCIDENTS

| CFS Change in Flows | Hours before an Accident -1 Hr | -2 Hr | -3 Hr | -4 Hr |
|---|---|---|---|---|
| -3000 | 1 | 0 | 0 | 1 |
| -2000 | 1 | 2 | 4 | 2 |
| -1000 | 6 | 12 | 4 | 5 |
| 0 | 17 | 16 | 17 | 11 |
| +1000 | 14 | 16 | 10 | 14 |
| +2000 | 11 | 3 | 7 | 10 |
| +3000 | 3 | 1 | 6 | 5 |
| +4000 | 1 | 1 | 3 | 1 |
| +5000 | 0 | 3 | 2 | 3 |
| +6000 | 0 | 1 | 1 | 1 |
| +7000 | 2 | 1 | 1 | 1 |
| +8000 | 0 | 0 | 0 | 1 |
| +9000 | 0 | 0 | 1 | 1 |

## D I S C U S S I O N

The accident rate for Lees Ferry appears to be comparable to the national average and does not appear to be skewed by the river flows. The most frequent type of accident appears to involve minor propeller damage as a result of hitting a gravel bar in the morning during a period of fluctuating flows and has an average damage loss of 86 dollars and is not reported. Approximately 5 percent of all accidents are reported to the National Park Service. Of those reported the most common accident appears to be a capsizing of a 12-14 foot fishing boat which is cruising in strong current on a clear day with little to no wind and is being operated by a person with 21-500 hours of boating experience.

The accident survey covered periods of both high steady flows and low fluctuating flows. Accidents reported during the survey were more frequent during the fluctuating, low flow period. The data was not available to determine if these incidents were the result of fluctuating flows, low flows, or a combination of both. Boaters experiencing a period of low fluctuating flows after a long period of high steady flows may also have had an effect on the data. Again it is not possible with the existing database to determine if this had an effect or the magnitude of the effect.

Accidents reported during the survey were primarily low cost and involved primarily property damage with an average loss of $86. None

of these accidents were reported to the National Park Service for inclusion in the accident reporting system. Only two accidents were reported to the National Park Service on the data collection days. Only one of these was flow related and occured during the high flow period. This data appears to confirm the belief of National Park Service Rangers that primarily they hear about or become involved in only the most serious or life threatening accidents.

## CONCLUSIONS AND RECOMMENDATIONS

It is unfortunate that a more thorough statistical analysis could not be completed. As a result no statistical significance could be used to determine a cause and effect relationship, if any, between flows or change in flows and boating accidents. The low number of accidents identified in both the survey and the accident report analysis also makes drawing conclusions difficult.

The survey identified a high number of minor property damage accidents which occurred during predominately low, fluctuating flows and at known gravel bars in the river. Operator experience with and forewarning of these conditions is unknown. The accident reports covered the more serious property damage and injury involved incidents. Underhill found a significant number of accidents ocurring at high flows. The longer term data of this study seemed to support that finding. In addition, changes in flow and/or boat operation at the time of the accident appeared in a large number of cases. The total flow regime and the number of boaters exposed to that regime need to be determined. Large fluctuations in flows appeared more important than previously thought. What sort of boater education might be needed? Is an information system providing boaters with the expected flows reduce accidents.

A trend was visible in the data which allows us to ask more pointed questions than before. These questions should be studied further in a long term survey covering all flow regimes and all seasons of recreational use. Accident reports alone cannot show the whole picture. If at all possible a more thorough study should be undertaken to address these important issues.

## REFERENCES

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A C K N O W L E D G E M E N T S

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