Changes to Grand Canyon Camping Beaches, Year 2000: Annual Report of Repeat Photography by Grand Canyon River Guides, Inc. (Adopt-a-Beach Program)

by

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Executive Summary

The Adopt-a-Beach (AAB) program has completed its fifth year as a study that monitors annual camping beaches in Grand Canyon. This program, sponsored by Grand Canyon River Guides, Inc., is implemented by a 100% volunteer force of river guides, scientists, and NPS personnel. Results are submitted to various agencies such as the Cultural Resources Program of the Grand Canyon Monitoring and Research Center (GCMRC). Furthermore, results are presented to the Adaptive Management Program so that private and commercial recreational interests are represented as stakeholders in Colorado River management as reported to the Secretary of the Interior.

Adopt-a-Beach is a program of repeat photography that documents the condition of a selected set of Grand Canyon camping beaches from April through October of each year. The program assesses visible change to beaches resulting from changing regulated-flow regimes, rainfall, wind, and human impacts. Volunteers for this program are unique in that they run the Colorado River many times in one season, and they are able to provide sets of repeat photographs for each study beach. To date, guides have produced over 1500 repeat photographs and associated field sheets having recorded the sequential condition of beaches throughout the commercial boating season, year after year. Research results include total change to beaches after being impacted by certain flow regimes, longevity of the 1996 beach/habitat building flow (BHBF) deposits, change to individual beaches between monitoring seasons, and primary and secondary processes that cause a decrease in camping beach area.

Flood experiments were conducted during spring, summer, and fall of 2000. Habitat maintenance flows (HMF) of 30,000 cfs were released for 4 days in early May and again in early September. The intervening period was subjected to moderately high fluctuating flows of 16,000-18,000 cfs throughout May, followed by low steady summer flows (LSSF) of 8000 cfs until early September.

The spring HMF showed that 63% of studied beaches (n = 32) gained area within the 20,000 to 30,000 cfs zone. Most of the changes, determined from photographs, resulted in extension of beachfront area toward the river. About half of the beaches showed a small increase in elevation of about 0.10 meters (as estimated from reference points in photos). The rest of beaches remained the same size and only one beach, Stone Creek, decreased in area. The highest percent of increases (87%) appeared in the Marble Canyon reach (n = 8), although the other reaches showed increases of 50% and 65%, respectively. Many guides reported that their adopted beaches gained new sand primarily below the 20,000 cfs line. Morphological changes resulted in new low-elevation benches and sand bars that covered pre-existing gravel-and-boulder bars.

The fall HMF did not show as much gain above 20,000 cfs compared to the spring HMF. Fifty-five percent of beaches (n = 20) gained campsite area. Mostly, beach areas increased if they had been eroded by the high fluctuating flows, a 31/2-week duration, immediately following the spring HMF, or if recent rainfall from the monsoon season caused flash flooding and gully cutting. Beaches not affected by these factors showed very little change in beach area after the fall HMF. In assessing cumulative changes from both HMFs, Muav Gorge showed the highest percentage of increases.

Observations from the 2000 summer season show an overall increase in beach size from the previous years of 1997-1999 but a substantial decrease from the BHBF deposit of 1996. This result implies that the spike flow conditions help to maintain an acceptable beach size for camping when low steady flows or low fluctuating flows are imposed. However, they are inadequate for maintaining overall beach elevation above the 30,000 cfs line.

The longevity of the BHBF deposit since 1996 shows varying results. As of Fall 1999, 59% of camps had returned to their pre-BHBF condition (O'Brien and others 2000). Results of the 2000 HMF flows showed that 78% of beaches were again larger than their pre-BHBF condition, within the 20,000 to 30,000 cfs zone. Campsite areas within the 30,000 and 45,000 cfs zone have continued to decrease, overall. A few sites have apparently developed more stable deposits within this zone, as they show no to very little change.

The Low Steady Summer Flows (LSSF) provided more diverse camping, both upstream and downstream of campsites within the study set, and within the campsite itself, according to guide response for 31 beaches. The combination of the HMF followed by the LSSF proved beneficial to 78% of all studied beaches.

These results contrast with those of the 1999 river season, during which a high percentage of beaches lost area due to flash floods, and a small percentage were affected by fluctuating flows. Before 1999, beaches have been eroding at a decreasing rate, mostly from fluctuating flows, as reported by guides and supported by visual cutbank retreat in photographs (O'Brien and others 2000). Typically, rapid adjustment of newly aggraded beaches to fluctuating flows following a high release leads to initial high rates of erosion. These rates then fall off over time (Hazel and others 2001). According to many guide remarks, campsite beaches were "primed and ready" for the HMF and LSSF regime of 2000.

These results suggest that any newly deposited sand will be quickly eroded if subsequent high fluctuating flows are released from Glen Canyon Dam. This was evidenced by the fall HMF of 1997. Over the winter, high flows stripped away the new deposit and any benefit to improved camping by spring 1998 went largely unseen by river guides and recreationalists. To date, 80% of beaches show some evidence of high-elevation sand deposited by the 1996 BHBF. However, the amount of sand appears to be diminishing from year to year. Annual implementation of HMFs in spring and in fall would help preserve this deposit by maintaining the beachfront. Beach habitat building flows are needed periodically to rebuild campsite areas above the 30,000 cfs line.

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INTRODUCTION

Adopt-a-Beach (AAB) is a program of repeat photography conducted through volunteer efforts and implemented by Grand Canyon River Guides, Inc. (GCRG). This nonprofit, grassroots organization represents the interests of the Grand Canyon river running community. River guides (including commercial, private, and scientific groups), who work throughout the summer months on the Colorado River, are interested in how controlled-flow releases from Glen Canyon Dam affect beaches that are used for campsites. Furthermore, factors other than controlled flows that might be affecting campsite change are addressed in this study. Throughout the continued period of this program, 1996-2000, guides have observed changes to beaches and have recorded this information through repeat photography and written comments associated with each photograph.

In 1981, the Glen Canyon Environmental Studies (GCES) began under the administration of the Bureau of Reclamation to study the effects of controlled flow releases from the dam on the downstream river ecosystem (U.S. Department of Interior 1987), including effects on sediment supply and recreational resources. Studies of sediment dynamics showed that fluctuating flow releases from the dam have had a degrading effect on sand bar deposits (Hazel and others 1993, Schmidt and Graf 1990) since the closure of the dam. However, beaches can also be replenished by high flows adequate to entrain bedload sand and cause deposition to high elevation areas of beaches (Parnell and others 1997, Wiele and others 1995). Studies of campsite resources demonstrated that impact to sand bars due to erosion decreases the carrying capacity and campable area available for river parties and backpackers (Kearsley and Warren 1993, Kearsley and Quartaroli 1997).

In 1992, the Grand Canyon Protection Act was passed by Congress to ensure that ecological and cultural resources downstream of the dam would be monitored for changing conditions imposed by operations of the dam. The October, 1996 Record of Decision for operation of the dam states that the dam:

> "….must be managed in such a way as to protect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park….were established, including, but not limited to, natural and cultural resources and visitor use"(U.S. Department of Interior 1996).

The Grand Canyon Dam Environmental Impact Statement recommends that scheduled, high-flow releases of short duration be periodically implemented (U.S. Department of Interior 1995). Sand bars form when sediment carried by the river, either from bed load or suspended load, is deposited by the action of eddy currents in recirculation zones. This occurs primarily on the downstream end of debris fans, but also in areas along the river's channel margin (Schmidt 1990). Habitat maintenance flows (HMF) are within powerplant capacity (31,500 cfs), whereas those above this discharge are beach/habitat building flows (BHBF). The former were intended to maintain existing camping beaches and wildlife habitat; the latter to more extensively modify and create sand bars, thus restoring some of the dynamics that resulted from flooding in the ecosystem.

Inception of Adopt-a-Beach was a result of the first scheduled BHBF of 45,000 cfs scheduled for Spring, 1996. Specifically, the AAB program was launched by GCRG to document the effects of the high flow on camping beaches. Guides photographed beaches and recorded information about changing conditions prior to the high flow, just after the high flow, and throughout the 1996 commercial river season. The overall conclusion of that study demonstrated that the BHBF was highly effective in depositing new high-elevation sand, but that the post-BHBF high steady summer flow schedules caused rampant erosion of sand bars (Thompson and others 1997).

Camping beaches are an important resource for river guides conducting trips through Grand Canyon. Both commercial and private river trips, as well as backpackers, rely on wide sandy areas for camping and recreating. As a way to contribute to resource management, AAB now submits annual results to the Adaptive Management Program. The results and conclusions are synthesized through a representative that serves on Technical Work Group (TWG) board. River guides make the program possible, contributing 100% of the manpower, the entire data set of repeat photographs, and valuable input about the condition of beaches throughout each season and between years. Monitoring includes information on natural and human-induced impacts to beaches such as cutbank retreat, wind erosion and dune formation, rain gully formation and the effects of visitation and camping. The purpose of this report is to present the findings of the 2000 data collection effort, and to document the qualitative evidence of continued, first-hand observations by professional river guides. This study also furthers the effort to report cumulative observations of beach conditions pertinent to the monitoring years from 1996 through 2000.

The river season of 2000 was unique in that a low steady summer flow (LSSF) of 8,000 cfs surrounded by two HMFs of 30,000 cfs were implemented from early May through late September. Therefore, specific research questions put forth by GCMRC and concerned guides and scientists are as follows:

- Do small spike flows help maintain beaches and campable area?
- Do low steady summer flows (LSSF) provide better camping for river parties?
- What are the main processes causing decreased beach size throughout the summer?
- Is the 1996 flood deposit of 45,000 cfs still present and how has it changed on beaches over time?
- Based on these results, what does the AAB program conclude about future resource management of campsite beaches?

Through analysis of photos and data sheets completed by guides, this report attempts to answer these and other research questions.

METHODS

Data Collection

The primary method of assessing camping beaches in this study is through analysis of repeat photography. During the summer months (April 1-October 31) volunteers (river guides, scientists, GCNP personnel) photograph a specific "adopted" beach every time they pass through the river corridor. Disposable waterproof cameras and data sheets, provided by GCRG, are distributed to all adopters of beaches. At the end of the commercial season (October), guides mail cameras and data sheets back to GCRG for analysis. A qualified scientist, who is active in Grand Canyon issues and is very familiar with AAB study sites, is contracted from year to year to analyze photographs and data, draw up results and offer conclusions to resource managers concerned with recreational and cultural interests in Grand Canyon.

This project allows each participant to take stewardship of a site, and enables him or her to detect ongoing changes over the course of a season. During each visit, guides photograph their adopted beach from pre-established photo locations that provide different views of the beach: specifically, the beachfront, and an overview of the camp where the topography allows. In sites where overviews are impossible, a photo location is selected to reveal as much of the camp as possible. In the last 5 years, however, thick tamarisk encroachment has led to recent re-establishment of many photo locations. Re-establishment of photo locations will be on-going as needed, in order to obtain the necessary photo angles.

A data sheet (Appendix A) accompanying each photographed visit addresses changes to the condition of the beach and the possible causes of changes that are visible. Also included are site location, date, time, and approximate river flow. Photographed visits for each beach average 4 per season. The number of visits for each beach can range from one (in which case the data cannot be used) to eight. Many guides take the initiative to photograph different angles of episodic events such as debris flow or flash flooding. Such photos can be highly beneficial to researchers concerned with various resources impacted by episodic events at a particular site.

The photographs for all beaches are carefully labeled and are presently being archived onto compact discs. Information gleaned from photographs and from data sheets are entered into a master database using Access 2000. A crosscheck of the two different sources of information help to fill gaps in data and help to standardize changes from one visit to the next. For instance, if the guide comments do not provide enough information about the site at the time a photograph was taken, the photo is used to assess the site for that visit. If the photo shows very little or no change in the appearance of the beachfront but the guide's data sheet provides enough descriptive information about conditions throughout the site, the comments receive priority. The current Access database contains over 800 records of assessed changes and guide comments for the monitoring years 1996-2000.

Study Locations

Since 1996 the AAB program has studied 43 beaches from within three *critical reaches* of the river corridor (Figure 1). The practice of assessing camping beach resources within critical reaches was first developed by Kearsley and Warren (1993), and modified for the 1996 Adopt-a-Beach study by Thompson and others (1996). A critical reach is defined as a section of the river where camps are in high demand and few in number. The same reach system has been in use for all years of study, 1996-2000: They are as follows: 1) Marble Canyon, river miles 9-41; 2) Upper Gorge, river miles 71-114; and 3) Muav Gorge, river miles 131-165.

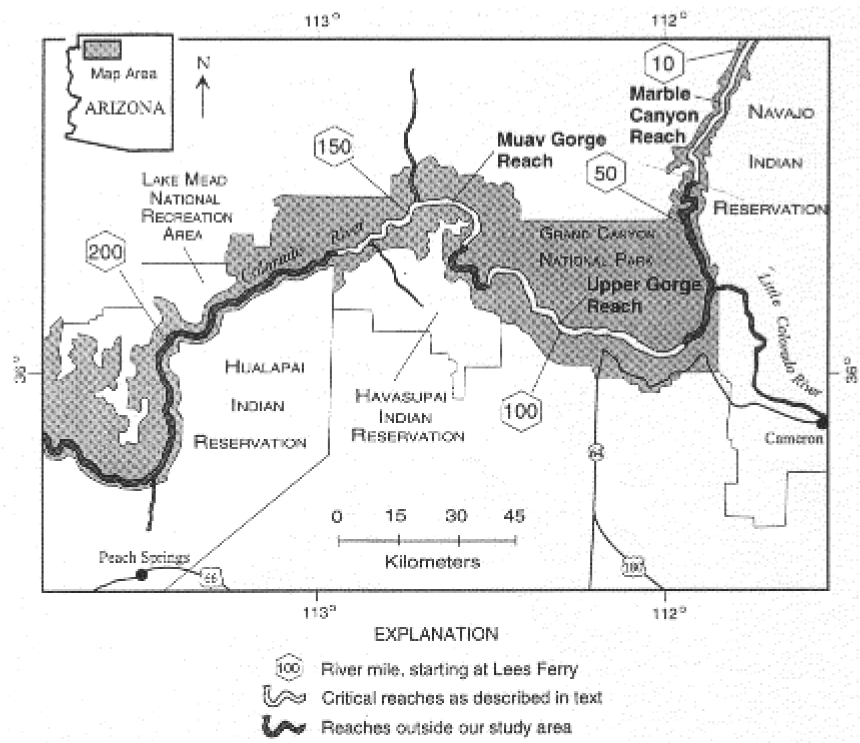

***Figure 1**. Locations of the three critical reaches in Grand Canyon National Park (after Thompson and others 1997). Each reach contains a sample set of between 12 – 16 beaches.*

Table 1 shows all popular campsites (n = 43), inventoried in 1996, within the three critical reaches. Every beach in the inventory has an established photographic location that shows an optimum view of the beachfront and as much of the actual camping area as possible. Each year, GCRG motivates the collective populus of guides to adopt as many beaches as possible. To encourage a relatively compete data set from year to year, GCRG encourages adoption of high-priority beaches (n = 27) first. These beaches have been adopted for most of the study years. Usually, they are camps that can be used year after year, and thus are continually in high demand. The remaining beaches are adopted once high-priority beaches have been claimed. Beaches that have only been adopted once throughout the period of study have been given lowest priority for continued study.

The time-series photos taken within study locations allow assessment of relative change over the course of each season and between monitoring years. Assessment is standardized according to the average fluctuating flow zone of 20,000 cfs (determined by Kaplinski and others 1994). From year to year GCRG assesses change to beach area and shape above the 20,000 cfs zone up to the 45,000 cfs zone, the level of the 1996 BHBF. Should any flows exceed 45,000 cfs in the future, GCRG would analyze beach change up to the height of the new deposit or scour line. The 2000 LSSF flow of 8,000 cfs allowed for consistent analysis of change to low-elevation bars (below the 20,000 cfs line) from early June to early September. Likewise, if higher or lower steady summer flows were imposed in the future, the area of analysis would shift accordingly.

Table 1. *Original beaches inventoried in 1996 that lie within the three critical reaches. Beaches adopted in 2000 are bolded (n = 34).*

Marble Canyon		**Upper Gorge**		**Muav Gorge**	
Mile	**Camp**	**Mile**	**Camp**	**Mile**	**Camp**
8.0	Badger	**76.6**	**Hance**	**131.1**	**Below Bedrock**
12.2	**Salt Wash**	84.0	Clear Creek	**132.0**	**Stone Creek**
19.1	**19 Mile**	**84.5**	**Above Zoroaster**	**133.0**	**Talking Heads**
19.9	20 Mile	**91.6**	**Trinity**	**133.5**	**Race track**
20.4	**North Cyn**	92.2	Salt Creek	133.6	Tapeats
23.0	**23 mile**	**96.1**	**Schist Camp**	133.7	Lower Tapeats
29.3	Silver Grotto	**96.7**	**Boucher**	**134.6**	**Owl eyes**
34.7	**Nautiloid (Upper)**	**98.0**	**Crystal**	**137.0**	**Backeddy**
34.8	**Nautiloid (Lower)**	**99.7**	**Lower Tuna**	**143.2**	**Kanab**
37.7	**Tatahatso**	102.7	Shady Grove	**145.6**	**Olo**
38.3	**Bishop**	**107.8**	**Ross Wheeler**	**148.5**	**Matkat Hotel**
41.0	**Buck Farm**	**108.3**	**Bass**	**155.7**	**Last Chance**
75.6	**Below Nevils**	**109.4**	**110 Mile**	**164.5**	**Tuckup**
		114.3	Upper Garnet	**166.4**	**Upper National**
		114.5	**Lower Garnet**	**166.6**	**Lower National**

Data were grouped according to: (1) river season, beginning on April 1st and ending October 31st; and (2) winter season, the intervening period that begins November 1st, 1999 and ends March 31st, 2000. Trends of change were analyzed in previous years of 1996-1999. Data were also categorized according to critical reach in order to rank which reaches show more change over time. Finally, guide comments about the changing quality of campsites are summarized into a rudimentary camp quality index. Although this index is in its developmental stage, it assesses changes of vegetation encroachment, boat parking, steepness of slope for camp access, and rockiness. This index will be more detailed for river season 2001, as newly designed data sheets were distributed at the beginning of the season (Appendix B).

Relative changes as seen either in the photos or written on field data sheets were categorized according to increase, decrease, or no change with respect to the previous visit. Changes pertain to the whole beach as delimited in the photo frame, using individual physiologic features of that beach as references for comparison. Individual factors (see Appendix A) affecting camp quality changes are recorded as: better, worse, or same.

For the river season of 2000, photos of beaches that immediately preceded and followed each HMF (Figure 2) were assessed for changes. During the LSSF changes were assessed separately. Since n values were different for each category, percent of beaches were calculated. Therefore, comparisons between time periods and between critical reaches could be standardized.

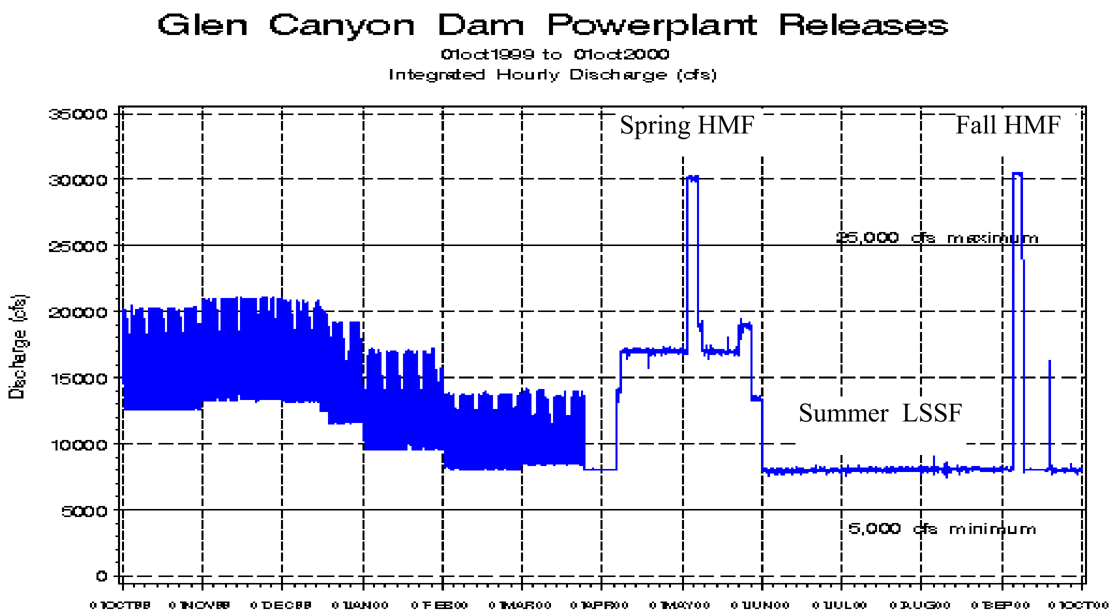

Figure 2. *Glen Canyon Dam releases for water year 2000 (October 1, 1999 – October 1, 2000). Graph shows the LSSF bracketed by the spring and fall HMFs.*

RESULTS

The number of adopted beaches with useable data totaled 34 out of the 36 beaches that were originally adopted for the river season of 2000. This number is much improved from 1999, during which 29 beaches were adopted. It is still greater from 1998, during which time only 21 beaches were adopted. The number of records entered in the database for the river season of 2000 totaled 164. Each record represents an individual visit to a beach and has 1-3 photos associated with it. As encouraged by other Grand Canyon researchers, several adopters took extra snapshots of various episodes such as flash flooding in Olo Camp and debris flows at Bass Camp. These are available to any interested researchers who wish to use the data.

Results of the Winter Season (November 1, 1999 to March 31, 2000).

In order to fill gaps between time periods of each river season, we assessed winter season change. The visible change to beaches is documented by comparing the last photo of the previous river season with the first photo taken the following spring. Processes, such as erosion from rainfall or fluctuating flow, are often visible in the first new photo of the river season. Otherwise, the category "Don't Know" is recorded.

Unlike previous years, data for the 1999-2000 winter season are incomplete as most guides had not taken photographs of their beaches prior to the spring HMF, initiated on May 3, 2000. Out of 11 beaches for which data was recorded, 3 showed a decrease, 2 showed an increase, and 7 showed no change (Figure 3).

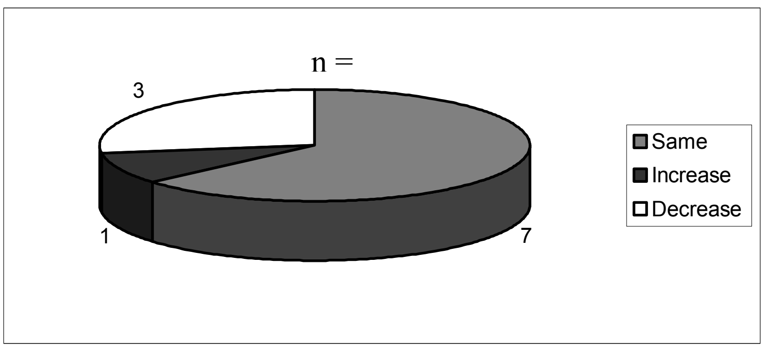

Figure 3*. Number of beaches showing change over the 1999-2000 winter season.*

All beaches but one show series of old cutbanks at the beachfronts in the early spring 2000 photos. These cutbanks are not apparent in the fall 1999 photos and implies that change to beach area is due to a changing flow regime. Figure 2 shows a dramatic increase in fluctuating flow in November and December 1999. Only 1 beach showed effects from rainfall, but its beach size remained the same.

Figure 4 compares percent of beaches that decreased, increased, or stayed the same for each of the study years during the winter period. The trend demonstrates that the percent of beaches decreasing in size from winter events, whether it be fluctuating flow or rainfall, is continually falling off until the spring HMF of year 2000. This declining rate of decrease exemplifies the initial rapid adjustment of newly aggraded bars to relatively normal dam releases following the 1996 BHBF. This data agrees with that of Hazel and others 2001, where sand bar thickness has been decreasing every year since 1996, but at a decreasing rate.

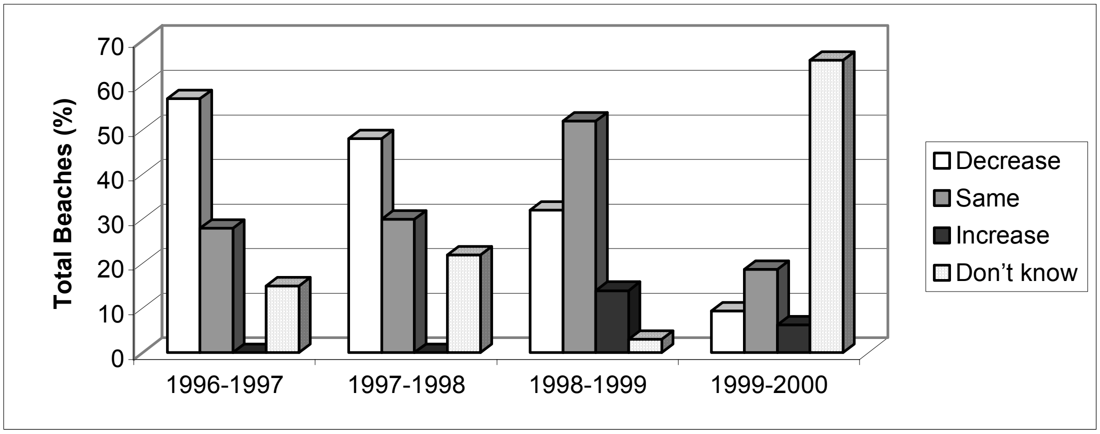

__Figure 4__. Comparison of change observed during winter seasons 1996-1997 through 1999-2000.

Results of the Habitat Maintenance Flows

Two spike flows of 30,000 cfs were released from Glen Canyon Dam for four days in early May 2000 and again in September 2000. These flows deposited sand on high elevation bars (above the average high flow zone of 20,000 cfs) for 65% of beaches after the spring HMF and 56% after the fall HMF (Figure 5). The spike flows primarily increased beachfront property and only increased beach elevation at most by approximately 0.1 meters on the higher elevation bar (above 20,000 cfs) up to the 30,000 cfs line. Boulders and tree stumps were used as references in photos in order to estimate beach elevation change. Only one beach, Stone Creek, lost sand from its high elevation bar due to any of the high flows. The rest of beaches showed negligible change.

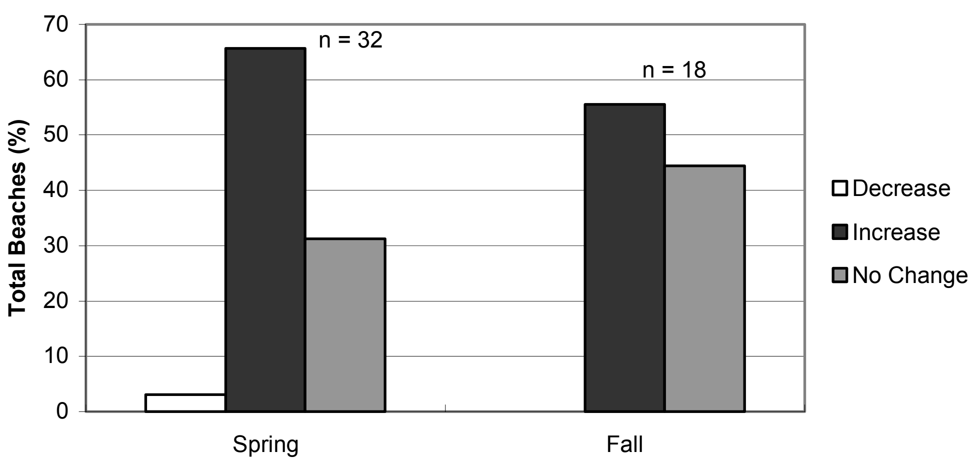

__Figure 5__. Number of beaches showing change due to the spring and fall HMFs.

The distribution of change to beaches within a reach is illustrated in Figure 6. After the spring HMF (Figure 6 (A)), all reaches showed a net increase in area, except for Upper Gorge, which showed an equal distribution between increase and no change.

Marble Canyon showed the greatest number of increases from the spring HMF, although it has the lowest n value.

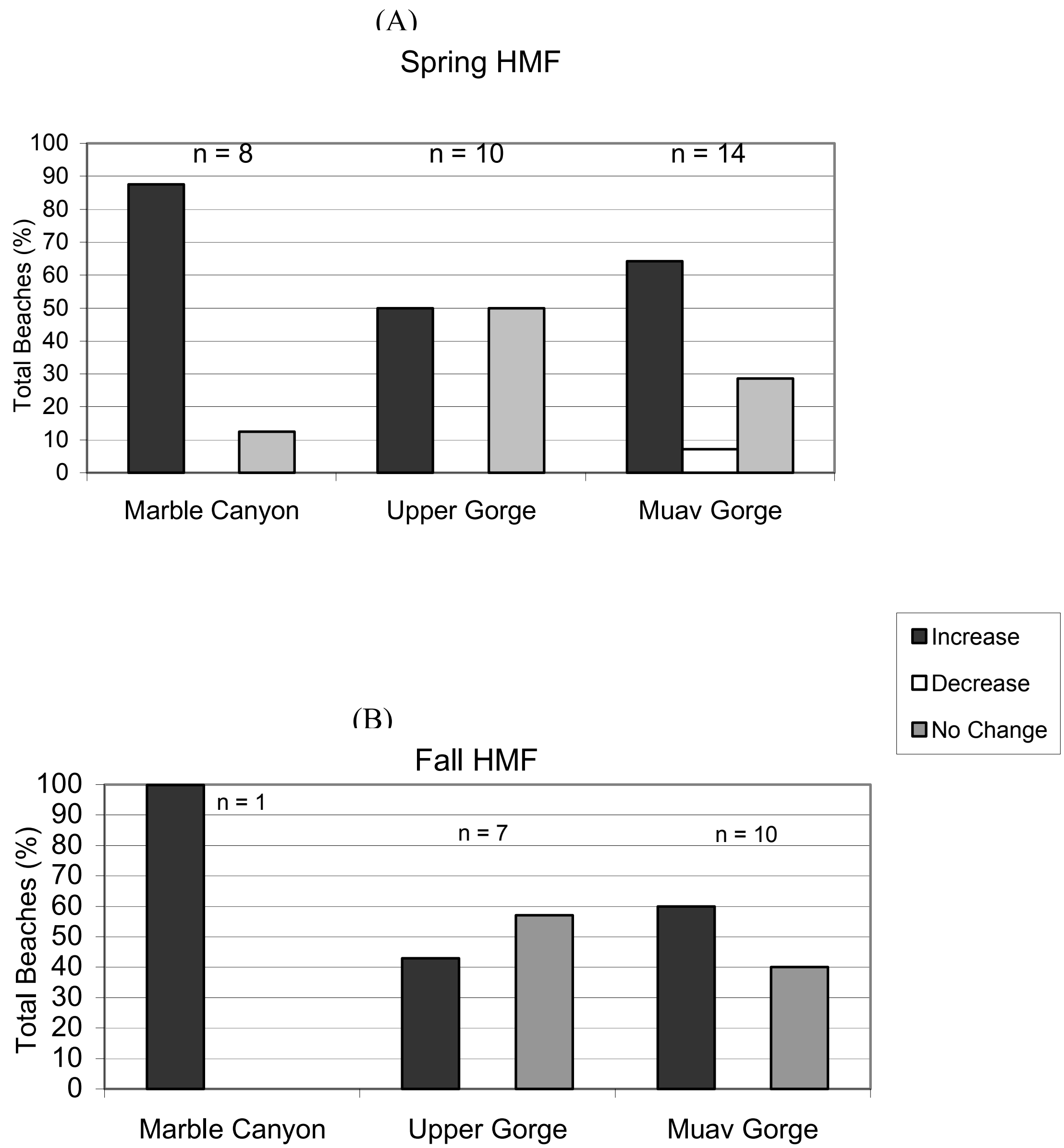

Figure 6. *Number of beaches per critical reach showing change due to: (A) the spring spike flow; and (B) the fall spike flow. Note that Marble Canyon only has 1 data point for the fall spike.*

The fall HMF showed a more equal distribution between increases and no change for two of the reaches (Figure 5 (B)). Results for Marble Canyon cannot be determined since data for only one beach was available. When the two HMFs are compared by reach (omitting Marble Canyon), Muav Gorge benefited overall. The net increases to Muav

Gorge beaches may be a result of greater sediment supply below the Little Colorado River and greater distance downstream of Glen Canyon Dam (Schmidt 1990; Schmidt and Graf 1990). Photos showing each of the HMF deposits were compared side by side for each beach. Individual beaches that benefited the most from the fall HMF were subjected to severe erosion at some point after the spring HMF and before the fall HMF. Size and shape of the beaches were largely the same for both periods immediately following the spikes, yet a large number of decreases were seen and reported throughout the summer. Therefore, sediment from the fall HMF simply infilled eroded areas of beaches, returning them to a configuration similar to those after the spring HMF.

Processes Causing Decreased Beach Size.

In order to determine primary causes of erosion, various processes causing beach change, whether erosional or depositional, were recorded via guide comments and analysis of photographs. Morphological characteristics were recorded as follows: 1) cutbank formation, newly exposed rocks, and bank retreat due to fluctuating flows or another flow regime; 2) bench formation, sand covering rocks, and extension of beach front due to fluctuating flows or another flow regime; 3) gully formation or new debris due to rain and side-canyon flash floods; 4) surface scour or mounded sand due to wind; and 5) change to beach-front slope due to visitation. One primary and one secondary cause were identified for each visit per site.

Figure 7 shows all identifiable processes that contribute to change on beaches. The only depositional processes were the HMFs, which impacted the largest number of beaches. Erosional processes were high fluctuating flows throughout the month of May and people using the beaches. Rain and wind were less significant. In isolating processes from reach to reach, impacts from fluctuating flows were most evident in Muav Gorge, while erosion from people was highest in Marble Canyon. This suggests that Marble Canyon beaches are subjected to the most visitation, as campsites are fewer than in other reaches. However, negative impacts would need to be assessed before management recommendations can be suggested for Marble Canyon beaches. Therefore, data sheets for year 2001 data collection have been redesigned to specifically address types of visitation impacts to campsites (Appendix B).

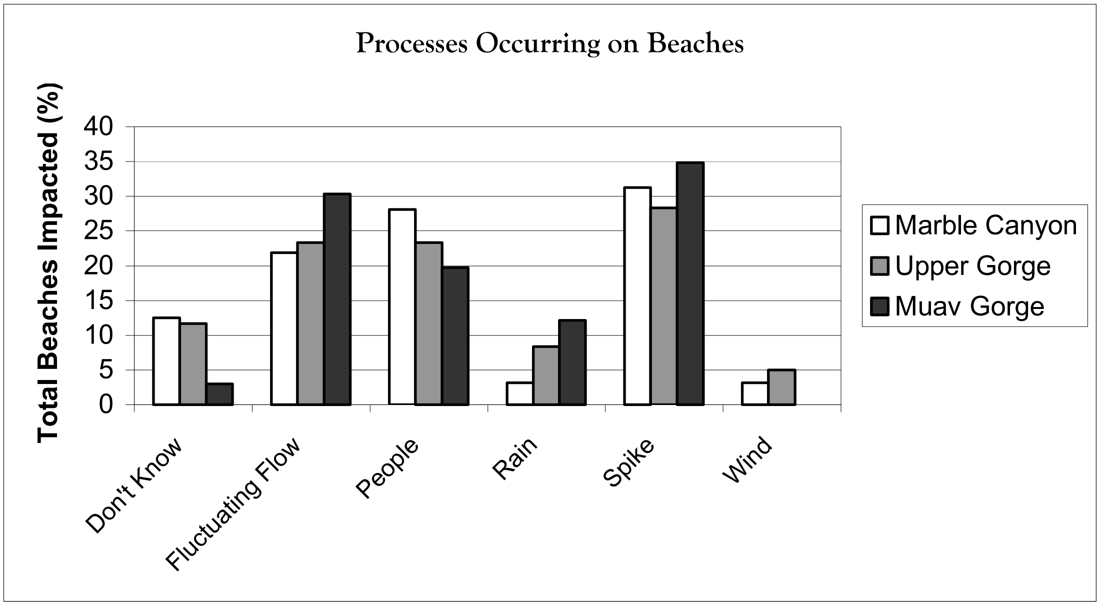

Figure 7. *Percent of beaches affected by various processes, analyzed by reach. All processes whether or not they caused net change in beach size are included here.*

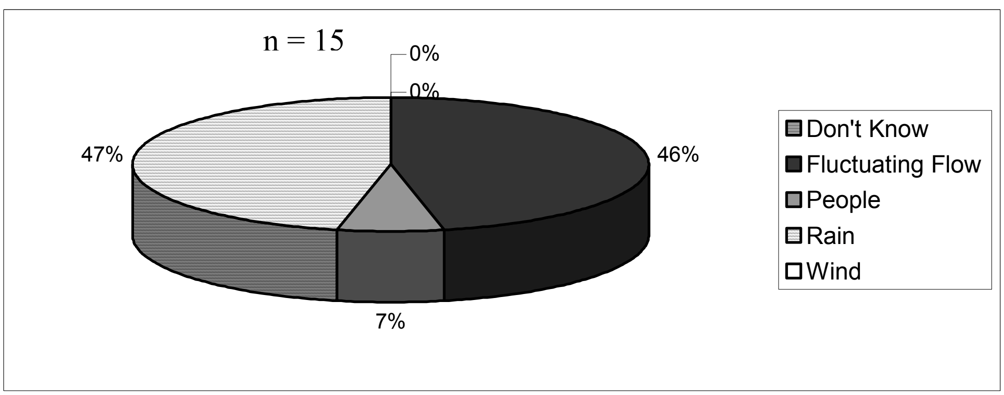

Figure 8*.* *Percent of beaches showing visible decreased area due to processes other than spike flows.*

Decreases to beach size (Figure 8) throughout the summer were mostly attributed to high fluctuating flows throughout the month of May and flash flooding from rain during the monsoon season. Beaches impacted by fluctuating flows showed progressive cutbank retreat throughout the month of May. Beaches impacted by rain showed loss in area via gully formation or gravel and rock influx. Decreases from visitation, primarily due to foot traffic up and down the beachfront, were not as common, although impacts are seen on most beaches.

Available Camping from the Low Steady Summer Flow

Low steady flows of about 8000 cfs lasted from June 1 to September 4. During this time, guides responded that many small new beaches, upstream and downstream of their adopted beach, became available for camping. Also, adopted beaches such as Clear Creek, Olo, and Talking Heads (all of which are mostly under water at higher flows), again became useable camps under the LSSF. Available campsite space and ease of using a beach for camping, a collective term referred to as "campability, " was assessed for change throughout the season. With the onset of the LSSF after the spring HMF (Figure 8(A)), 77% of beaches were either not affected or showed some kind of improved campability. These camps contained either more sandy beachfront property, decreased rockiness for better boat parking, or a relatively flat bench for kitchen set-up and camping. Guides found camping to be harder on 23% of beaches, where many

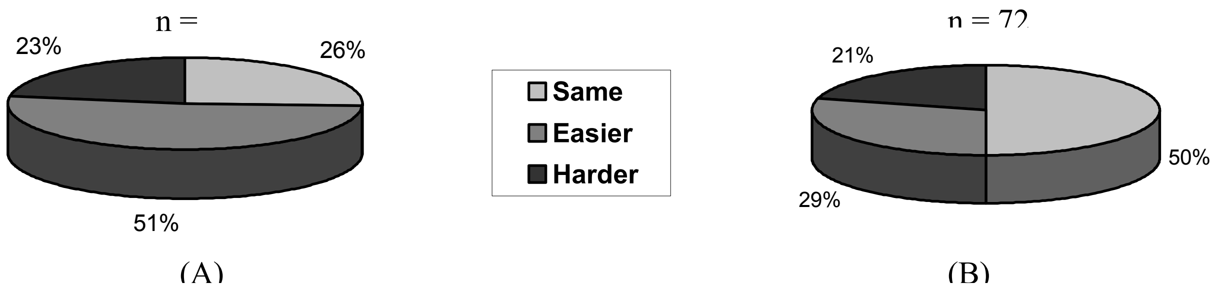

Figure 8. *Campability during the LSSF: (A) first response by guides with the onset of the LSSF; and (B) all response to campability through the duration of the LSSF.*

new rocks were exposed in boat parking areas, such as Tuckup and Lower Tuna, or beachfronts became overly steep, such as Lower National, Bass, Ross Wheeler, and Matkat Hotel. However, these camps were still used all throughout the season.

Campability throughout the full duration of the LSSF (Figure 2) is illustrated in Figure 8(B). Campability remained the same for 50% of beaches throughout this time period, and improved for 21% of beaches. Initially, many camps had overly steep beach fronts with the drop to the LSSF; yet throughout the summer, people trampled and stabilized slopes, making access to the main camp much easier.

Longevity of Beaches Since the 1996 Beach/Habitat Building Flow

Beach/Habitat Building Flows are of critical importance to maintaining campsite beaches in Grand Canyon. In 1996, Glen Canyon Dam released a flow of 45,000 cfs in order to suspend sediment stored in eddies, and deposit it to high elevation sand bars. This highly successful flood flow benefited a large majority of campsites in Grand Canyon (Kearsley and Quartaroli 1997; Thompson and others 1997). Therefore, the persistence of this deposit is of great interest to resource managers and users of these high elevation bars. Each year, end-of-season photos are compared to pre-BHBF photos (taken in March 1996) to determine if any sites have returned to their original pre-flood condition. In some cases sites appear to have lost more area than the pre-flood condition.

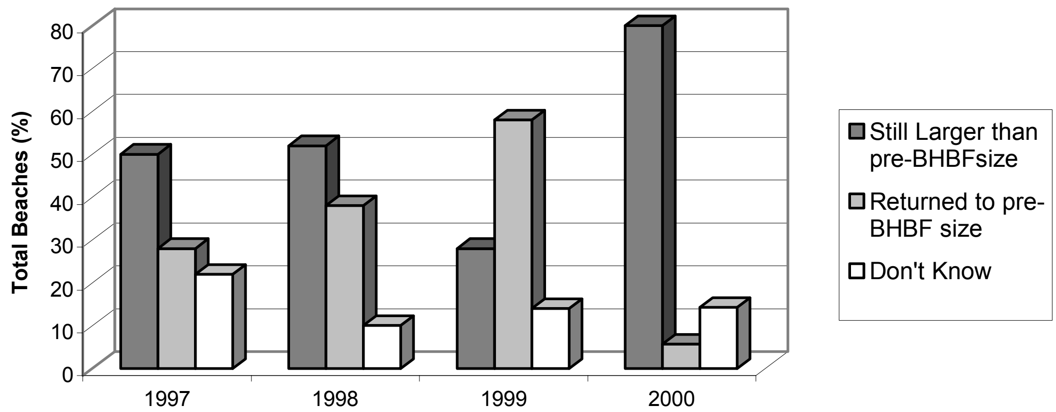

Figure 9. *Longevity of the 1996 BHBF deposit as of September/October 2000.*

As of September/October 1999 (Figure 9), 58% of beaches showed a return to pre-BHBF conditions, while 28% showed greater sand coverage than the respective pre-BHBF photograph. When assessed through the years of study, the trend shows an increase in percentage of beaches returning to the pre-BHBF condition. The rate increase is especially prevalent in 1999, at which point more than 50% of beaches had returned to the pre-BHBF condition. Then in 2000, the HMFs of 2000 improved campsite area for 80% of beaches. However, sand replenished to this deposit mostly affected low-elevation bars, as the spike flows were limited in stage height.

CONCLUSIONS

Results of this study since 1996 show that beaches have continued to decrease in size, system-wide up until the HMF of 2000. Over years 1996-1999, the net effect of controlled flow releases from Glen Canyon Dam resulted in the continued winnowing of beachfront property and loss of campsite area. Most of the impacts from fluctuating flows were reported in 1997-1998 (O'Brien and others 2000). By the1999 river season, impacts from fluctuating flows (averaging 20,000 cfs) were not as profound, because beaches were closer to reaching equilibrium with the controlled flow regime (O'Brien and others 2000). Analysis from winter season 1999-2000 confirms this concept. Cases depicting decreased beach area were few in number, while beaches showing no change increased substantially when compared to previous years.

More cases of decreased beach size from rainfall and visitation were reported for river season 1999 than in previous years. It is unknown whether these effects were cumulative throughout the years and therefore more noticeable in this season, or whether the 1999 monsoon season was more intense than in previous seasons. Nonetheless, guides and scientists thought that beaches were virtually "primed and ready" if not overdue for receiving new sand after 3 years of erosion and no beach-building flows (personal communications with Andre Potochnik, recreational representative for the Adaptive Management Work Group and Matt Kaplinski, recreational advisor to the Technical Work Group).

The percent of beaches benefiting from the HMFs were greater after the spring spike than after the fall spike. Sand concentrations are assumed to be similar during both test flows. I attribute the slight difference to available accommodation space. The opportunity for deposition was greater for beaches in spring because much erosion had occurred since the last HMF of 1997. Following erosion throughout the summer, the fall spike simply rebuilt beaches back to a their post-spring-spike condition. Likewise, the Namdor team (the beach erosion survey team from Dept. of Geology, Northern Arizona University) found little difference in sand bar response between the HMFs of Spring and Fall (Namdor unpublished data 2001).

Deposition from the HMFs built beach elevation by only a small amount up to the 30,000 cfs line. However, enough sand was deposited to improve campable area only slightly beyond that which existed before the BHBF. Still, higher stages, given adequate sediment storage, are needed to build and maintain camp beaches in Grand Canyon. This is consistent with the Namdor findings (unpublished data 2001), whose sample set shows increases in campable area only up to the 31,000 cfs line. Above that, campable area has been decreasing since 1998. Their group also recommends that the effect of a reduced sand supply in the Colorado River can be offset by higher stages of a very short duration. Results of this concept were strongly supported by Topping and others, 2000, who reported that deposition rates are highest during the first day or two during a high flow release. Wiele and Franseen, 1999, created models of deposition and erosion for different high stages at large cultural areas. Their studies suggest that sediment is available for short duration, high flow BHBFs up to 90,000 cfs.

Processes eroding beaches throughout the summer were primarily the high fluctuating flows in May. The high fluctuations averaged between 16,000 –18,000 cfs daily for 31/2 weeks following the Spring HMF, and eroded many beachfronts. If possible, lower fluctuating flows should follow a HMF for several months. This would allow beaches to de-water and stabilize to some degree.

The LSSF regime, according to guide comments, yielded much better camping than in the 3 previous years. Some of the problems with the LSSF were increased rockiness in boat parking areas and longer, steeper slopes in accessing the main camps. The most negative effect of the LSSF was the rampant development of tamarisk seedlings occupying the newly exposed beachfronts. However, more camps that would normally be under water, became available for use. Overall, the LSSF offers some improvement for campable area given the relatively small spike flows of 2000. Still, many guides reported that camping quality from the LSSF pales in comparison to that of the BHBF of 1996.

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Grand Canyon River Guides, Inc., would like to thank first and foremost the adopters for volunteering the time to pull over and photograph their beaches trip after trip and year after year, and for their valuable written observations and comments. It takes time and effort to do this, and the dedication shown by guides has literally kept this

program alive for five years. The result is the most comprehensive collection of repeat photographs of critical camping beaches in existence for Grand Canyon. An added benefit is the outreach to the public about this effort, and how our resource in Grand Canyon is affected, degraded or maintained by the influence of man and technology. Special thanks go to Lynn Hamilton for exhaustive work in support of this project; Andre Potochnik for his continued hard work as GCRG's (and therefore, this project's) representative of recreational interests in the Adaptive Management process; Matt Kaplinski for sharing results and playing advisor to the Technical Work Group. Finally, big thanks go to our contributors: the Grand Canyon Monitoring and Research Center and the Grand Canyon Conservation Fund.

References Cited and Related Bibliography

Brian, N.J. and Thomas, J.R., 1984. The 1983 Colorado River beach campsite inventory. National Park Service Division of Resource Management, Grand Canyon National Park, Grand Canyon. 56 p.

Carothers, S. W. and Brown, B. T., 1991. *The Colorado River Through Grand Canyon: Natural History and Human Change*: Tucson, University of Arizona Press. 235 p.

Graf, W.L.,1988. *Fluvial processes in Dryland Rivers*: New York, Springer-Verlag. 346 p.

Hazel, J.E. Jr., Kaplinski, M.A., Beus, S.S., and Tedrow, L.A., 1993. Sand bar stability and response to interim flows after a bar-building event on the Colorado River, Arizona: implications for sediment storage and sand bar maintenance: EOS Fall Meeting Abstracts, vol. 74. p. 43.

Hazel, J.E. Jr., Kaplinski, M.A., Parnell, R.A., Manone, M.F., and Dale, A., 1999. Topographic and bathymetric changes at thirty-three long-term study sites: in *The Controlled Flood in Grand Canyon*: Geophysical Monograph Series, vol. 110, p. 161-184.

Hazel, J.E. Jr., Kaplinski, M.A., Parnell, R.A., and Manone, M.F., 2001. Monitoring the effects of the spring 2000 habitat maintenance flow on Colorado River ecosystem sand bars: Northern Arizona University, Department of Geology, Sand Bar Studies Fact Sheet. 2 p.

Kaplinski, M.A., Hazel, J.E. Jr., and Beus, S.S., 1994. Monitoring the effects of interim flows from Glen Canyon Dam on sand bars in the Colorado River corridor, Grand Canyon National Park, Arizona: Report for Glen Canyon Environmental Studies, Northern Arizona University, Department of Geology. 62 p.

Kaplinski, M.A., Hazel, J.E. Jr., Manone, M.F., Parnell, R.A., and Dale, A., 1999. Final report for Colorado River sediment storage in Grand Canyon: Northern Arizona University, Department of Geology. 69 p.

Kearsley, L.H., and Warren, K.W., 1993. River campsites in Grand Canyon National Park: inventory and effects of discharge on campsite size and availability: National Park Service Division of Resource Management, Grand Canyon National Park, Grand Canyon. 65 p.

Kearsley, L. and Quartaroli, R., 1997. Effects of a beach/habitat building flow on campsites in Grand Canyon: Final Report of Applied Technology Associates for the Glen Canyon Environmental Studies.18 p.

O'Brien, G.O., Jansen, J., Thompson, K.S., Potochnik, A.R., and Burke, K.J., 1997. Effects of continuous high flows and daily fluctuating flows from Glen Canyon Dam on Grand Canyon beaches, 1997 and 1998: a continuation of a repeat photography study by Grand Canyon River Guides, Inc. (Adopt-a-Beach Program**).** Administrative report for Grand Canyon Monitoring And Research Center by the Grand Canyon River Guides Adopt-a-Beach program. 44 p.

O'Brien, G.O., Burke, K.J, and Hamilton, Lynn, 2000. Effects of natural flow and controlled-flow releases from Glen Canyon Dam on Grand Canyon beaches, 1999: a continuation of a repeat photography study by Grand Canyon River Guides, Inc. (Adopt-a-Beach Program). Administrative report for Grand Canyon Monitoring And Research Center by the Grand Canyon River Guides Adopt-a-Beach program, 22 p.

Parnell, R.A., Dexter, L., Kaplinski, M.A., Hazel, J.E. Jr., Manone, M.F., and Dale, A., 1997. Effects of the 1996 controlled high flow release from Glen Canyon Dam on Colorado River sand bars in Grand Canyon: final report for the beach habitat building flow: submitted to Glen Canyon Environmental Studies by Northern Arizona University, Department of Geology, 22 p.

Schmidt, J.C., 1990. Recirculating flow and sedimentation in the Colorado River in Grand Canyon, Arizona: Journal of Geology, v. 98, p. 709-724.

Schmidt, J.C., and Graf, J.B., 1990. Aggradation and degradation of alluvial sand deposits, 1965 to 1985, Colorado River, Grand Canyon National Park, Arizona: U.S. Geological Survey Professional Paper 1493, 74 p.

Thompson, K.S., Potochnik, A.R., and Burke., K.J., 1997. Adopt-a-Beach: Boatman's Quarterly Review (Published by Grand Canyon River Guides, Inc.) v. 10, no.1.

Thompson, K.S., Potochnik, A.R., and Burke., K.J., 1997. Effects of the beach-habitat building flow and subsequent interim flows from Glen Canyon Dam on Grand Canyon beaches, 1996: a repeat photography study by Grand Canyon River Guides (Adopt-a-Beach program). Administrative report for Grand Canyon Monitoring And Research Center by the Grand Canyon River Guides Adopt-a-Beach program. 22 p.

Topping, D.J., Rubin, D.M., Nelson, J.M., Kinzel, P.J., and Corson, J.C., 2000. River sediment transport 2: systematic bed elevation and grain size effect of sand supply limitation: Water Resources Research, vol. 36, p. 543-560.

U.S. Department of the Interior, 1987. *River and Dam Management*: a review of the Bureau of Reclamation's Glen Canyon Environmental Studies: National Academy Press, Washington D.C., 203 p.

U.S. Department of the Interior, 1995. Operation of Glen Canyon Dam Final Environmental Impact Statement: Bureau of Reclamation, Salt Lake City, Utah, 337 p.

U.S. Department of the Interior, 1996. Record of Decision (ROD) on the Operation of Glen Canyon Dam Final Environmental Impact Statement (EIS): Bureau of Reclamation, Salt Lake City, Utah.

Webb, R.H., Pringle, P.T., and Rink, G.R., 1989, Debris flows from tributaries of the Colorado River, Grand Canyon National Park, Arizona: U.S. Geological Survey Professional Paper 1492, 39 p.

Wiele, S.M. and Franseen, M., 1999. Modeling of mainstream flow and sediment dynamics at cultural resources: Interim Report to Grand Canyon Monitoring and Reseach: Submitted by the U.S. Geological Survey, Lakewood, Colorado, 144 p. (final publication is currently under peer review).

Wiele, S.M., Andrews, E.D., and Griffin, E.R., 1999. The effect of sand concentration on depositional rate, magnitude, and location in the Colorado River below the Little Colorado River: in *The Controlled Flood in Grand Canyon*: Geophysical Monograph Series, vol. 110, p. 131-145.

Appendix A

Data sheet used by river guides to identify beach location, date and time and document observed changes for year 2000.

Appendix B

Modified data sheet used by river guides for recording beach, date and time for year 2001.

Appendix C

Data entered into Access 2000 database, as recorded by guides and interpreted from repeat photographs.