

University of Colorado Law School

Colorado Law Scholarly Commons

Dams: Water and Power in the New West
(Summer Conference, June 2-4)

1997

6-3-1997

Glen Canyon Dam: Flood Flows and Adaptive Management in the Lower Colorado River Basin

Edmund D. Andrews

Follow this and additional works at: <https://scholar.law.colorado.edu/dams-water-and-power-in-new-west>



Part of the [Energy and Utilities Law Commons](#), [Energy Policy Commons](#), [Environmental Engineering Commons](#), [Environmental Indicators and Impact Assessment Commons](#), [Environmental Law Commons](#), [Environmental Policy Commons](#), [Hydraulic Engineering Commons](#), [Hydrology Commons](#), [Natural Resources Law Commons](#), [Natural Resources Management and Policy Commons](#), [Water Law Commons](#), and the [Water Resource Management Commons](#)

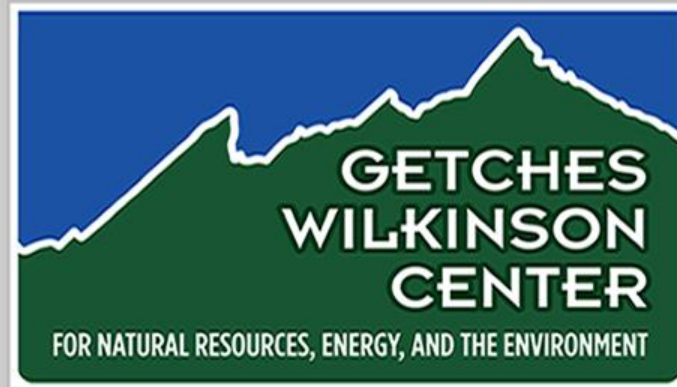
Citation Information

Andrews, Edmund D., "Glen Canyon Dam: Flood Flows and Adaptive Management in the Lower Colorado River Basin" (1997). *Dams: Water and Power in the New West (Summer Conference, June 2-4)*.
<https://scholar.law.colorado.edu/dams-water-and-power-in-new-west/13>

Reproduced with permission of the Getches-Wilkinson Center for Natural Resources, Energy, and the Environment (formerly the Natural Resources Law Center) at the University of Colorado Law School.



William A. Wise Law Library
COLORADO **LAW**
UNIVERSITY OF COLORADO **BOULDER**



Getches-Wilkinson Center Collection

Edmund D. Andrews, *Glen Canyon Dam: Flood Flows and Adaptive Management in the Lower Colorado River Basin*, in *DAMS: WATER AND POWER IN THE NEW WEST* (Natural Res. Law Ctr., Univ. of Colo. Sch. of Law, 1997).

Reproduced with permission of the Getches-Wilkinson Center for Natural Resources, Energy, and the Environment (formerly the Natural Resources Law Center) at the University of Colorado Law School.

**Glen Canyon Dam: Flood Flows and Adaptive
Management in the
Lower Colorado River Basin**

Edmund D. Andrews
U.S. Geological Survey
3215 Marine Street
Boulder, CO 80302

Dams: Water and Power in the New West

June 2-4, 1997

Natural Resources Law Center
University of Colorado
School of Law
Boulder, Colorado

C

C

C

Glen Canyon Dam: Flood Flows and Adaptive Management in the Lower Colorado River Basin

by Edmund D. Andrews

- I. The Colorado River Compact apportioned the flow of the Colorado River between the Upper and Lower Basin States. The compact point dividing the basins is located at Lee Ferry, Arizona in a short accessible reach of river between the end of Glen Canyon and the beginning of the Grand Canyon. The Compact requires the Upper Basin to release 75 million acre-feet of water over any 10 year period.
 - A. Glen Canyon Dam was authorized in 1956 and completed in 1963. The primary purpose for the dam is to control flows to the Lower Basin, and thus allow the States of the Upper Colorado River Basin to develop their apportioned share of the water supply, while meeting their commitment to the Lower Basin.
 - B. Hydroelectric power generation was established as an incidental purpose. The Secretary of the Interior was directed to operate Glen Canyon so as to generate "the greatest practicable amount of power," Colorado River Storage Project Act, 1956, 70 Stat. 105, § 7.]
- II. Prior to the construction of Glen Canyon Dam, Colorado River flows through Grand Canyon varied from less than 1,000 ft.³/sec. to as large as 400,000 ft.³/sec. and carried a sediment load exceeding 100 million tons in some years, Andrews (1991).

- A. Discharge varied greatly throughout the year. Mean annual peak discharge was about 90,000 ft.³/sec., Andrews (1990).
 - B. The Colorado River was muddy and carried a large sediment load that averaged 65 million tons per year.
 - C. Water temperature was cold in winter, approximately 35 °F, and very warm in mid-summer, approximately 85°F.
- III. The configuration and operation of Glen Canyon Dam substantially altered the characteristics of the Colorado River downstream through Grand Canyon National Park.
- A. The seasonal variation in discharge was largely suppressed. The daily range of flow, however, was increased as water was released to meet electrical power demand, Wiele and Smith (1996).
 - B. Water released from Glen Canyon Dam is essentially sediment free.
 - C. Water released from Glen Canyon Dam is relatively cold year around, approximately 46 °F.
- IV. Surprisingly little attention was given to the possible downstream ecological effects of Glen Canyon Dam when it was planned and constructed. No environmental analysis or review was done. By the mid-1970's, however, significant physical and biological changes in the river channel and the riparian corridor became apparent, Dolan and others (1974) and Howard and Dolan (1981)
- A. Sand bars which occur in low velocity zones along channel margins were being gradually eroded and were not being replenished.
 - B. Former riparian vegetation, primarily mesquite and catsclaw, within the zone annually inundated by the peak discharge was dying, and regeneration was insufficient, Turner and Karpiscak (1980) and Johnson (1991)

- C. Debris fans deposited by tributary flash floods were no longer eroded by large spring snowmelt floods down the Colorado River. Consequently, debris fans increasingly constricted the channel and many rapids were becoming more difficult to navigate, Schmidt and Rubin (1995) and Webb (1996).
 - D. Four of the six endemic species of fish remained only in greatly reduced numbers. Subsequently, these four species, humpback chub, Colorado squawfish, razorback sucker, and bonytail, have been listed or proposed as endangered. Exotic fishes became established in large numbers, Minckley (1991).
 - E. Degradation of tributary channels accelerated the erosion of alluvial fans and associated archaeological sites, Hereford (1993).
- V. When construction of Glen Canyon Dam began in the summer of 1957, less than 500 people had floated the Colorado River through Grand Canyon National Park. Less than 20 years later, 20,000 people per year made this trip.
- A. The direct economic value of "running the Colorado River", exceeds the average annual revenues from the sale of hydroelectric power generated at Glen Canyon Dam.
 - B. River runners depend almost exclusively on sand bars for camp sites. Through various parts of Grand Canyon, sand bars are limited and there is intense competition for the available camp sites.
- VI. In the early 1980's, the Bureau of Reclamation requested funds to renovate and upgrade turbines at Glen Canyon Dam. The upgrades would have allowed an increased range of daily powerplant operations. Following objections to funding of the renovations, the Bureau of Reclamation agreed to initiate the Glen Canyon Environmental Studied (GCES) to investigate the effects of daily powerplant operations on the resources of Grand Canyon Nation Park.

- A. GCES focused primarily, although not exclusively, on the daily range of discharge and the hourly rate of change in discharge.
 - B. It was generally assumed that the river channel was severely depleted in sand. That is, the supply of sand from tributaries was less than the downstream transport to Lake Mead, Schmidt and others (1993).
 - C. The opportunity to replenish and rebuild sand bars was believed to be quite limited due to an insufficient supply of sand.
 - D. Large daily fluctuations in discharge, occasionally from 3,000 to 30,000 ft.³/sec., a stage range of about 15 ft., appeared to erode sand bars more rapidly than a relatively constant flow regime, Wiele and Smith (1996).
 - E. Furthermore, for a given daily volume of water released from the dam, a widely fluctuating flow will transport more sediment than a constant flow. Thus, daily powerplant operations affect the balance between sediment supply and transport throughout Grand Canyon.
- VII. An Environmental Impact Statement concerning the operating rules for the Glen Canyon powerplant was completed in 1995, U.S. Bureau of Reclamation (1995).
- A. The Secretary's Record of Decision issued in October 1996 reduces the daily range of flow released from the powerplant to 5,000 ft.³/sec. for monthly releases of 600,000 acre feet or less, 6,000 ft.³/sec. for monthly releases of 600,000 to 800,000 acre-feet and 8,000 ft.³/sec. for monthly releases greater than 800,000 acre-feet. The maximum rate of change in discharge is limited to increases of 2,500 ft.³/sec. per hour and decreases of 1,500 ft.³/sec. per hour.

- B. Occasional floods to benefit aquatic and riparian resources in Grand Canyon Nation Park, varying from 30,000 to 45,000 ft.³/sec., are included in the long-term adaptive management plan.

VIII. Sand budgets calculated for various reaches of the Colorado River and assumed alternative powerplant operations determined that there was a surplus, not a deficit of sand in the channel, except during the highest runoff years. Thus, the long term loss of sand bars was due to a lack of high flows which would deposit new sand on the bars rather than a lack of available sand supply.

- A. Two major tributaries to the Colorado River, the Paria and Little Colorado River, contribute approximately 16 million tons per year of sediment and 5.4 million tons per year of sand. This contribution represents about 20 percent of the historical sediment transport through Grand Canyon prior to the construction of Glen Canyon Dam, Andrews (1991).

- B. Detailed laboratory, and field investigations of the eddies formed downstream of channel constrictions determined that eddies are very effective sediment traps. Sand bars, however, can only be built to within a foot or so of the water surface. Hence, the lack of relatively high flows resulted in sand bars that were mostly submerged by flows within the range of normal powerplant releases.

- C. Flood Hypothesis - Flows substantially greater than the powerplant capacity, about 30,000 ft.³/sec. will deposit sand rapidly and construct bars standing well above the range of normal powerplant releases.

- 1. The deposition rate of sand in eddies varies with discharge to about the fourth power. Consequently, for a given volume of water that bypasses the powerplant, a larger, shorter duration flood will deposit substantially more sand than a smaller, longer duration flood.

2. Concern for the stability of the dam's spillway tunnels constrained the maximum release to 45,000 ft.³/sec..
3. Although there was substantial scientific evidence indicating the benefits of flood flows for a number of Park resources, as described above, it was recognized that only the replenishment of sand bars could be accomplished by flows significantly less than unregulated mean annual peak discharge of 90,000 ft.³/sec. Thus, the 1996 experimental flood was focused primarily on sand bars and the reconstruction of backwaters.

IX. Political and economic issues raised by the experimental flood concerned primarily the reduction in hydropower generation and the discretion of the Secretary of the Interior to balance a number of competing Departmental objectives and resources, Ingram and others (1991).

- A. All water released from Glen Canyon Dam is credited toward the Upper Basin States commitment under the Colorado River Compact.
- B. Water releases in excess of the powerplant capacity reduce total electrical power generation and revenues.
- C. Net revenues from the sale of hydropower generated at Glen Canyon Dam in 1996 were \$99 million. Financial cost of the experimental flood reduced net revenue by 2.5%, Harpman (1997).

X. Effects of the experimental flood on Park resources were, for the most part, beneficial for the aquatic and riparian resources of Grand Canyon National Park, Collier and others (1997). Very few negative impacts have been noted. Several

flood investigators have recommended that future powerplant operations include the release of large, short duration floods every two to three years.

- A. Sand bars were rebuilt throughout Grand Canyon. Approximately 70 percent of the sand bars used for camping by river runners were larger after the flood. The sand bar area exposed above the range of normal powerplant releases increased by an average of approximately 25 percent, and exceeded 200 percent at some locations.
- B. The deposition rate of sand was highest during the first 24-48 hours. As much as 2 meters of sand was deposited on some bars.
- C. Most of the rebuilding of sand bars occurred during the first few days.
- D. Relatively large quantities of sand were deposited in mouths of most tributaries and will slow tributary channel degradation, at least temporarily.
- E. The available supply of sand stored in the Colorado River channel was greater than had been believed, especially in the reach upstream of the Little Colorado River.
- F. Some recently enlarged debris fans were eroded and one major rapid was significantly modified.
- G. Native fish appeared to be unaffected by the flood. Some species of exotic fish may have been displaced somewhat.
- H. Riparian vegetation both native and exotic were generally unaffected. Locally, some stands of exotic vegetation were scoured.

References

- Andrews, E. D., 1990, Effects of streamflow and sediment on channel stability of the Colorado River—A perspective from Lees Ferry, Arizona, *in* The Geology of North America: v. O-1; Surface Water Hydrology: Wolman, M. G. and Riggs, H. C. (eds.): Geological Society of America, p. 304-310.
- Andrews, E. D., 1991, Sediment transport in the Colorado River basin, *in* Colorado River Ecology and Dam Management; Marzolf, G. R. (ed.): National Academy Press, Washington, D.C. , p. 54-74.
- Collier, M. P., Webb, R. H. and Andrews, E. D., 1997, Experimental flooding in Grand Canyon, *Scientific American*, v. 276(1) p. 82-89.
- Dolan, R., Howard, A. and Gallenson, A., 1974, Man's impact on the Colorado River in the Grand Canyon, *American Scientist*, v. 62, p. 392-401.
- Harpman, D. A., 1997, Glen Canyon Dam Beach/Habitat - Building Test Flow - An ex post analysis of hydropower cost, Report EC - 97-01, U.S. Bureau of Reclamation, Denver, CO, 54 pp.
- Hereford, R., 1993, Surficial geology, geomorphology, and erosion of archaeological sites along the Colorado River, Grand Canyon, Grand Canyon National Park, Arizona, U. S., Geological Survey, Open File Report 93-517, 46p.
- Howard, A. and Dolan, R., 1981, Geomorphology of the Colorado River in the Grand Canyon, *Journal Of Geology*, v. 89(3), p. 269-298.
- Ingram, Helen, Tarlock, A. D., and Oggins, C. R., 1991, The law and politics of the operation of Glen Canyon Dam, *in* Colorado River Ecology and Dam Management; Marzolf, G. R. (ed.): National Academy Press, Washington, D.C. , p.10-27.

Johnson, R. R., 1991. Historic changes in vegetation along the Colorado River in the Grand Canyon, *in* Colorado River Ecology and Dam Management; Marzolf, G. R. (ed.): National Academy Press, Washington, D.C. , p. 178-206.

Minckley, W. L., 1991, Native fishes of the Grand Canyon Region: An obituary?, *in* Colorado River Ecology and Dam Management; Marzolf, G. R. (ed.): National Academy Press, Washington, D.C. , p.124-177.

Schmidt, J. C., Rubin, D. M. and Ikeda, H. 1993, Flume simulation of recirculation flow and sedimentation: *Journal of Water Resources Research*, v. 29, p. 2925-2939.

Schmidt, J. C., Rubin, D. M., 1995, Regulated streamflow, fine-grained deposit and effective discharge in canyons with abundant debris fans: *in* J. E. Costa, ed. Natural and Anthropogenic Influences in Fluvial Geomorphology, American Geophysical Union, Monograph, 89, p. 177-196

Turner, R. M. and Karpiscak, M. M., 1980, Recent vegetation changes along the Colorado River between Glen Canyon Dam and Lake Mead, Arizona, U.S. Geological Prof. Paper 1132, 125p.

U. S. Bureau of Reclamation, 1995, Operation of Glen Canyon Dam: Colorado River Storage Project, Arizona, Final Environmental Impact Statement, Final Report: Bureau of Reclamation, Salt Lake City, Utah, 337 pp.

Webb, R. H. 1996, Grand Canyon: A Century of Change, University of Arizona Press, 290 p.

Wiele, S. M. and Smith, J. D. 1996. A reach-averaged model of diurnal discharge wave propagation down the Colorado River through the Grand Canyon: *Water Resources Research*, v. 32, no. 5, p. 1375-1386..

C

C

C