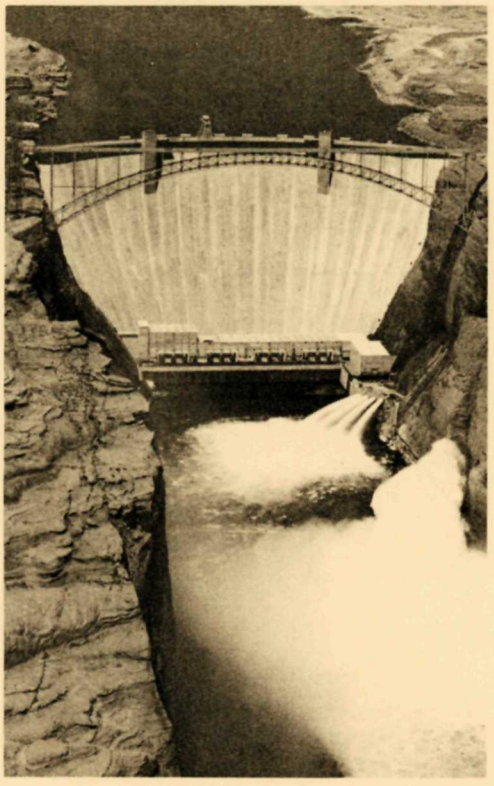
GLEN CANYON ENVIRONMENTAL STUDIES
PHASE II

5,000 CUBIC FEET PER SECOND FLOW STUDY



Prepared By:

Glen Canyon
Environmental Studies
Bureau of Reclamation

March 1990

United States Department of the Interior
BUREAU OF RECLAMATION
UPPER COLORADO REGIONAL OFFICE
P.O. BOX 11568
SALT LAKE CITY, UTAH 84147

IN REPLY
REFER TO:

JUN 20 1990

MEMORANDUM

To: Glen Canyon Environmental Studies
Technical Study Team Members

From: Glen Canyon Environmental Studies
Program Manager

Subject: Glen Canyon Environmental Studies - Transmittal of the Report on the October 1989 Low Flow Study

Enclosed for your information is a copy of the Glen Canyon Environmental Studies (GCES) report 5,000 Cubic Feet Per Second Flow Study which is the documentation of the work that was accomplished during the low flow test in October 1989. The information presented in this report has been used by the GCES researchers in the development of the remainder of the GCES Phase II study program.

Please contact the GCES Office in Flagstaff, AZ if you have any questions at (602) 527-7363. Regards.

enclosure

David L. Wegner

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5,000 CUBIC FEET PER SECOND FLOW STUDY

I. INTRODUCTION

Flows of 5,000 cubic feet per second (cfs) (Graph 1) were released from Glen Canyon Dam (Figures 1 and 2) for 4 consecutive days from one minute past midnight on the morning of October 6 to midnight on October 9, 1989, for the Glen Canyon Environmental Studies (GCES) Phase II program. This report documents the technical studies which were conducted during this period, prior to the steady flows, and after resumption of "normal" flows. Objectives, study sites, parameters evaluated, and methodologies are given for each study. A discussion on the information gathered, preliminary results, logistical requirements, an estimate of the cost for each study, and suggested changes for future studies are also presented.

A. Objectives.

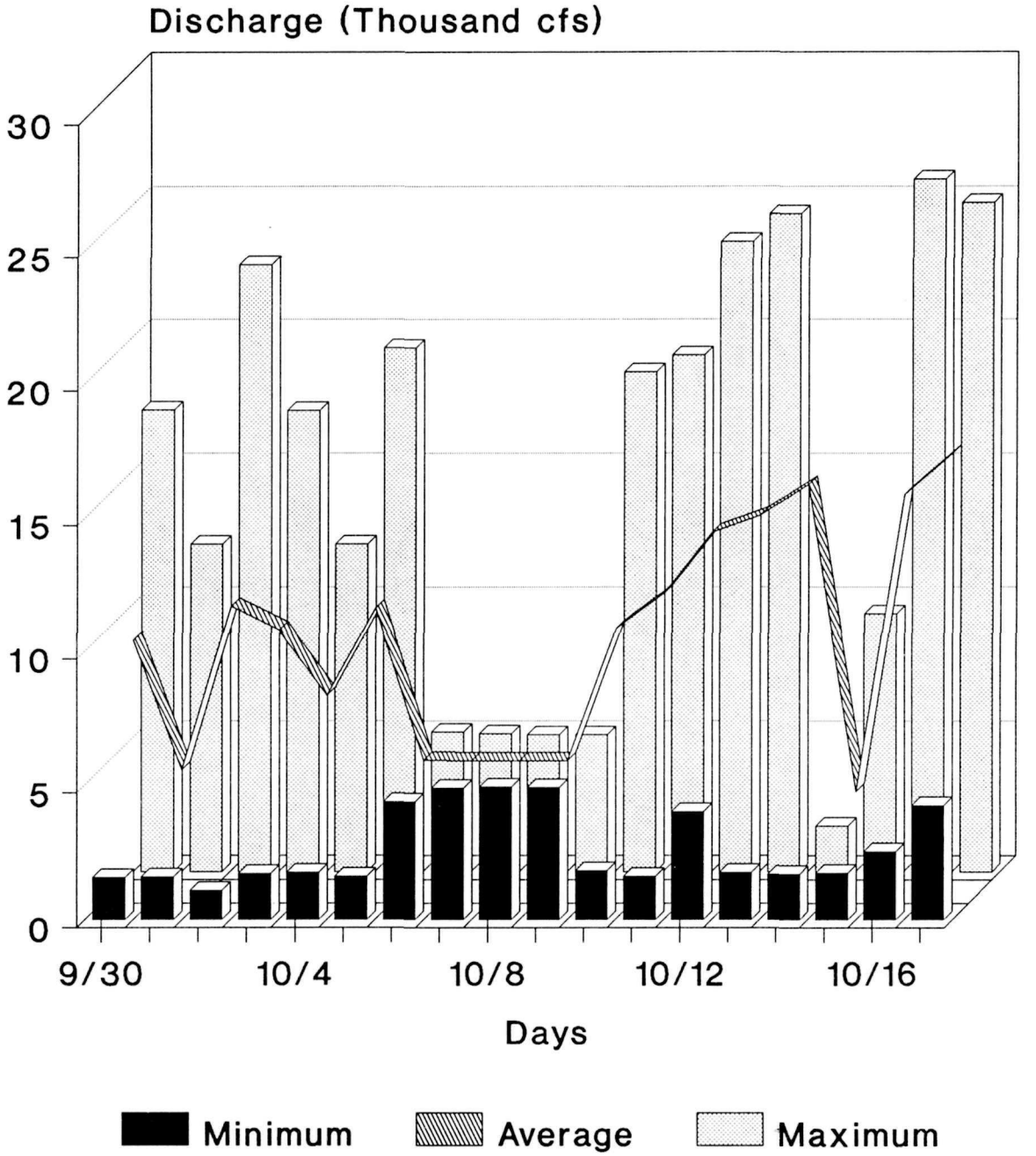
The objectives of the 5,000 cfs flow test can be classified in both short- and long-terms. In the short-term, the research projects, conducted under a constant 5,000 cfs flow, were designed to give information that was unattainable during the "normal" low and fluctuating flows from Glen Canyon Dam. Long-term objectives were two-fold: (1) to design the studies as part of the GCES integrated research plan, and (2) to better understand the dynamics of the Grand Canyon ecosystem.

The test period of October was chosen in order to replicate the 5,000 cfs flow aerial photography taken during October 21-23, 1984 (Graph 2). An understanding of the necessary pre-planning, communication, cooperation, research integration, and logistical requirements exercised during the October 1989 study effort will aid in the efficient and successful planning of inter- and intra-agency studies required for future studies and unusual or unexpected research contingencies.

Over 35 individuals from several agencies and groups actively participated in the 5,000 cfs flow study: Bureau of Reclamation (Reclamation), National Park Service (NPS), U.S. Geological Survey (USGS), U.S. Fish & Wildlife Service (FWS), Arizona Game and Fish Department (AGF), Western Area Power Administration (Western), private consulting firms (HBRS Inc. and G.F. Moody and Associates, Inc.), and the GCES senior scientist from Arizona State University.

GLEN CANYON DAM RELEASES

September 30 to October 17, 1989



Graph 1. Minimum, average, and maximum releases from Glen Canyon Dam for September 30 to October 17, 1989, (information courtesy of Glen Canyon Dam Powerplant, Bureau of Reclamation).

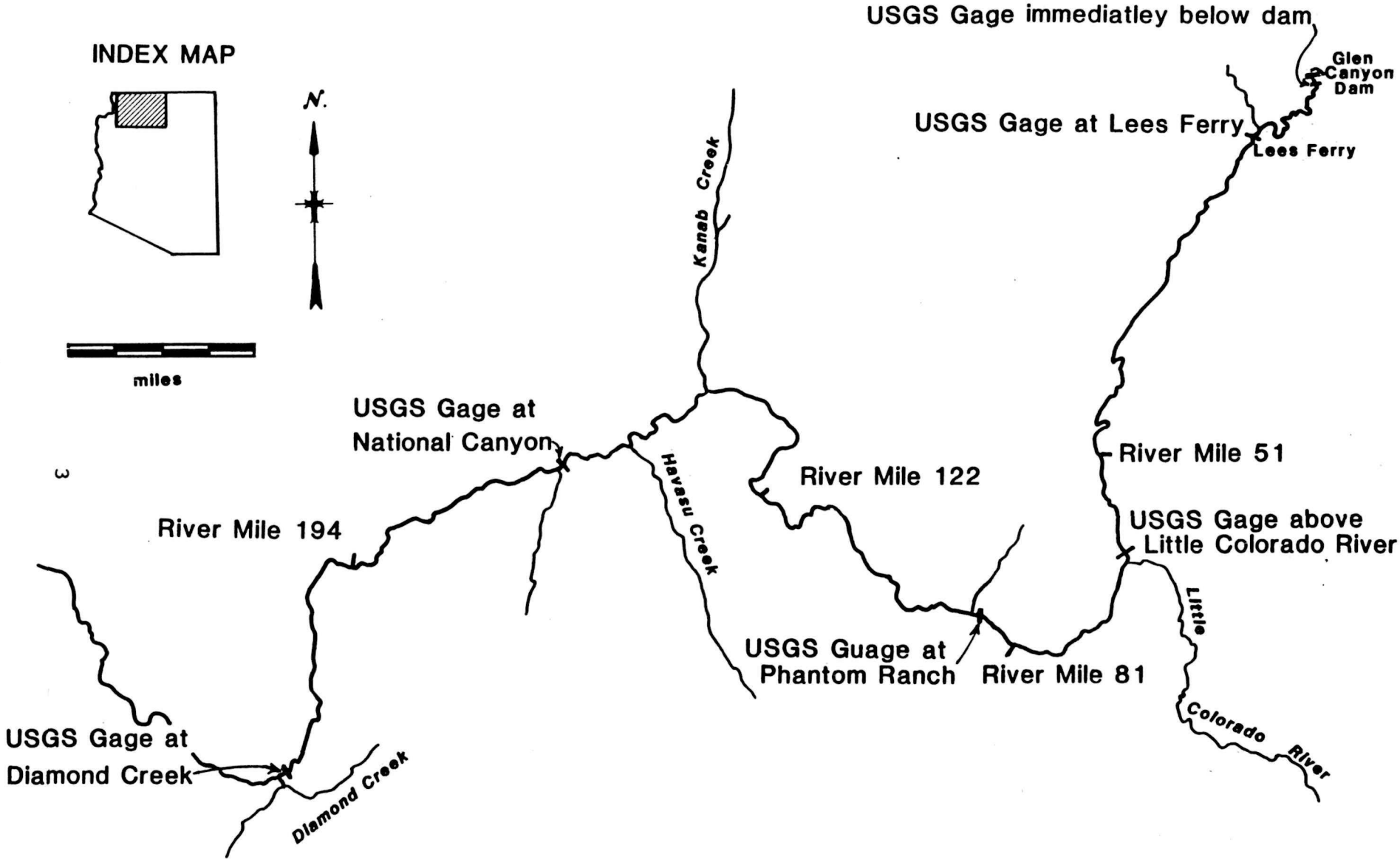


Figure 1. Map of Grand Canyon National Park showing U.S. Geological Survey gages and National Park Service Beach study sites.

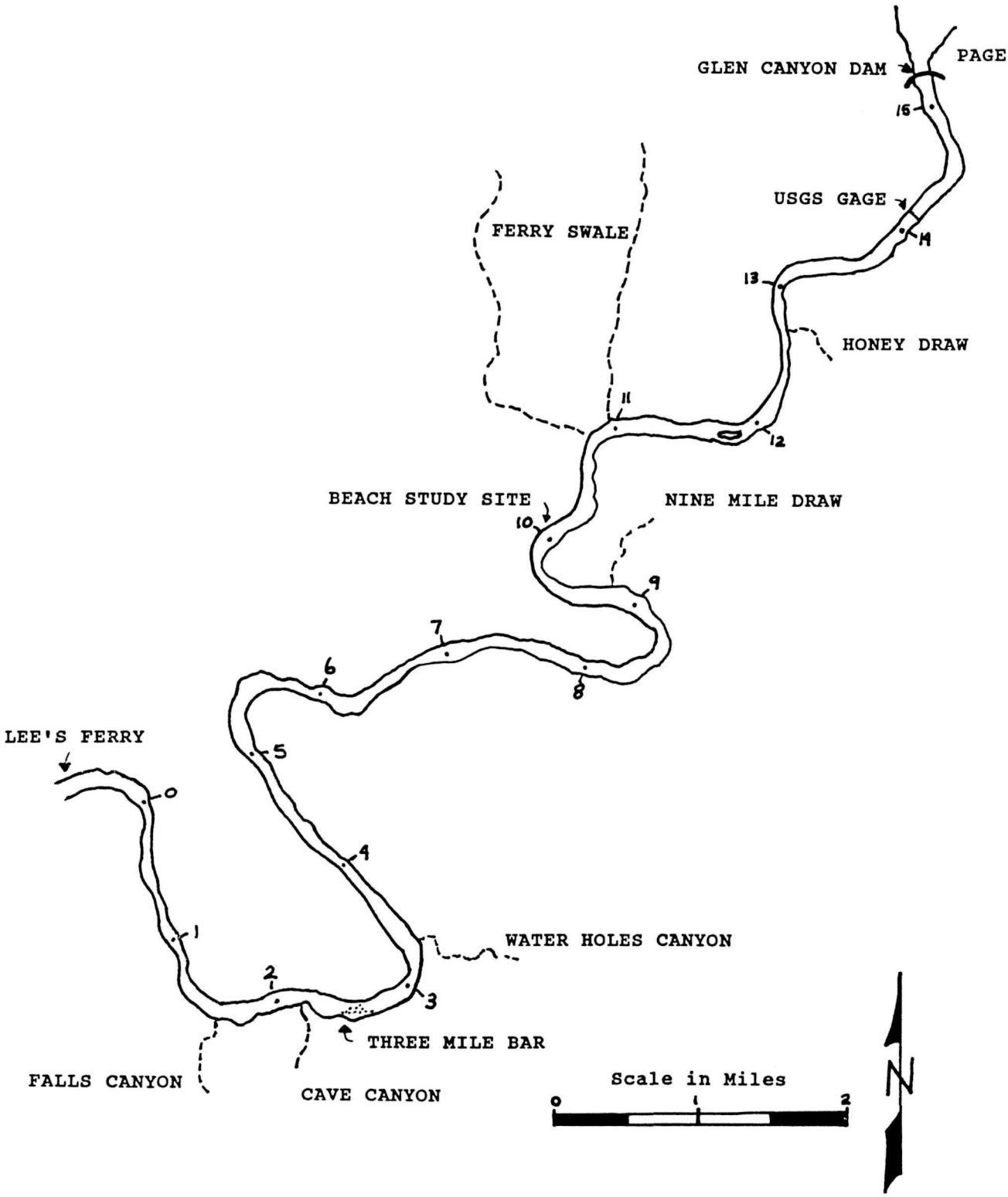
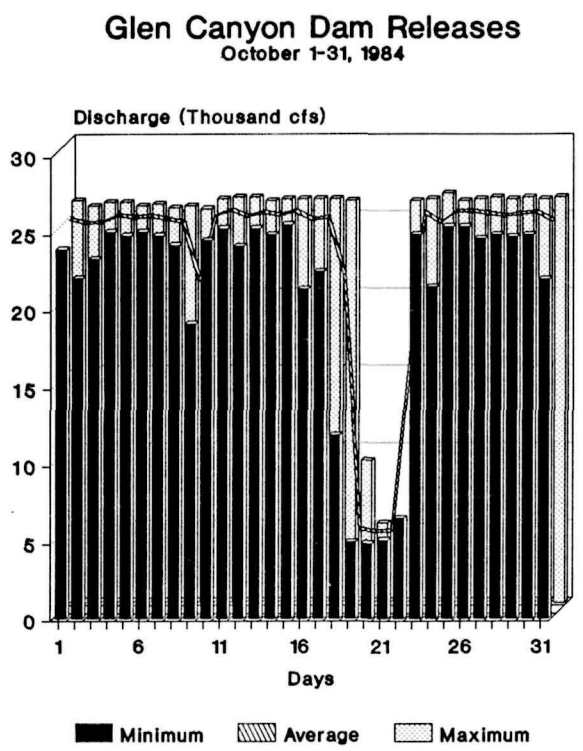
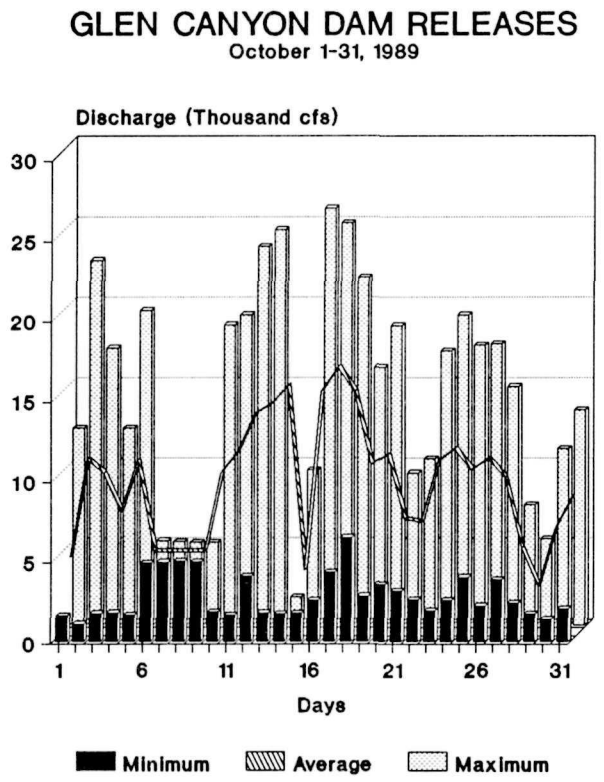


Figure 2. Map of the Glen Canyon Dam Tailwater reach showing U.S. Geological Survey gage, National Park Service beach study site, and trout fishery access study site (map adapted from U.S.D.I. 1984).





Graph 2. A comparison of the minimum, average, and maximum discharges from Glen Canyon Dam for the months of October 1984 and 1989 (information courtesy of Glen Canyon Dam Powerplant, Bureau of Reclamation).

II. STUDY PLAN DEVELOPMENT

A. Broad Planning. A GCES document (U.S. Department of Interior 1989) titled, "Phase II Technical Study Plan Outline: Fiscal Year 1989 and Process for Completion of the Technical Studies" was prepared by members of the Environmental and Economic Teams (comprised of members from agencies within the U.S. Department of the Interior [Reclamation, NPS, FWS, and USGS], AGF, Western, Colorado River Basin States, Colorado River Storage Project Power Customers, environmental and recreation constituents, and private consultants. The plan was the first attempt to outline the specific studies required to address the Phase II objectives of the GCES.

Part IV of the document outlined critical fiscal year 1989 study needs. Two primary areas of study need were the acquisition of river corridor photography and to initiate biological and sediment studies. In order to match the 1984 aerial photography, the month of October and the flow level of 5,000 cfs were recommended. A time period of 3 to 5 days was requested in order to allow for equilibration of the river flows through the Grand Canyon and return of water to the river which had been held in bank storage.

B. Development of Resources to Study. Following an Integration River Research Trip (July 7-16, 1989), research proposals prepared by scientists from the agencies involved with the GCES were submitted to Dr. Duncan Patten, the GCES Senior Scientist. An outline of the draft research plan (Appendix 1) was developed at an August 31, 1989, research meeting following review of the proposals. Several studies were added to the work after the meeting and were therefore not reviewed. The draft research plan identified nine topics and the objectives, methodology, and logistics were outlined.

Three study reaches with specific studies were identified: Glen Canyon Dam (GCD) to Lake Mead (aerial photography); GCD to Diamond Creek (stream discharge, beach dynamics, water chemistry, and water mass movement); and GCD to Lee's Ferry (calibration of dam discharge, access to the trout fishery at Three Mile Bar, bathymetric mapping, and trout spawning).

C. Study Plan. A final study plan (Appendix 2) was completed and distributed to the GCES Technical Study Teams on September 18, 1989. Objectives, justification, methods, and logistical requirements were identified. A core scientific group meeting was held on September 28, 1989, to clarify and finalize logistical and personnel requirements. Personnel involved in the study effort are listed in Appendix 3.

III. STUDY COORDINATION

A. Project Coordination. The majority of the logistical details, research and river permit applications, and day-to-day communication between all entities were accomplished by the GCES office located in Flagstaff, Arizona.

B. Communication with Private River Runners. A July 27, 1989, letter (Appendix 4) was distributed by the NPS River Subdistrict Office to all private river runners with permits to raft the Colorado River during September/October 1989. The letter notified the river recreationists of the aerial photography overflight and the 5,000 cfs continuous flows during October 6-9, 1989.

In addition, the USGS issued a press release to inform the public of the study (Appendix 4). The release was distributed to The Arizona Daily Sun (Flagstaff, AZ); the National Park Service (Grand Canyon, AZ); The Arizona Republic (Phoenix and Flagstaff offices, AZ); Lake Powell Chronicle (Page, AZ); and the Mohave Daily Miner (Kingman, AZ). In addition, the USGS prepared a handout (distributed at Lee's Ferry) about the Rhodamine dye study to inform the public, anglers, and river runners.

C. Request for 5,000 cfs Flow. On May 19, 1989, a request was made to Western for sustained releases of 5,000 cfs for a 4-day period in October at Glen Canyon Dam. In a June 23, 1989, (Appendix 4) response, Western's Salt Lake City Area Office estimated that $92,000 would be the total financial impact for this 4-day period based upon non-firm purchase rates. Two impact components were identified: a shift of on-peak hydro-generation to the off-peak period and additional on-peak thermal purchase requirements to meet the firm load.

Western was requested by Reclamation (Appendix 4) on July 27, 1989, to provide specific flows during the 4-day period for Flaming Gorge Dam and Glen Canyon Dam. In order to minimize the power system impacts, high fluctuating flows at Flaming Gorge (during July 30 to October 16) were purposely scheduled to coincide with the limited releases from Glen Canyon Dam during October 6-9. Additionally, releases from Crystal Dam of up to a maximum of 1,700 cfs during the same 4-day period were scheduled.

D. USGS Gage Coordination. To provide additional stream discharge, sediment transport, and water quality information, a gage was reinstalled below Glen Canyon Dam during the week of September 12-15, 1989. The gage was first established October 22, 1964, at a site 4500 feet (1350 meters) downstream from the dam and was discontinued on September 30, 1972. In the early 1980's, the instrumentation and cableway were removed by Reclamation when it became an attractive nuisance for recreationists. The gage shelter was left intact.

Cable cars and instrumentation were installed from September 15 to October 2 at three gages downstream during a motor river trip operated through Reclamation's river logistics contract with O.A.R.S. Inc.: Colorado River above confluence of the Little Colorado River (**09383100**), Colorado River above National Canyon (**09404120**), and Colorado River above Diamond Creek (**09404200**). No installation was required at the gage located at near Grand Canyon (**09402500**) as it has been in operation since early 1920's.

E. Photographic Coordination. In order to provide aerial photographic coverage of the river corridor from Glen Canyon Dam to Pierce Ferry and for the Little Colorado River and Paria River, several permit applications were made. Information on special Federal aviation regulation 50-2 (amended) for special flight rules in the vicinity of Grand Canyon National Park was obtained from the Federal Aviation Administration (FAA). Permission was obtained from the Superintendents of Grand Canyon National Park and Glen Canyon National Recreation Area for fixed-wing and helicopter photography. Additional permission to fly the Little Colorado River was obtained from the Navajo Nation. The FAA Flight Standards District Office (Las Vegas) also required triplicate FAA Form 7711-2 for certificate of waiver of authorization for aerial photography in Grand Canyon National Park.

A new procedure by the Office of Aircraft Safety (Boise, ID) entailed a briefing program for the pilots composed of a 15-minute video tape and background materials. The Department of the Interior has a blanket authorization to fly in Grand Canyon National Park. The fixed-wing photography was obtained through a Reclamation contract with Gene F. Moody & Associates, Inc., of Tulsa, Oklahoma. The video photography was obtained by the Reclamation helicopter and pilot based out of Salt Lake City, Utah.

Arrangements were made with the Reclamation photographer, Michael Phillips, to provide on-site, 35 millimeter photographic documentation of researchers, spawning bars, anglers, USGS gage workers, and other items of scientific interest.

F. National Park Service Coordination. NPS helicopter support requests were made for transport of personnel, equipment, food and supplies to inner-Grand Canyon study sites. Helicopter support in Grand Canyon is regulated by the Superintendent of Grand Canyon National Park through the Internal Aviation Oversight Committee, chaired by the Park Management Assistant. Costs for helicopter transport (1989 dollars) are $418.70 per hour.

The NPS Bell Jet Ranger 206-B3 ship stationed at the South Rim Helibase was used for all supply flights. A total of 500 to 700 pounds (personnel and equipment combined) can be carried per

trip. Dates, times, number of flights, trip passenger list (manifest), weight of each passenger, and estimated weight of cargo (food, equipment, and supplies) were prepared and submitted by the GCES office in mid-September to the Division of Resources Management at Grand Canyon National Park. To provide support (both to and from the remote study sites), requests were made for the USGS gage work at near Grand Canyon and National Canyon, and for the NPS beach surveying work at River Miles (RM) 51, 81, 122, and 194.

To assist with safety and timely loading of the helicopter, equipment was weighed prior to the flight and the weight written on the packages. Food items were double bagged and weights written on the outside of the packages. White gas could only be transported in small "Sigg"-style containers. No propane or pressurized containers can be transported inside the ship. Due to weather (wind, temperature, and density altitude) and safety considerations, most flights were scheduled for early morning (7 a.m. to 11 a.m.), with most trips terminated by noon.

A GCES Colorado River research river trip application was approved by the River Subdistrict Office at Grand Canyon National Park for an 11-day row trip to deliver equipment, supplies, and personnel to the four NPS beach study sites below Lee's Ferry. This trip was operated through Reclamation's river logistics contract with O.A.R.S., Inc. In addition, arrangements were made with the NPS staff at Lee's Ferry for boat transport of NPS and USGS personnel to and from study sites in the Glen Canyon Dam tailwater.

Permission was obtained from the Superintendent of Grand Canyon National Park for the use of the Rhodamine WT (tracer) dye during the 5,000 cfs flow study (Appendix 4) under the following conditions: that the dye be used according to label restrictions, concentrations at point of entry will not exceed the LC50 values for rainbow trout (330 parts/million), and that if there are observed effects (such as mortality of disablement of fishes) that the operation be ceased and the NPS notified immediately. Permission for all agency personnel to camp in "day-use only" areas in the Glen Canyon tailwater within Glen Canyon National Recreation Area (GCNRA) was obtained through the Superintendent of GCNRA. In addition, the private river runner orientation trailer at Lee's Ferry was made available to all personnel for use of the phone, equipment storage, and as a central meeting location.

G. Bureau of Reclamation Coordination. Permission was obtained from the Chief of Operations and Maintenance Division at Glen Canyon Dam for USGS personnel to have access to the Glen Canyon Dam gage (through tunnel adit Number 12), that agency personnel had access to the transformer deck for the Rhodamine WT dye

insertion, and that AGF personnel had access to the drift tubes for water sample collection.

The GCES offices in Flagstaff and Salt Lake City communicated regularly in order to ensure logistical, personnel, and scheduling efforts.

IV. INDIVIDUAL STUDY OBJECTIVES AND PROGRAM

Twelve studies were initiated during the October 6-9, 1989, flow study. Objectives, locations, parameters evaluated, and methodologies are discussed for each study below. Study personnel for each study are outlined in Appendix 3.

A. Dam Rating, Flow Characteristics, and Water Quality. Principle Investigator: USGS, Flagstaff Office.

1. Objectives. Six objectives were identified for this USGS study: (1) determine the streamflow discharge at each gaging station prior, during, and after the constant-flow release; (2) determine gains and/or losses between gaging stations during constant-flow conditions; (3) determine velocity profiles during the constant-flow release; (4) determine streambed configuration at gaging stations for constant-flow conditions; (5) estimate the primary production of the system for fluctuating and constant-flow conditions; (6) and determine the dynamics of nutrient loads throughout the system during fluctuating and constant-flow conditions.

2. Locations. Five gage locations (figures are given for River Mile (RM) below Lee's Ferry and USGS gage number) were occupied for the study: below Glen Canyon Dam (located 4500 feet below Glen Canyon Dam, 09379910), at Lee's Ferry (RM 0, 09380000), near Grand Canyon gage (RM 87, 09402500), above National Canyon (RM 166, 09404120), and above Diamond Creek gage (RM 225, 09404200).

3. Parameters evaluated and methodology. USGS personnel measured several parameters: streamflow discharge, channel geometry, velocity profiles at centroids of equal discharge cross sections, pH, specific conductance, alkalinity, and dissolved oxygen. Samples were collected for analysis of concentrations of nutrients, suspended-sediment, and major ion.

Quality assurance procedures were followed throughout the study effort. This included calibration of equipment, acid rinsing of churn splitters, immediate checking of discharge measurements, reading of barometric pressure prior to measuring dissolved oxygen, documentation of flowmeter spin tests before and after measurements, flagging of B-reel

cables to account for air line correction and depth/velocity errors, chilling of all water-quality samples, and transportation of all samples to the lab immediately after returning from the field.

USGS personnel either camped at the site or used nearby hotel accommodations. Personnel at the gage near Grand Canyon were given permission to use the NPS Trail Crew Bunkhouse and some meals were provided by the Fred Harvey Phantom Ranch lodge. Food for these individuals was transported to Phantom Ranch by the NPS mule packer.

B. Rhodamine Dye Study. Principle Investigator: USGS, Arizona District Office.

1. Objectives. The objective of this USGS study was to determine the water-mass movement at constant and fluctuating-flow releases.

2. Locations. About 90 liters of Rhodamine Wt dye were introduced into the Colorado River from the transformer deck of Glen Canyon Dam. Samples were collected at the gages below Glen Canyon Dam (0.85 river miles (mi) downstream from the dam), at Lee's Ferry (16 river mi downstream from the dam, in an eddy on the right bank 17.3 river mi below the dam just below the Paria River confluence, and near Grand Canyon (103.4 river mi downstream from the dam).

3. Parameters evaluated and methodology. Water samples were collected at each sampling site and analyzed in the field for concentration of dye. Samples covered the full dye cloud at the three upstream sites, and the peak and tail of the cloud at the downstream site. Dye concentration in samples retained was reanalyzed in the USGS laboratory in Tucson under uniform temperature conditions.

C. Bedload Measurements. Principle Investigator: USGS, Arizona District Office.

1. Objectives. The objectives of this USGS study were to measure sediment transported of bedload during constant flows of 5,000 cfs at one point along the channel and to compare that transport rate with transport at higher steady flow (measured previously) and at 5,000 cfs flows that are a part of daily fluctuations.

2. Location. Bedload transport samples were collected on the Colorado River above National Canyon (09404120).

3. Parameters evaluated and methodology. Data were collected on bedload, bottom material, suspended sediment, water discharge, velocity profiles, water temperature, and

bed configuration. Bedload samples were collected using two different types of samplers: a Helley-Smith and a new pressure-differential-type sampler referred to as the "Darth Vader." Bedload samples were collected from ten cross-sections and repetitively from single verticals.

D. Nutrient Evaluations. Principle Investigator: AGF, Phoenix Office.

1. Objectives. The objectives of this study, conducted by AGF and FWS, were to determine input concentrations and loading rates for nutrients, organic matter, and zooplankton from water passing through the dam and to measure these same constituents 16 miles downstream at Lee's Ferry. AGF, FWS, and USGS personnel assisted in the collection of water quality samples. For information on the USGS nutrient evaluations, please refer to Section IV, Part A, on pages 10-11.

The water discharged through Glen Canyon Dam constitutes more than 90 percent of the average flow entering Lake Mead. Nutrients delivered from the depths of Lake Powell through the dam are a major source for primary production in the tailwater, and particularly so for the reach between the dam and Lee's Ferry.

This information, when combined with measurements of discharge, volume, and rate of flow will provide the basis for determination of import-export rates and budgets for that reach.

2. Locations. Water was withdrawn as it passed through the drift tubes in Glen Canyon Dam and along a transect approximately one-quarter mile above the boat dock at Lee's Ferry.

3. Parameters evaluated and methodology. The following parameters were measured during this study: (1) dissolved nitrate-nitrite nitrogen; (2) dissolved ammonia; (3) Kjeldahl nitrogen; (4) total phosphate phosphorus, (5) orthophosphate phosphorus; (6) silica; (7) dissolved organic matter; (8) fine particulate organic matter; (9) coarse particulate organic matter, and (10) zooplankton. Dissolved nutrients and organic matter were determined on samples filtered through Whatman GF/A glass-fiber filters (0.7 micron). Fine particulate organic matter was that fraction which passed through a 1-mm mesh nylon net, but was captured by the glass-fiber filters, and the coarse organic fraction was that portion of the sample remaining on the net. All nutrient and dissolved organic matter samples were refrigerated following collection and held at low temperatures during transport to the water quality laboratory in Phoenix.

Particulate organic matter samples were kept frozen during this same period. Samples were taken at approximately 10-hour intervals in an attempt to collect from the same water mass at both locations. Hydrolab[1] (Model SVR2-SU Sonde Unit) measurements (water temperature, conductivity, pH, and dissolved oxygen) also were taken at the Lee's Ferry station.

E. Beach Study. Principle Investigator: NPS, Grand Canyon National Park.

1. Objectives. The effects of two discharge regimes (steady flows and the resumption of fluctuation flows) were evaluated on beach profile and bank-stored groundwater quality at five sites in the river corridor. Four objectives were identified for this NPS study: (1) measure the effects of fluctuating versus constant discharge on beach profiles on a daily basis; (2) measure desiccation rates of beach soils under constant discharge; (3) measure the effects of fluctuating versus constant discharge on bank stored water movement through beaches; and (4) measure the effects of fluctuating versus constant discharge on bank-stored water quality in beaches.

2. Locations. Five sites were chosen for study: one site above Lee's Ferry (RM -10 [Right (side of river when looking downstream)]) and four sites below Lee's Ferry (RM 51 [Left], RM 81.1 [Left], RM 122.1 [Right], and RM 194.1[Right]). Each site was a large, stable beach with a maximum diversity of beach micro-environments in its reach, including: eroding versus aggrading faces, low versus high gradient slopes, return channel versus reattachment deposits (except RM 81.1 [Left]), fine (silt) versus sand substrates, and substrate above the 40,000 cfs stage. Historical data on beach profiles was available for three of the five sites.

3. Parameters evaluated and methodology. NPS personnel and volunteers evaluated four parameters: beach profiles, desiccation of beach soils, bank storage, and water quality of bank storage. Study sites were initially set-up during an 11-day, two-boat river trip (operated by the Reclamation river logistics contractor O.A.R.S., Inc.) in late September 1989 by surveying a 50-foot grid over each beach surface. A finer scale was established where possible. Plastic-coated scour wires were implanted to a depth of 0.5 m at each node on the grid. At three sites, nine piezometers (wells) monitored bank-stored water head and quality. The wells ranged in depth from 1.3 to 3 meters. A soil texture survey

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[1]Hydrolab is a trademark and trade name of Hydrolab Environmental Data Systems of the Hydrolab Corporation, Austin, TX.

was conducted on each site. Sampling to determine beach soil desiccation rates was conducted at 5 centimeter (cm) and 50 cm depths at the approximate 12,000 cfs, 28,000 cfs, and 40,000 cfs stages on each site.

F. Aerial Photography. Principle Investigator: GCES, Flagstaff Office.

1. Objectives. The objective of the Reclamation aerial photography was to document October 1989 conditions at 5,000 cfs in order to compare to similar photography taken October 21-14, 1984.

2. Locations. The photographic study area was from Glen Canyon Dam to Pierce Ferry along the Colorado River corridor (approximately 296 mi) and from Cameron to the confluence with the mainstem along the Little Colorado River (approximately 40 miles).

3. Parameters evaluated and methodology. To achieve the study objectives, black and white, continuous coverage of the river corridor at a scale of 1:3000 taken at 6,000 feet above mean sea level was requested from the Reclamation contractor. The black and white photography was designed to yield stereo coverage (40 percent overlap between each frame). A Cesna 206 aircraft (fixed-wing) with two pilots was used for the photography. The contract called for one set of black and white contact prints, one set of black and white negatives, a photographic index map of the flight lines flown and the number of pictures for each flight line, and a completion report (detailing pertinent information on the photography such as weather conditions, flight conditions, area of coverage, and any other information to interpret the imagery).

Two, white aerographic panels (2 feet by 6 feet per section of panel) in the shape of an "X" were placed 100 meters apart on the vermillion colored Navajo Sandstone formation on the north side of the Colorado River above Three Mile Bar. The panels were placed to enable scaling of the aerial and video photography.

G. Video Imagery. Principle Investigator: GCES, Flagstaff Office, and Reclamation, Upper Colorado Regional Office.

1. Objectives. The objective of the Reclamation aerial video imagery taken from helicopter was to test the use of video photography for research use in Glen and Grand Canyons. Video photography is less expensive to procure, yields immediate use and/or viewing, and can be entered into a computerized data base for viewing on a screen, frame by frame.

2. Locations. The color, video photography was acquired from Glen Canyon Dam to Lee's Ferry (approximately 16 mi), the lower 10 miles of the Paria River above its confluence with the mainstem, 10 miles above and below the Little Colorado River, and the Little Colorado River from the confluence to Grand Falls (approximately 70 mi).

3. Parameters evaluated and methodology. Color, video photography of the river corridor was taken approximately 2000 feet above ground level from a Bell Jet Ranger 206 Series helicopter. A Tyler helicopter nose mount was used to hold an Ikegami 730 video camera. The mount is a camera platform that allows for internal control and a yields a steadier image than hand-held video photography. A Sony 6800 video tape deck recorded the image on rolls of 3/4 inch color, video film (each roll contains 20 minutes of film). A black & white and a color monitor inside the helicopter allowed for immediate viewing of the image. Ground panels placed 100 meters apart were placed in the Glen Canyon Tailwater at Three Mile Bar to facilitate scaling of the photography.

H. Still Photography. Principle Investigator: Reclamation, Upper Colorado Regional Office.

1. Objectives. The objective of the Reclamation still photography was to document activities in the Glen Canyon tailwater for use in reports, presentations, and for historical interest.

2. Locations. Photography was made through the entire 16 miles of the Glen Canyon tailwater from both land and boat locations.

3. Parameters evaluated and methodology. Color, slide film was used to take photographs of scientific areas of interest, spawning bars, scenic locations, gages, anglers and researchers.

I. Trout Fishery Access. Principle Investigator: HBRS, Madison, Wisconsin.

1. Objectives. The objective of this study, conducted by HBRS, Inc., was to evaluate the effect of flow on boater access in the Lee's Ferry trout fishery above Three Mile Bar. In previous studies, the constriction at Three Mile Bar has been identified as the most commonly cited problem for boat anglers on the 16 mile stretch of the Colorado River between Glen Canyon Dam and Lee's Ferry.

2. Locations. Observations were made from the largest boulder situated on the river left (when looking downstream) near the downstream edge of the major part of the constriction known at Three Mile Bar. This constriction is approximately located at RM -3.4 above Lee's Ferry.

3. Parameters evaluated and methodology. The parameters of interest in this study were the success or failure of each attempt to pass Three Mile bar. Each attempt was evaluated on two dimensions. A run was described as successful if at the end of the attempt the boat was in deep water on the opposite side of the restriction from which it started. A run was described as clean if no obvious problems were encountered during the attempt. Attempts were classified as clean unless the boat and/or motor hits rocks or one or more of the boaters left the boat and pulled the boat over the constriction. Other data collected include time of attempt, horsepower and make of motor, number of passengers, length of boat, whether the boat was piloted by a fishing guide, and direction of the attempt.

A staff gage was installed at RM -3.6 (Left) prior to the October work and the gage was read from the shoreline several times during the day when flow conditions were changing. In addition, data on river stage (measured at five minute intervals) was collected using a staff gage and an automatic stage recorder installed during the November field work.

The access data collected will be analyzed using a discrete choice model. The estimated discrete choice model will predict the probability of a successful attempt as a function of the river stage as well as other variables.

J. Isolated Pool Study. Principle Investigator: GCES, Flagstaff Office.

1. Objectives. The objective of the Reclamation study was to study the presence or absence of isolated pools or backwaters.

2. Locations. The entire 16 river mile reach between Glen Canyon Dam to Lee's Ferry was evaluated.

3. Parameters evaluated and methodology. Backwaters (isolated and connected) were identified from aerial photography taken October 21, 1989. A census was taken during the 5,000 cfs flow test by visual observation from a motorized raft. The condition of the backwaters (aggradation and/or degradation by bedload material, access eliminated, size, and presence or absence) was noted for the site locations identified from the aerial photography and in the field.

K. Spawning Bar Analysis. Principle Investigator: AGF, Phoenix Office.

1. Objectives. Study objectives of the AGF study were to survey by standard USGS methodology a set of spawning bars in the Lee's Ferry reach and to measure particle size distribution of sediments forming these bars.

2. Locations. Spawning bars approximately 0.9 and 6.6 river miles below Glen Canyon Dam (these sites are called RM -14 and -8 respectively) were surveyed and sampled during the study.

3. Parameters evaluated and methodology. Topographic surveys of the two spawning bars were accomplished with Electronic Distance Meter (EDM). USGS personnel made transit surveys at two spawning bars. Particle size distribution was measured across transects perpendicular to the long axis of the bars. A point intercept method was used to measure surficial sediments. Maximum and minimum diameters were measured of each particle underlying 1 meter marks on a tape stretched from interior vegetation line to approximately 3 meters beyond the water's edge. Degree of embedment was classified by a 4-point scale with intervals of 25 percent. Sediments were also excavated to a depth of 10 cm in the interior, middle, and river bound sections along the transects. Coarser particles (>2.5 cm diameter) were fractionated by screening and weighing in the field. The remaining portion was bagged and returned to the laboratory for screening and weighing.

L. Cross-Sectional Evaluation. Principle Investigator: GCES, Flagstaff Office.

1. Objectives. The objectives of the Reclamation cross-sectional evaluation was to determine depths in the tailwater (using a fathometer), establish transect point along the direction of travel (using photographic stations, written map descriptions, and representative sections of the channel), and to provide cross-section measurements at 0.3 mile intervals.

2. Locations. Selected aquatic habitat areas within the 16 river mile reach between Glen Canyon Dam to Lee's Ferry were studied.

3. Parameters evaluated and methodology. A descriptive scale was developed to qualitatively separate, by visual observation the bedload substrate material into separate categories based on size of material from fine silts to cobbles of 5-6 inches. Data was collected by personnel

traveling the cross sections by motorized raft. A Lowranz[2] X16 Fathometer was used to measure channel depth.

V. STEADY FLOW TEST RESULTS

The following section outlines the number of samples collected, the period of sampling, specific problems encountered, an estimate of the costs incurred, and suggestions for changes for future studies. Only preliminary results are given for many of the studies, pending complete analysis of the data and preparation of final reports by the responsible researchers.

A. Dam Rating, Flow Characteristics, and Water Quality.

1. Number of samples collected. The following number and type of samples were collected and measurements made: streamflow measurements (36), velocity profiles (10), water quality field measurements (numerous), nutrient samples of dissolved and totals (59), major ions (28), suspended sediment samples (28), and total organic carbon (approximately; 59). The numbers of samples of streamflow measurements, velocity profiles and suspended sediment include samples collected for bedload measurements discussed in Section C, page 20.

Information on the following macronutrients were collected: nitrogen (NH+ORG at N, T), nitrogen (total NH_4 as N), phosphorus (dissolved), phosphorus (dissolved ortho as P), nitrogen (dissolved NO_2+NO_3 as N), phosphorus (total ortho as P), nitrogen (dissolved NH_4 as N), nitrogen (total NO_2 as N), and nitrogen (total NO_2+NO_3 as N). Information on the following major ions were collected ("+" = cations and "-" = anions: calcium (dissolved +), chloride (dissolved -), ROE (dissolved at 18°C), fluoride (dissolved -), magnesium (dissolved -), turbidity (NTU), potassium (dissolved +), silica (dissolved), sodium (dissolved +), pH, specific conductance, alkalinity total ($CaCO_3$), sulphate (turbidity of dissolved -), and bromide (dissolved -). In addition, total organic carbon information was collected.

2. Period of sampling. Samples were taken from October 4-15, 1989.

3. Specific problems encountered. There was too much work for the number of personnel in the field. Communications with personnel at remote sites (i.e., gages at National Canyon and Diamond Creek) was difficult to non-existent.

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[2]The Lowrance X-16 is a sonar, micro-computer assisted, recording depth sounder manufactured by Lowrance Electronics, Inc. of Tulsa, OK.

4. Costs. A preliminary, proposal cost estimate (prepared by the USGS Water Resources Division, Tucson, AZ; dated August 18, 1989) for labor, overtime, travel, vehicles, and report time was $12,680 for the gage work, and an estimate for labor, overtime, travel, sample analysis was $19,800 for the water quality sampling. The cost of two river trips to reinstall the Glen Canyon Dam gage and install instrumentation and cablecars on the gages downstream was $3,394.00. The dam rating, flow characteristics, and water quality cost approximately $35,874.

5. Changes for future study. Future work of this type requires more personnel, lighting for night work, and better communications with remote sites.

B. Rhodamine Dye Study.

1. Number of samples collected. Thirty samples over the dye cloud, spaced at 2 minute intervals were collected at the upstream site, 29 at Lee's Ferry spaced at 15 to 30-minute intervals, 22 in the eddy at about 45-minute intervals, and 10 near Grand Canyon at about 45-minute intervals. Many more samples were collected and analyzed, but only those containing dye and a few samples for background fluorescence determination were retained for reanalysis in the laboratory.

2. Period of sampling. Dye was introduced at the dam at 5 p.m. on October 8 and the tail of the dye passed the downstream sampling point at about 5:30 p.m. on October 12. Sampling continued at a downstream site until October 13, when it was determined that the dye must have passed and been too dilute to measure. Passage time of the dye at the site below the dam was 1.05 hours, and at Lee's Ferry was 12.4 hours. Passage time of the full dye cloud was not measured at the site near Grand Canyon, however, the trailing edge of the dye cloud was sampled.

The measurement of dye movement from the dam to the first site (gage below Glen Canyon Dam) and the second site (gage at Lee's Ferry) were made at a very steady 5,000 cfs. The measurement from Lee's Ferry to near Grand Canyon was made under the fluctuating flows of the 2 days that followed the steady-flow period (Graph 1).

Travel time and velocity of the dye-cloud peak in reach 1 (Glen Canyon Dam to the gage below Glen Canyon Dam) was 1.03 hr and 0.83 mi/hr (1.21 ft/s), respectively; in reach 2 (Glen Canyon Dam to Lee's Ferry), 20.2 hr and 0,83 mi/hr, and in reach 3 (gage at Lee's Ferry to gage near Grand Canyon), 67.0 hr and 1.30 mi/hr (1.91 ft/s). Total time

from introduction of dye to the last sample containing dye at the near Grand Canyon site was 3.9 days. Peak dye concentration at the downstream site was about 2 micrograms per liter (parts per billion).

3. Specific Problems Encountered. The dye measurement was added to the plan very late in the planning process required that supplies and equipment be purchased and equipment borrowed in a "crisis" mode at the end of a fiscal year, when any purchasing or transactions are difficult.

Time for thorough planning was not available. Equipment was received just in time to make the measurements and function and calibration could not be checked. Lack of time to adequately train personnel and to "check out" equipment in part led to the failure to sample the leading edge of the dye cloud at the downstream site. The plan for introduction of dye was not well thought-out ahead of time, and the process was cumbersome, required many people, and may have resulted in a double peak in dye concentration curve observed at the first site.

4. Costs. The Rhodamine Dye study cost approximately $21,826.

5. Changes for future study. A longer time from approval to implementation would allow time for planning of a more efficient program that is more likely to give all the information wanted.

C. Bedload Measurements.

1. Number of samples collected. A total of 390 bedload samples, five suspended-sediment depth-integrated cross-sections, six discharge measurements (several of which included multiple-depth velocity profile measurements), and three bed-material cross-section samples were collected.

2. Period of sampling. Samples were collected between October 7 and 12, 1990.

3. Specific problems encountered. The logistics of helicopter transport of personnel and equipment in and out of the canyon were difficult. However, equipment and provision problems were corrected after coordination with the NPS.

4. Costs. An estimate of the costs for data collection, data analysis, salaries, and travel was $81,200.

5. Changes for future study. The study design was sound, however, there is a need to measure bedload over a complete diel hydrograph. Measurements should also be made at other

steady flows, i.e., 12,000 cfs, 25,000 cfs, and above 35,000 cfs.

D. Nutrient Evaluations.

1. Number of samples collected. Samples were collected at Glen Canyon Dam, Lee's Ferry, Paria River, and at two springs in the Lee's Ferry reach. A total of 32 series of samples were collected.

2. Period of sampling. Sampling began on the morning of October 5 (prior to the flow test) and concluded in the afternoon of October 10 (after the flow test). During this period, three series of samples were collected (pre-, post-flow, and during the flow). Each series contained a day and night set (midnight and noon) from Glen Canyon Dam and one series at Lee's Ferry (approximately 8 hours later).

3. Specific problems encountered. Scientists were over-taxed, with some individuals working from 8 a.m. to 11 p.m. on days which required combined nutrient and spawning bar sampling. Planning time was insufficient and, as a result, anticipated schedules were not always met and logistical support was not always available.

4. Costs. Costs for nutrient and organic matter analyses were borne by the Arizona Department of Environmental Quality. Manpower, per diem, and travel costs for AGF personnel totaled approximately $2,000. Equivalent costs for FWS personnel totaled $7,470. Nutrient evaluations cost an estimate of $2,000. An estimated total of $11,470 was expended for the nutrient evaluations.

5. Changes for future study. Sampling should be extended to include depth profiles of Hydrolab variables, nutrients, organic matter, and zooplankton in Lake Powell above Glen Canyon Dam. Measurement of primary production and respiration need to be made at least for the Lee's Ferry reach. Future studies should also incorporate measures of trout stranding, behavioral responses of fishes to steady and fluctuating flows, effects of desiccation on algal and invertebrate fish food resources, and changes in physico-chemical parameters and fish populations in selected back-waters. All of these studies obviously cannot be ac-complished during every controlled flow period, so they should be partitioned into relevant seasonal objectives.

Adequate time and manpower must be allowed for development of study designs, coordination of efforts, provisioning of logistical support, and integration of products if these studies are to be carried out properly. In addition, all studies should be reviewed prior to initiation by the Senior

Scientist and his research advisory panel to ensure their credibility.

E. Beach Study.

1. Number of samples collected. The number of samples collected were: 300 soil profile samples (60 samples for each of the five sites), 720 soil desiccation rate samples (20 samples/transect for three transects per site for two sampling periods at six sites), and 360 water quality samples (120 samples taken from three locations [piezometers, river, and backwaters]).

2. Period of sampling. Beginning on October 3, one or two crew (depending on the site) were transported to each site by helicopter where other access was not possible. Data collection of beach profile changes was conducted daily during low discharge cycles for 2 to 3 days prior to initiation of the constant discharge test, during the 4-day test, and for 1 to 3 days following the test. All sampling was completed by October 16. Head level and water quality data were collected in piezometers and in the river on daily basis, or more frequently when discharge changes were rapid.

Sediment samples were returned to the laboratory and dried to constant mass at 60°C. Laboratory analyses of sediment samples include sieving for textural determination, soil pH, and other geochemical parameters. Water quality analyses included pH and alkalinity. A total of 120 samples (10 low flow and 10 high flow pre-test samples, 20 during-test samples, and 10 low and 10 high post-discharge samples per site) were analyzed for cation (Ca, Mg, Na, K) and anion (Cl, Fl, SO_4, bicarbonate) concentrations by the NAU geochemistry staff at the Bilby Research Center.

3. Specific problems encountered. All crews reported insufficient staffing and more help was needed. In particular, bank-stored groundwater data collection required two individuals/team for collecting and processing samples. Equipment problems included failure of a field pH meter, sedimentation of several piezometers, failure of one titration unit, and loss of several scour wires. Because of their distance from Glen Canyon Dam, some sites required extensive work during the nighttime hours, and better lighting was required.

4. Costs. The cost of the river trip to set-up the study was $5,917.00. Other costs, totaling $38,523, included: salaries, helicopter transport, equipment, lab analyses, and overhead. The total for the beach study was approximately $44,400.

5. Changes for future study. Increased emphasis should be placed on evaluating changes in specific topographic features by higher density sampling, especially within topographic features of interest (e.g. return channel, downstream cutbanks, etc.). Fathometer analysis of channel morphology should be included in future studies. Equipment improvements should include: Electronic Distance Meter (EDM) or similarly accurate surveying devices; fathometer; stainless steel scour wires with resin-based anchors; and improved scour wire installation equipment.

Improved piezometer installation techniques will be required for future studies. Other equipment improvements include pre-fabricated piezometers; Hydrolab or similarly advanced water chemistry technology; better bailers for piezometers; and continuous data recorders for river stage and bank-stored water temperature.

F. Aerial Photography.

1. Number of samples collected. A total of 1,246 9-by-9-inch black and white photographic prints (and associated negatives) correlated with six flight line index maps were delivered by the contractor.

2. Period of sampling. The plane and pilots operated out of the Page, Arizona airport. Three days of photography were acquired during October 7-9.

3. Specific problems encountered. The contractor did not deliver the photography at the scale (1:3,000 or 1-inch on the photo equals 250 feet on the ground) requested due to the use of a 6-inch focal length of the camera. The average scale was 1:4,800 (or one inch on the photo equals 520 feet on the ground) for 30-40 percent of the photography, with 1:5000 being the largest scale. Upon recognition of this error, the contractor agreed to reprint the photography at the proper scale. However, the error in scale is significant in that resolution of the enlarged prints has been diminished.

Hurricane Hugo passed through Arizona during the first week of October. If the weather system had created unstable air and cloud cover over Grand Canyon, the aerial photography would have been cancelled until weather conditions were improved. This would have necessitated a rescheduling of the 5,000 cfs constant flow. It was fortunate that the weather during the constant flow period was excellent with less than 10 percent cloud cover.

The two, white aerial target panels in the Glen Canyon Dam tailwater were not visible in the black and white aerial

photography. Either the panels need to be larger or of another color to be visible and useful in scaling.

4. Costs. The aerial photography cost $38,798.

5. Changes for future study. To ensure 1:3,000 scale photography taken at 6,000 feet above mean sea level an aerial photographic camera with a focal length of 12 inches is necessary.

G. Video Imagery.

1. Number of samples collected. The video photography yielded 10 rolls of color video film at a resolution of 360 lines of resolution, which has an approximate scale of 1:3,000 to 1:4,000 (true scale to be determined).

2. Period of sampling. Video photography was gathered from October 6-8.

3. Specific problems encountered. No problems were encountered.

4. Costs. The video imagery cost approximately $3,344.

5. Changes for future study. Future video photography should request a specific scale which would be most useful to research objectives. Placement of several ground panels for scaling would facilitate scaling of photography.

H. Still Photography.

1. Number of samples collected. A total of 6 rolls of 24 exposures (144 slides) were taken.

2. Period of sampling. Photographs were taken between October 6-9.

3. Specific problems encountered. No problems were encountered.

4. Costs. The still photography cost approximately $500.

5. Changes for future study. No changes suggested.

I. Trout Fishing Access.

1. Number of samples collected. A total of 293 observations were made during the 5,000 cfs flow weekend. In addition, another 232 observations were made during the weekend of November 16-19. Overall 400 of the attempts to pass Three Mile Bar were successful and no difficulties

encountered. Another 48 attempts were successful but during these attempts the anglers either hit rocks with their boat or motor or pulled the boat over the bar. Another 27 attempts were made in which the anglers were unsuccessful in passing the bar but did not hit rocks. Finally, another 50 attempts occurred in which the anglers were unsuccessful in passing the bar and hit their boat or motor on rocks during the attempt.

2. Period of sampling. Data was collected from 6 a.m. on Thursday, October 5 through 2 p.m. on Sunday, October 8. Additional data was collected from 6 a.m. on Thursday, November 16 through noon on Sunday, November 19.

3. Specific problems encountered. Most difficulties related to the reading the registration number of boats and the staff gage, particularly during periods of high use and/or low light conditions.

4. Costs. Estimated cost for travel, data collection, analysis, and reporting was $15,143.

5. Changes for future study. This study will provide a great deal of information about boating access at Three Mile Bar. There are other areas at which boater access may be a problem. Future studies may focus on collecting data on access problems at these other points.

J. Isolated Pool Study.

1. Number of samples collected. A total of 21 backwaters (connected and isolated) were identified from October 21, 1984, aerial photography. A total of 24 backwaters were identified during the 5,000 cfs flow period. Eleven backwaters (52 percent) present in 1984 were absent in 1989. Six backwaters (29 percent) were altered. Four backwaters (19 percent) remained similar in size. Three backwaters not present in 1984 were present in 1989.

2. Period of sampling. Samples were collected during October 6-9.

3. Specific problems encountered. No problems were encountered.

4. Costs. The isolated pool study cost approximately $2,000.

5. Changes for future study. No suggestions are made for future studies.

K. Spawning Bar Analysis.

1. Number of samples collected. A total of 14 samples were collected from the two bars (nine from RM -14 and five from RM -8).

2. Period of sampling. Samples were collected during October 6-9.

3. Specific problems encountered. Available manpower was overtaxed, with some individuals working from 8 a.m. to 11 p.m. on days requiring nutrient and spawning bar sampling. Planning time was insufficient and, as a result, anticipated schedules were not always met and logistical support was not always available.

4. Costs. Approximately $250 was spent on equipment and $350 on labor for a total of $600.

5. Changes for future study. The distribution of redds on the spawning bars was an item of information that was not collected during the study period as the trout spawning normally peaks during December. This information should be gathered by future studies of this type.

L. Cross-Sectional Evaluation.

1. Number of samples collected. A total of 54 cross-sections were sampled.

2. Period of sampling. Samples were collected during October 6-9.

3. Specific problems encountered. The effect of riffles and air bubbles effected the accuracy of the graph chart. The velocity of the motor boat was very variable. Identification of the exact area where fathometer soundings were taken was difficult to locate exactly and relocation at a future date is unrepeatable. Difficulties were experienced in maintaining the boat over the thalweg due to momentum of the boat, currents, and other factors. There were limitations in equipment for accurately measuring the channel bottom. Light and shadow effect problems were encountered which limited visibility of the channel by reducing light penetration from 5-8 feet (under good conditions visibility ranged from 15-18 feet).

4. Costs. The cross-sectional evaluation cost approximately $2,000.

5. Changes for future study. A side-scan sonar would be more effective in developing a bathymetric map. Also,

multiple fathometers placed on a horizontal plane to the surface and measuring perpendicular to the direction of travel would refine data collection.

VII. DISCUSSION

The October 1989 low flow studies provided an opportunity for the GCES team to acquire essential ecological and recreation information. It also provided the opportunity to determine how we could start integrating scientific programs. One of the major objectives was to learn from the effort and apply that knowledge to the broader GCES research flow studies. Of particular importance was developing an understanding of ecosystem response, how much money was expended, and how the information can be used.

A. Information Learned.

1. Environment. Specific information on the effect of steady, low flows on the ecosystem of the Glen Canyon Dam tailwater reach collected by the nutrient, beach, aerial photography, video imagery, still photography, isolated pool, spawning bar, and cross-sectional studies are pending completed analysis of the information gathered during the October 5,000 cfs flow study.

2. Discharge. Mass movement of water released from Glen Canyon Dam at 5,000 cfs travels at a slower rate (about 1 mile per hour) than expected. Fluctuating flows at a higher discharge than 5,000 cfs pass through the mass of water with the Rhodamine tracer dye.

3. Recreation. During studies of boater access, approximately three-fourths of all boaters successfully navigated Three Mile Bar. Success rates were very low for flows less than 3,000 cfs and were near 100 percent for flows above 10,000 cfs. Fishing success was poor at 5,000 cfs as trout appeared not to feed at the steady flow. However, fishing success was very good upon resumption of fluctuating flows following the constant 5,000 cfs flows. This may be due to an increase of food organisms in the drift created by the rising waters.

B. Cost of the 5,000 cfs Flow Studies.

1. Cost of Regulated Flow. The cost for the steady flows provided by Western Area Power Administration was $64,000 (Appendix 5). The decrease in estimated cost was due to an interchange of power with Hoover Dam, lower actual purchase rates, a change in operations at other Colorado River Storage Project powerplants, and reduced loads. It was estimated that expenses could have been as high as $171,500

if interchange had not occurred and on-peak premium price had been 28 mills per kWh rather than 21.5 mills per kWh.

2. Cost of the Research Studies. A total estimate of $257,195 was expended for the research portion of the low flow October 1989 studies. This amount is an estimate and includes items such as salaries, travel, per diem, laboratory costs, helicopter and fixed- wing photography, and other miscellaneous costs incurred. A cost breakdown of the studies is given below:

Dam Rating, Flow Characteristics and Water Quality	$35,874[3]
Rhodamine Dye Study	$21,826
Bedload Measurements	$81,200
Beach Study	$11,470
Aerial Photography	$44,440
Video Imagery	$ 3,344
Still Photography	$ 500
Trout Fishery Access	$15,143
Isolated Pool Study	$ 2,000
Spawning Bar Analysis	$ 600
Cross-Sectional Evaluation	$ 2,000

3. Total Estimated Cost of the 5,000 cfs Flow Study. Based upon the estimates for the regulated flow and the research studies, a total of $321,195 was expended by the 5,000 cfs flow study. This is approximately 0.40 percent of the fiscal year 1989 total power revenues of $81,286,688 from Glen Canyon Dam (Western Area Power Administration 1989).

D. How the Information Gathered Will Be Used. The information gathered by the 5,000 cfs flow study will be useful to managers and scientists to plan, implement, and achieve successful data collection for future scheduled research flows for Phase II of the Glen Canyon Environmental Studies program. The amount of pre-planning, logistical support, and coordination between several agencies and several scores of field researchers for a study area of the magnitude of Glen and Grand Canyons is an immense effort. Every attempt to streamline, refine, and improve communication, coordination, and integration should be made. This goal can only be achieved by learning from past experience and making a commitment to improve cooperation.

Measurements made during the study period (in flow and sediment) do not in themselves directly answer the specific questions being

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[3]The costs for the three USGS flow studies (Dam Rating, Flow Characteristics, and Water Quality; Rhodamine Dye Study; and Bedload Measurements) totaled approximately $138,900. The figures given here are an approximate break-down.

asked about the relation of flow to resources, but they do provide much-needed information for directing future work. Information on release of water from bank storage, significance of spring flows at 5,000 cfs main stem flow, the rate of transport of water particles with respect to the surface wave, and the amount of bedload transport at constant versus steady flows, characteristics of water chemistry at moderately low flows, and trends in water chemistry along the canyon at steady flow is required to develop the understanding of the physical system needed to ultimately answer the management questions being asked.

Upon the completion of analysis of the information gathered by specific research studies, final reports will be available for review and information. These "pieces of the puzzle" will become part of a complete data base on the response of the Glen and Grand Canyon ecosystem and recreation to a steady flow of 5,000 cfs.

VII. SUPPORT AND LOGISTICS

The 5,000 cfs constant flow study could not have been completed without the cooperation of individuals representing the Federal and State agencies and groups (Appendix 3). Recognition is given below to each group.

A. Arizona Game and Fish Department. Assistance in the collection of Glen Canyon Dam nutrient and spawning bar studies was given by the AGF Lee's Ferry creel clerk, Kirsten Tinning.

B. Bureau of Reclamation. Assistance at Glen Canyon Dam was given by Dick White and Norbert Schmidt from the Operations and Maintenance Division. Video photography was obtained through the assistance of the Upper Colorado Region's helicopter pilot, Bob Calderwood, and photographer, Michael Phillips. The latter also provided still photography. The GCES Flagstaff office personnel provided boat transportation and field assistance in data collection were given to the trout fishery access study, the cross-sectional evaluation, for the insertion of the Rhodamine dye, and for the AGF water quality sampling.

C. National Park Service. Helicopter transport, permits (aerial and Rhodamine dye), and equipment were provided by the NPS at South Rim, Grand Canyon National Park. Boat transportation of USGS and NPS personnel was provided by Tom Workman, the NPS ranger at Lee's Ferry. Permits for camping and aerial photography were given by Glen Canyon National Recreation Area.

D. U.S. Fish and Wildlife Service. Boat transportation and field data collection was obtained through the assistance of Frank Baucom and Debra Bills, from the FWS, Phoenix.

E. U.S. Geological Survey. Logistical support and coordination of the USGS gaging station work was provided by the USGS Flagstaff subdistrict office. Eleven people from the Flagstaff office, four from the District office in Tucson, and one from the National Research Program in Tucson participated in measurements at gaging stations, the dye study, topographic surveys of spawning bars, and bedload sampling. Field laboratory vehicles and equipment for sampling and field analysis of sediment and water samples were provided by the Tucson and Flagstaff subdistricts. USGS offices in North Dakota and Missouri loaned fluorometers, automatic samplers, and some supplies for the dye study. The USGS Hydrologic Instrumentation Facility in Bay St. Louis, LA, facilitated delivery of some needed supplies.

F. Western Area Power Administration. Controlled flows were obtained through the cooperation of the Western Salt Lake City Area Office.

G. Glen Canyon Fishing Guides. Glen Canyon fishing guides contributed informal observations of fish behavior in the Glen Canyon tailwater. Two guides reported that rainbow trout were sluggish and easily caught by hand following the insertion of the Rhodamine dye. Several guides reported that fishing success improved following the resumption of fluctuating flows.

LITERATURE CITED

U.S. Department of the Interior. 1984. Draft Lee's Ferry Upriver Recreation Plan and Environmental Assessment. National Park Service, Glen Canyon National Recreation Area. February 1984, NPS 2184, 37 pp.

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Western Area Power Administration. 1989. Fiscal Year 1989 Colorado River Storage Project Final Power Repayment Study. Prepared by the Salt Lake City Area Office.

APPENDIX 1

GLEN CANYON ENVIRONMENTAL STUDIES

October 6-8, 1990 Constant Flow: 5000 cfs

RESEARCH PLAN (OUTLINE)

A. Research From Glen Canyon Dam to Lake Mead:

Aerial Photography

Fixed-wing black and white 1:3000

Glen Canyon Dam to Pierce's Ferry
Little Colorado: Cameron to Main stem
Paria: about 10 miles upstream

Bur. of Rec. Helicopter, 2000' above surface, TV color

Glen Canyon Dam to Paria
Mainstem at Little Colorado, up and down stream 10 mi.
Paria: about 10 miles upstream

Requirements:

Contracts
Permits
Ground truth white crosses (possible)

Research:

Comparison with 1984 photos
Beach and bar survey
Need to develop appropriate mapping procedures.

B. Research from Glen Canyon Dam to Diamond Creek

Stream Discharge

Use of Stream Gages at:

Glen Canyon Dam
Lee's Ferry
Grand Canyon (Phantom Ranch)
Diamond Creek

Requirements:

Installation of cables and cable cars
Placement of personnel at sites
Sampling times:
Staggered: Oct. 7,8,9,10 at Glen Canyon Dam and Lee's Ferry
8,9,10,11 at Grand Canyon
9,10,11,12 at Diamond Creek

Research:

Discharge measurements during gage setup and beach measurement trip (early September)

Ratings: during flux (while installing)
prior (installation), during, and after constant flow

Bedload sampling: during at only Diamond Creek

Flow models, equilibration time, bed load changes.

Beach Dynamics

Measurements of beach sediment change processes and bank storage water

Requirements:

Selection of two or three appropriate beaches, tied to beach survey data
Placement of teams with equipment (possible oars boat trip)

Research:

Detailed survey of sediment loss (or change), possible use of time lapse photography, tied to flows, both fluctuating and constant.

Sampling change in bank storage water levels and chemistry using shallow tubes driven in beach.

Sampling period:
Two day prior to constant flow to two days after.

Water Chemistry

Changes in nutrients over time and through the system

Requirements:

Personnel at gage sites
Availability of cold storage and rapid transport equipment
Possible hydrolab at certain sites
Availability of qualified labs to do analyses

Research:

Test for total and dissolved P, NH3, nitrate, nitrite, kjeldahl or total N, organic matter (coarse, fine, dissolved, silica.

Sampling:
Timing: to approximate following water mass

(staggered downstream, four times per 24 hrs at each site on days when sampled)

Water Mass Movement (a possible study)

Determining movement of a particular mass of water through the system

Requirements:
Selection of appropriate inert tracer (e.g., rhodamine)
Personnel in place (use gage sampling personnel)

Research:
Use tracer to test model (developed prior or after?)

Sampling:
Place tracer at gage sites on same day after system has reached equilibrium (or closest to it.)

C. Research From Glen Canyon Dam to Lee's Ferry

Calibration of Dam Discharge

Determine relationship between dam releases and stream gage data

Requirements:
Gage in place just below Glen Canyon Dam
Personnel in place during constant flow

Research:
Calibrate rating of gage

Access at 3-Mile Bar

Determine relationship between boat access and flows

Requirements:
Staff gage placed at 3-mile bar, permanent location but removable, must be in water at 1000 cfs and observable from survey location. (May need reconnaissance trip prior to setting gage)

Research:
Test survey and observational procedures with staff gage in position.
Calibrate staff gage to upstream Glen Canyon gage.

Bathymetric Mapping

Generate a preliminary bathymetric map of upper 16 miles.

Requirements:

Boats for upstream access

Research:

Follow thalweg
Identify possible transects for channel x-section survey
Preliminary analyses of Cladaphora substrate
Qualitatively estimate Cladaphora biomass above and below 5000 cfs flow level.

Trout Spawning

Determine spawning grounds at 5000 cfs

Requirements:

Selection of 3 spawning bars (may need reconnaissance trip or use meeting with guides.)
Boat access

Research:

Determine boundaries of spawning areas
Determine area of redds survival
Extrapolate to upper 16 miles using aerial photos

APPENDIX 2

United States Department of the Interior

BUREAU OF RECLAMATION
UPPER COLORADO REGIONAL OFFICE
P.O. BOX 11568
SALT LAKE CITY, UTAH 84147

IN REPLY
REFER TO:
UC-410

SEP 18 1989

Glen Canyon Environmental Studies
Technical Study Teams

Subject: Glen Canyon Environmental Studies - Study Plan for the October 6-9, 1989, Steady Stream Flow Test

Enclosed for your information is the Study Plan developed by the Glen Canyon Environmental Studies (GCES) researchers and Dr. Duncan Patten for the October 6-9, 1989, steady flow test below Glen Canyon Dam. Currently, study teams are in the Canyon establishing test sites and initiating the work effort necessary to complete the proposed studies. The aerial photography negotiations are complete. Now all we need are the flows and good weather!

We will be working with the individual study groups to establish the logistical support required. If you have any questions regarding this study plan, please direct them to this office at (801) 524-6086.

Thank you for your continued support of the GCES program and the Environmental Impact Statement process.

Sincerely,

David L. Wegner

David L. Wegner
GCES Program Manager

Enclosure

GLEN CANYON ENVIRONMENTAL STUDIES

October 4-11, 1989

RESEARCH PLAN

On October 6 (1 AM) to Midnight October 9, 1989 the release from Glen Canyon Dam into the lower Colorado River will be a constant 5000 cfs. During this period, the Glen Canyon Environmental Studies plans on carrying out a series of research projects that, if done at a constant flow, will give information that is unattainable at the present low and fluctuating flows resulting from dam operations.

The following research plan gives a brief summary of the projects that will be accomplished during this period. In most cases, these projects are backed up with more detailed proposals prepared by the particular research group. These proposals are attached as appendices to this plan.

A. Research from Glen Canyon Dam to Lake Mead

Aerial Photography

Objectives:

Compare stream geomorphology and the consequences of fluvial process between 1984, when aerial photos were taken at 5000 cfs, and 1989.

Map beach and gravel bar areas at 5000 cfs for use in determining beach changes and surfaces available for trout spawning.

Identify Cladophora distribution in upper reaches of the mainstem.

Develop appropriate mapping procedures to be used for resource identification and possible application to GIS.

Justification:

Aerial photos were taken in 1984 at flows of 5000 cfs, thus the present constant flow will allow comparison of many features along the river. These include, primarily, features related to stream hydraulics and fluvial processes such as beaches and bars. It is believed that these features have changed and continue to change as a result of the present releases from the dam. By comparing two points in time with the same flow regime, estimates of the changes can be made. Cladophora, a medium for food sources for some of

the fish species in the stream, may have its substrate altered by various stream flows. An established baseline of Cladophora distribution at a constant flow will allow comparisons with past and future measurements.

Methods:

Aerial photography will be by both fix-winged plane and helicopter. The fix-wing plane will take B/W photos which will be used for 1984-1989 comparisons. The helicopter will take TV photography which will be used for local site and stream characteristics.

Fixed-wing plane: black and white plates 1:3000.
- Glen Canyon Dam to Pierce's Ferry
- Little Colorado: Cameron to Mainstem
- Paria: about 10 miles upstream

Helicopter: color TV movies, 2000' above surface
- Glen Canyon Dam to Paria
- Mainstem at Little Colorado up and down stream about 10 miles
- Little Colorado: upstream to Blue Springs
- Paria: about 10 miles upstream

Requirements:

Contract with fixed-wing photo contractor
Arrangements with BR helicopter
Permits from FAA and National Parks
Placement of ground truth crosses (possibly)

B. Research from Glen Canyon Dam to Diamond Creek

<u>Stream Discharge</u>

Objectives:

Establish stream gage rating at (1) known pre-constant flow fluctuating flows and (2) during constant flows.

Determine stream stage discharge during (1) pre-constant flow when fluctuating flows are known, (2) constant flow and (3) post-constant flow .

Determine relationship between dam discharge data and stream gage (below dam) discharge data.

Improve present flow routing model

Determine (if possible) the equilibration time for the system using stage discharge data.

Determine changes in bedload at Diamond Creek.

Justification:

Stream stage discharges have not been measured during GCES under low and fluctuating flows because high water releases occurred during the early years of GCES. Accurate discharge readings are necessary to better develop the flow routing model for the system. During the constant flow, stream discharge data will be used to determine how long it takes for the system to reach an apparent equilibrium at a constant 5000 cfs. This can be used to estimate other rates for reaching equilibrium at other flows and will allow for more accurate requests for prescribed flows in the future. With the system switching from fluctuating flows to constant flows, the bedload data at Diamond Creek should indicate how stable the bedload is at a constant flow and how the change effects the bedload. The data on the discharges from the dam have not always agreed with stream gage discharge data during fluctuating flows. Comparisons of these data during constant flows should allow establishment of a quantitative relationship between these measurements.

Methods:

Stream discharge gages (cables and cable cars) will be established at six locations between Glen Canyon Dam and Diamond Creek but for this study only four will be used. These are: Glen Canyon Dam, Lee's Ferry, Grand Canyon and Diamond Creek.

Data collection platforms may be established at each location to allow continuous monitoring of stage discharge with recorders as well as monitoring of additional stream parameters such as water chemistry.

Preliminary discharge measurements will be made during the gage setup and beach monitoring trips in early September.

Pre-constant flow (fluctuating flows) gage ratings will be made during the gage installation trip. Ratings will also be made during the constant flow and post-constant flow periods.

Bedload sampling will only be made at Diamond Creek.

Measurement and/or sampling periods for gage ratings, stage discharge calibration and other samples (e.g., water chemistry) will be staggered to take advantage of short personnel time and mass movement of water units. These sampling times will be:

Glen Canyon and Lee's Ferry: Oct. 7-10
Grand Canyon: Oct. 8-11
Diamond Creek: Oct. 9-12

Requirements:

Permission from NPS for installation of cables and cars, data collection platforms, and stage discharge recorders.
Permission from NPS for water sampling for bedload and other purposes.
Placement of sufficient personnel and equipment, and intergroup communication ability.

Beach Dynamics

Objectives:

Determination of the processes that move beach sediment on a dial basis.

Determination of the changes in bank storage water levels and chemistry of bank storage water.

Justification:

Beaches in Grand Canyon have gradually been reduced in size during the period following initiation of Glen Canyon Dam. This has been supported by comparison of aerial photos; however, the processes that influence this gradual degradation have not been accurately evaluated, especially on a short term basis. Changes of flows from low fluctuating to constant and back to fluctuating creates a good opportunity to determine the differential influences of fluctuating and constant flows on beach degradation. A constant flow of 5000 cfs, bordered by fluctuating flows, will also allow evaluation of the movement of bank storage water. Determination of water levels in the beaches will permit water sampling and therefore analysis of bank storage water chemistry. This will be useful in determining the relative role of bank storage water in the chemistry of eddies and the mainstem Colorado.

Methods:

Two or three beaches (tied to the beach survey) will be selected for measurements.

Beach aggradation/degradation processes on a daily basis will be measured with detailed surveying (more measurement transects than the beach survey) and possibly time-lapse photography.

Changes in bank storage water levels and water

chemistry will be measured using small tubes (PBC) driven into the beach along transects. Levels and samples can be measured and taken from these tubes.

Water chemistry parameters will be primarily nutrient compounds (e.g., nitrogen, phosphorus, etc.)

Sampling period will be at least two days prior to the constant flow (fluctuating flows) and two days after the constant flow. This will allow measurements of the response of the beach front to alteration of flow regimes from fluctuating flows into constant flows and the reverse.

Requirements:

Permission from NPS for two oars boat trips to place personnel on the beaches and to pick them up.

Permission from NPS to keep a team on a beach for at least a week and to place micro-survey sampling devices on the beach during this period.

Permission from NPS to place sampling tubes in the selected beaches and to take water samples.

Water Chemistry

Objectives:

Determine the nutrient changes in the river at one location over a period of time under different flow regimes.

Determine the nutrient changes over the length of the river system under different flow regimes.

Justification:

Nutrients in the river are the basis of primary productivity and therefore the support system for all trophic levels in the river. Fluctuating flows create irregular exchanges of nutrients with bank storage water, sediments stored in eddies and the channel, as well as other inputs. Nutrient dynamics measured under constant flow conditions, bordered by fluctuating flows, should allow evaluation of the change and movement of nutrients in the system under two sets of conditions and the gradient between them.

Methods:

Tests will be for total and dissolved phosphorus, ammonia, nitrate, nitrite, kjeldahl or total nitrogen, organic matter (coarse, fine and dissolved) and silica.

Sampling timing will approximate the movement of a water mass through the system, i.e., staggered downstream at the four gaging stations used for discharge measurements. Water samples will be taken four times per 24 hrs at each site on days when sampled.

Requirements:

Permission from NPS to install data collection platform at gaging sites (see Stream Discharge section).

Permission from NPS to take water samples.

Placement of personnel at gaging sites.

Availability of cold storage and rapid transport equipment to get samples to analytical laboratory.

Availability of qualified analytical labs to do analyses.

Possible placement of hydrolab on one or more platforms.

Water Mass Movement

Objectives:

Determine the rate at which a particular mass of water moves through the system from Glen Canyon Dam to Diamond Creek or Lake Mead.

Justification:

The movement of peaks and troughs through the system during fluctuating flows does not correspond with the movement of a particular mass of water, thus use of stage discharge measurements are only estimates of water movement through the system. Nutrient and sediment dynamics of the system are closely aligned with water mass movement as well as discharge whether fluctuating or constant. Knowing the rate of movement of a mass of water through the Canyon will make evaluation of nutrient and sediment dynamics more accurate. Initial measurements of mass movement should be based on constant flows to allow for future comparisons with different fluctuating flows.

Methods:

Use of an appropriate inert tracer (e.g., Rhodamine WT).

Tracer will be placed at gage sites on the same day after the system has reached equilibrium (or closest

thing to it.) Water will be sampled for evidence of tracer at the next downstream gage site and hopefully at lower gage sites if dilution has not weakened the signal too much. Placement and detection of the tracer must be accurately timed.

Requirements:

Approval by NPS of appropriate tracer.

Placement of personnel at gage sites during constant flow.

Availability of detection equipment for all sites (e.g., fluorometer for Rhodamine).

C. Research From Glen Canyon Dam to Lee's Ferry

Access at 3-Mile Bar

Objectives:

Determine the relationship between boat access and flows.

Justification:

Access by boats to the upper reach of the Colorado from Lee's Ferry to the Dam is limited by various bars and the amount of water flowing by them. 3-mile bar is the first impediment and therefore is used for access studies to the upper reach. Future surveys at 3-mile bar of the upstream movement of boats relative to flows is dependent on knowing the flows at the time of survey. Placement and calibration of a staff gage at 3-mile bar during the 5000 cfs constant flow will allow for accuracy of future surveys.

Methods:

Have a reconnaissance trip prior to the constant flow to determine the proper location for the staff gage.

Place staff gage in a permanent location, but the gage must be removable to prevent vandalism. The lower part of the gage must be in water at 1000 cfs and observable from survey locations.

During the constant flow, personnel will test survey and observational procedures with staff gage in position, and calibrate staff gage to upstream Glen Canyon Dam stream discharge gage.

Requirements:

Permission by NPS to place staff gage at 3-mile bar.

Reconnaissance trip prior to constant flow dates.

Personnel in place for survey testing during constant flow.

Bathymetric Mapping

Objectives:

Generate a preliminary bathymetric map of the upper 16 miles of the lower Colorado River (Lee's Ferry to Glen Canyon Dam).

Qualitatively identify and categorize through ground truthing the substrate types established on the Lee' Ferry 1984 5000 cfs map .

Justification:

The upper 16 miles of the lower Colorado River is considered a blue ribbon trout fishery. The topography and substrates of this reach greatly influence the ability of trout to spawn, trout food resources to develop and anglers and boats to have access. Based on 1984 constant flow photographs, substrates in and along the river have been mapped. 1989 constant flows will allow ground truthing of these mapped units. Tied to this is the need to have a more accurate bathymetric map of the river channel. On site bathymetric measurements to be compared with topographic maps and the 1989 aerial photos will permit development of a relatively accurate bathymetric map of this reach. This can then be used by researchers dealing with trout habitat and fishing access.

Methods:

Boat down stream from Glen Canyon Dam following the thalweg using sonar to determine bottom topography.

Preliminary identification of transects for future channel x-section measurements.

Ground truth substrates from 1984 map including preliminary analyses of Cladophora substrate and qualitative estimates of Cladophora biomass above and below the 5000 cfs flow level.

Requirements:

Boats for upstream research.

Personnel and equipment (e.g., sonar) for topographic and substrate analysis.

Trout Spawning

Objectives:

Determine trout spawning grounds and redd survivorship at 5000 cfs.

Justification:

Trout fishing in the upper reach is of economic importance to Arizona. The ability of the trout population to maintain itself rather than be continually stocked is an important consideration in management of this reach. Certain minimum flows may allow for sufficient trout spawning and survival to permit reduction in stocking. The availability of spawning grounds and survival of redds at low flows is not well known. Measurement of functional spawning areas and estimates of survivability of redds at 5000 cfs will greatly enhance the information on maintenance of the Glen Canyon trout population.

Methods:

At 5000 cfs, map the boundaries of spawning areas at three selected spawning bars. Selection of the bars may require a reconnaissance trip prior to the constant flow period or meetings with river guides.

At 5000 cfs, evaluate survival of redds (if present) at the selected spawning bars.

Using substrate mapping and aerial photos (1984 and 1989) extrapolate spawning areas and redds survival to full upper 16 mile reach.

Requirements:

Boats and personnel to work the selected bars and possibly for reconnaissance trip.

APPENDIX 3

United States Department of the Interior

BUREAU OF RECLAMATION
UPPER COLORADO REGIONAL OFFICE
P.O. BOX 11568
SALT LAKE CITY, UTAH 84147

IN REPLY
REFER TO:
UC-410

OCT 2 0 1989

Glen Canyon Environmental Studies
Low Flow Test Researchers

Subject: Glen Canyon Environmental Studies - Low Flow Test Researchers

We survived the October 6-9, 1989, study effort and from first analysis, we collected a tremendous amount of important information. The effort could not have been accomplished without your dedication and long hours.

So far, we have learned that the Rhodamine Dye works in the Colorado River, doesn't negatively impact the fish, and if properly handled, can work. Now, I just have to find a way to get red footprints off of the dam!

The aerial photography and video work was completed in spite of threatening weather earlier in the week, and from the initial evaluation of the photos it was also a success.

To make an operation like this work, everyone must work together. I think we made tremendous strides in understanding the ecosystem at 5,000 cfs, and towards a better integration of the environmental studies and results. Our intent is to pull together a summary report on our activities with the intent to discuss in detail at the November 14 and 15 technical team meetings. We will be contacting you for input to the summary report.

Thanks again.

Sincerely,

David L. Wegner

David L. Wegner
GCES Program Manager

cc: All researchers involved with the 5,000 cfs test (attached list)
Duncan Patten, Arizona State University

Glen Canyon Environmental Studies
Low Flow Studies
October 6-9, 1989
Alphabetical Researcher List

U.S. Geological Survey

Tucson Office: James Brown, Julie Graf, John Gray, Dave Hyndman, Bob Webb

Flagstaff Office: Don Bills, Frank Brewsaugh, Curt Crouch, Al Diaz, Bob Gauger, Greg Fisk, Bob Hart, John Rotte, Kent Sherman, John Sottilare, Wilma Smith

Arizona Game and Fish Department

Phoenix Office: Dennis Kubly, Devon Skinner

Flagstaff Office: Kirsten Tinning

National Park Service

Grand Canyon National Park: Jan Balsom, Mike Doster, Gerry Mitchell, Larry Nickey, Dave Osgood, Doug Ottosen, Peter Rowlands, Larry Stevens

Lee's Ferry: Chester Mycus, Tom Workman

Volunteers: Brian Cluer, Neil Cobb, Charleen Crabb, Michael Kearsley, Joyce Maschinski, David McCormick, Ted Melis, Peggy Pollack

Fish and Wildlife Service

Phoenix Office: Frank Baucom, Debra Bills

Bureau of Reclamation

Salt Lake City Office: Bob Calderwood, Reed Harris, Michael Phillips, Robert Williams

Glen Canyon Dam: Norbert Schmidt, Dick White

Glen Canyon Environmental Studies Office: Nancy Brian, Duncan Patten, David Wegner, Michael Yard

Volunteers: Helen Yard

Private Consultants

Hugh Hass, Gene F. Moody & Associates, Inc.
Gene F. Moody, Gene F. Moody & Associates, Inc.
Ron Rinas, Gene F. Moody & Associates, Inc.
Michael Welsh, HBRS

APPENDIX 4

ORIGINAL

Department Of Energy
Western Area Power Administration
P.O. Box 11606
Salt Lake City, Utah 84147

JUN 23 1989

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Mr. Wes Hirschi
Acting Regional Director
Bureau of Reclamation
Upper Colorado Regional Office
P.O. Box 11568
Salt Lake City, UT 84147

GLEN CANYON
ENVIRONMENTAL STUDIES
P. O. BOX 1811
FLAGSTAFF, AZ 86002

Dear Mr. Hirschi:

In response to your May 19, 1989, request, this is to confirm the ability for Western to accommodate sustained releases of 5,000 cubic feet per second (cfs) for a 4-day period in October 1989 at Glen Canyon Dam. I understand that this request is for the purpose of obtaining additional data for the Glen Canyon Environmental Studies (GCES).

As a participating agency in the GCES, we recognize the value in gathering additional information regarding critical resources in the Grand Canyon. I assure you that every attempt will be made by my staff to accommodate GCES needs. We assume that the data collection efforts will be coordinated to take maximum advantage of these special releases.

Please recognize, however, that in accommodating these special study releases, a significant impact to power generation will occur. I hope that, due to the significance of the changes to normal power operations, this request represents the extent of special release requests. Further, after consideration of the resultant changes required to normal operations to accommodate these releases, several qualifications are necessary.

The preferred time from Western's perspective would be the period you identified as "Priority One," the period from October 6-9. Your "Priority Two" period from September 29 through October 2 is not acceptable from a power system operation perspective since this latter period represents a transition from the summer season to the winter season when significant load and resource planning requirements also change. Should the need exist for an alternative date, Western supports the weekend of October 13-16.

After evaluation of the potential financial impacts due to the proposed special releases and deviation from normal water and power operations of Glen Canyon Dam and Powerplant, two impact components have been identified: a shift of onpeak hydrogeneration to the offpeak period, and additional onpeak thermal purchase requirements to meet firm load, which may be 935 MW at that time of year. Based upon (1) the large amount of purchase required (up to 500 megawatts per hour for many peak-load hours in the period), (2) the lack of flexibility in choosing the most attractive period to purchase, and (3) the need for the purchase to be relatively secure to meet firm load, a conservative estimate of the range of

total financial impact for this 4-day period could be $92,000. Purchase rates used in this estimate were current nonfirm rates. We believe financial impacts would be significantly greater if these special releases were for an extended period, and firm purchases were required.

Though Western will make every effort to maintain the 5,000 cfs constant releases, it is important to recognize the potential for emergency conditions during this period. In that event, it may be necessary to increase Glen Canyon releases and generation above the 5,000 cfs limit to maintain interconnected power system reliability. If an emergency condition should occur, Western will attempt to inform Reclamation as soon as possible of the pending changes.

Western's contact regarding the coordination of these special releases will be Mr. Jeffrey Ackerman (FTS 322-6209) in our Montrose District Office.

Sincerely,

Lloyd Greiner
Area Manager

cc:
Mr. John Allum
CREDA Marketing Committee
Director of Planning
Platte River Power Authority
Timberline and Horsetooth Roads
Fort Collins, CO 80525
(w/copy of incoming letter)

United States Department of the Interior

NATIONAL PARK SERVICE
GRAND CANYON NATIONAL PARK
P.O. BOX 129
GRAND CANYON, ARIZONA 86023-0129

IN REPLY REFER TO:
L7619(GRCA-8213)

JUL 13 1989

Memorandum

To: Project Manager, Glen Canyon Environmental Studies

From: Superintendent, Grand Canyon

Subject: Aerial Photography of the Colorado River Corridor

Thank you for your request regarding aerial photography of the Colorado River corridor for Phase II of the Glen Canyon Environmental Studies.

Your request, as described, is approved by this office pending final authorization by the Federal Aviation Administration's Flight Standards District Office. Please contact us again if some aspect (i.e., dates, altitudes) of the proposed flight changes.

for John H. Davis

cc:
Jack J. Washington, Flight Standards District Office #19, Federal Aviation Administration, 241 East Reno Avenue, Suite 200, Las Vegas, Nevada 89119

United States Department of the Interior
BUREAU OF RECLAMATION
UPPER COLORADO REGIONAL OFFICE
P.O. BOX 11568
SALT LAKE CITY, UTAH 84147

IN REPLY
REFER TO: UC-410

July 27, 1989

Glen Canyon Environmental Studies
P.O. Box 1811
Flagstaff, AZ 86002

TO: Private River Runners with Permits to Run the Colorado River during September/October 1989

The Glen Canyon Environmental Studies (GCES) has been directed (June 16, 1988) by the Assistant Secretaries for Water and Science and the Fish and Wildlife and Parks to quantify the impacts of the operations of Glen Canyon Dam on the natural and recreation resources of the Grand Canyon. Information is required on the affects of low flows on endangered fish species, the trout fishery, and beach erosion; as well as an economic analysis of operational options. To achieve these objectives, specific technical studies will be conducted during Phase II of the GCES.

An important study for this analysis is the acquiring of aerial photography of the Colorado River corridor from Glen Canyon Dam to Lake Mead. A flight of the Grand Canyon will be made this October. The 1989 photography will be compared to 1984 photography which was collected at 5,000 cfs in order to assess change in channel geometry, beaches, backwaters, and vegetation.

In order to provide a consistent data base for the aerial photography, flows from Glen Canyon Dam will be held at a constant 5,000 cfs for four days from October 6-9, 1989. We regret any inconvenience this may create for river running groups.

Should you have any questions or comments, please contact David Wegner, the Glen Canyon Environmental Studies Program Manager, at (602) 527-7363.

United States Department of the Interior
BUREAU OF RECLAMATION
UPPER COLORADO REGIONAL OFFICE
P.O. BOX 11568
SALT LAKE CITY, UTAH 84147

IN REPLY
REFER TO:

UC-430

JUL 27 1983

Mr. Lloyd Greiner
Area Manager
Western Area Power Administration
P.O. Box 11606
Salt Lake City UT 84147

Subject: Request for Specific Releases from Colorado River Storage Project (CRSP) Facilities (River Flow)

Dear Mr. Greiner:

As you are aware, we have been carefully coordinating specific flow requests for this summer and fall from CRSP dams. These requests are perhaps more difficult to accommodate due to the current low releases from all of the CRSP dams and we appreciate your concerns about the financial impacts to the power customers. We have analyzed the water availability problem and have found that we can support some of the requested flows while providing additional release water at CRSP dams to alleviate possible energy and capacity problems.

The following flows are approved for release from Flaming Gorge Dam:

Date	Flow (cfs)
July 30 - Aug 5	Releases to produce constant 1400 cfs flow at Jensen, Utah (estimated 1,100 cfs release)
Aug 6 - Aug 12	Fluctuating releases from the dam; 800 cfs at night and 2,600 cfs during the day
Aug 13 - Aug 19	Releases to produce constant 1400 cfs flow at Jensen, Utah (estimated 1,100 cfs release)
Sep 26 - Oct 2	Releases to produce constant 1400 cfs flow at Jensen, Utah (estimated 1,200 cfs release)
Oct 3 - Oct 9	Fluctuating releases from the dam; 800 cfs at night and 3,500 cfs during the day
Oct 10 - Oct 16	Releases to produce constant 1400 cfs flow at Jensen, Utah (estimated 1,200 cfs release)

The following releases are approved for release from Glen Canyon Dam:

Oct 6 - Oct 9	Constant releases of 5,000 cfs

All beginning dates of specific flows start at 0000 hours. All ending dates of flows conclude at 2400 hours. If there are questions regarding the details of these flows, please contact Mr. Randall Peterson at FTS 588-5571.

In order to minimize the power system impacts, we have purposely scheduled the highly fluctuating flows at Flaming Gorge Dam to coincide with the limited releases from Glen Canyon Dam. Additionally, we will provide releases from Crystal Dam of up to a maximum of 1,700 cfs during this same 4 day period. We would consider it prudent to evacuate as much storage as permitted by the fluctuation criteria at Crystal and Morrow Point Reservoirs in order to moderate any downstream impacts of the potentially higher generation at Blue Mesa and Morrow Point Dams. We also request that you increase or decrease the release from Crystal Dam as gradually as possible for the same reasons.

We understand the difficulties and impacts caused by these requests and appreciate your assistance. The Glen Canyon flows will meet the needs of the Glen Canyon Environmental Studies and the Flaming Gorge flows will provide aerial photography and backwater analyses not yet completed for the 1989 biological opinion.

Sincerely,

FOR W.J. HIRSCHI

Roland Robison
Regional Director

cc: District Manager
Western Area Power Administration
1800 South Rio Grande Avenue
Montrose CO 81401

Mr. Doug Young
Utah Division of Wildlife
c/o Utah Cooperative Fish Unit
College of Natural Resources
Utah State University
Logan UT 84321

Mr. Tim Modde, United States Fish and Wildlife Service, College of Natural Resources, Utah State University, Logan UT 84321

Mr. Keith Rose, Project Officer, United States Fish and Wildlife Service, 551-25 1/2 Road, Suite B-113, Independence Plaza, Grand Juction CO 81501

Mr. Harold Tyus, United States Fish and Wildlife Service, 1680 West Highway 40, Room 210, Vernal UT 84078

Mr. Bob Rusink, State Supervisor, United States Fish and Wildlife Service, 2060 Administration Building, 1745 West 1700 South, Salt Lake City UT 84104-5110

bc: Assistant Commissioner - Engineering and Research
Attention: D-3744

bcc: Power Operations Manager, Page AZ
Attention: GC-100
Chief, Curecanti Field Division, Montrose CO
Attention: CCI-100
Chief, Flaming Gorge Field Division, Dutch John UT
Attention: FG-100
UC-430, UC-410, UC-150, UC-700, UC-771, UC-600

United States Department of the Interior

BUREAU OF RECLAMATION
UPPER COLORADO REGIONAL OFFICE
P.O. BOX 11568
SALT LAKE CITY, UTAH 84147

IN REPLY
REFER TO:

August 21, 1989

To: Glen Canyon Environmental Studies Researchers

From: Glen Canyon Environmental Studies
Program Manager

Subject: Glen Canyon Environmental Studies - Planning Meeting for the October 1989 Steady Flow Studies

On Thursday August 31, 1989, a meeting will be held at the Glen Canyon Environmental Studies (GCES) office in Flagstaff, AZ to discuss the October 1989 steady flow studies. We are coordinating this meeting at the request of Duncan Patten in an attempt to focus our efforts and determine the level of detail required from each of you. To date, we have received four proposals for the October work. If we are to efficiently utilize the 5,000 cfs steady flows, we must coordinate our actions early.

The meeting logistics are as follows:

Date:	Thursday August 31, 1989
Time:	9:00 AM to 4:00 PM
Where:	GCES Program Office Flagstaff, AZ

The meeting will focus on the following points:

1. Review of the proposals received to date
2. Determination if the individual proposals can be accomplished during the four days of low flow
3. Determination if additional clarification or refinement is required
4. Determination of the logistical requirements and permits from Grand Canyon National Park
5. Determination of priority issues

The objective of this meeting will be to determine what we can accomplish. Then a full study plan, with all agreed upon studies, will be developed and presented to the individual bureaus, agencies and the Executive Review Committee.

We look forward to your participation. Please call 602-527-7363 to confirm your attendance.

United States Department of the Interior
NATIONAL PARK SERVICE
GRAND CANYON NATIONAL PARK
P.O. BOX 129
GRAND CANYON, ARIZONA 86023-0129

IN REPLY REFER TO:
N2219(GRCA-8213)
xL7619

SEP 20 1989

Mr. David Wegner, Program Manager
Glen Canyon Environmental Studies
Post Office Box 1811
Flagstaff, Arizona 86002

Dear Mr. Wegner:

Our staff has reviewed the Glen Canyon Environmental Studies' request to use Rhodamine WT (tracer) dye during the low flow studies for October 6 - 10, 1989.

We have concluded that use of the dye will be permitted. The following conditions apply (and will also be articulated on the research permit for the studies):

- The Rhodamine WT dye will be used according to label restrictions;

- Concentration of the dye at the point of entry will not exceed LC50 values for rainbow trout (300 parts/million). (The probably prescriptive rate for the dye will be approximately 30 liters per gaging station, depending on length of the reach and other variables);

- if there are observed effects, such as mortality or disablement of fishes, the operation will be ceased and the National Park Service notified immediately.

If there are any questions, or should a change in the study plan arise, please contact Jerry Mitchell at FTS 765-7753.

Sincerely,

for John H. Davis
Superintendent

cc:
Dean Radke and Julie Graf, U.S. Geological Survey, 300 West Congress, Tucson, Arizona 85701
Duncan Patten, Glen Canyon Environmental Studies, Center for Environmental Studies, Arizona State University, Tempe, Arizona 85281

United States Department of the Interior

GEOLOGICAL SURVEY

Water Resources Division
301 West Congress Street
Federal Building, FB-44
Tucson, Arizona 85701

Julie Graf
(602) 629-6671

For Release: Upon receipt -- (Prepared 10-03-89)

U.S. GEOLOGICAL SURVEY HYDROLOGISTS TO STUDY TRANSPORT CHARACTERISTICS OF THE COLORADO RIVER BY USE OF DYE TRACERS.

A red fluorescent dye will be put into the Colorado River at Glen Canyon dam at 7 p.m. on Sunday, October 8, 1989, as a part of the Glen Canyon Environmental Studies (GCES) low-flow studies. For those studies, discharge from the dam will be held at a constant 5000 cubic feet per second October 6-9 to provide information on the effect of low flows on trout, native fish, recreation, and camping beaches. The dye will turn the river a very bright red in the reach of river between the dam and Lees Ferry, and may be visible downstream from Lees Ferry. The dye to be used, Rhodamine WT, is nontoxic and is commonly used to "tag" a mass of water.

The rate of movement of the tagged mass of water and the extent to which it mixes with surrounding water will be measured by sampling at five U.S. Geological Survey gaging stations located about one mile below the dam; at Lees Ferry; at Phantom Ranch; above National Canyon; and above Diamond Creek. Concentrations of dye at Diamond Creek, about 240 miles below the point at which the dye will be introduced, are expected to be below 3 parts of dye per billion parts of water. As is always the case, Colorado River water should be treated according to National Park Service guidelines before it is used for drinking or cooking.

Note to editor: Julie Graf, contact person, will be at Marble Canyon Lodge, Marble Canyon, Az. (telephone 602 355-2225) from October 5 through 9.

Don Rabe
THE ARIZONA DAILY SUN
417 W. Santa Fe
Flagstaff, Arizona 86001

Mark Law
U.S. National Park Service
P. O. Box 129
Grand Canyon, Az. 86023

Barry Burkhart
THE ARIZONA REPUBLIC
120 E. Van Buren
Phoenix, Az. 85004

Mark Shafter
THE ARIZONA REPUBLIC
P. O. Box 1167
Flagstaff, Az. 86001

Lake Powell Chronicle
3 Elm Street
Page, Arizoan 86040

MOHAVE DAILY MINER
P. O. BOX 3909
Kingman, Arizona 86402

APPENDIX 5

Western Area Power Administration
Salt Lake City Area

COMPARISON OF ACTUAL VS. ESTIMATED IMPACTS TO PURCHASE POWER EXPENSES WITH OCTOBER SPECIAL RELEASES AT GLEN CANYON

November 11, 1989

Estimates of actual additional expenses incurred as a result of the 5,000 cfs constant release at Glen Canyon for the period from October 6 through October 9, 1989 are summarized in the attached Table 1. Based upon the analysis of actual power system operations during this period, Western concludes that an additional expense of $64,000 was incurred for this 4-day period.

An earlier estimates of expenses for this period of special release which was prepared in August, was estimated to be $92,000. This projected expense is summarized in the attached Table 2.

Actual expenses differ from those estimated in August because of the following reasons:

Use of Interchange -- Expenses were reduced since receipt of interchange energy reduced the total purchase power requirements. This interchange was comprised of intraproject interchange of approximately 9.2 gWh and interutility interchange of 8.7 gWh. If this interchange had not occurred, the on-peak premium price would have been 28 mills per kWh rather than 21.5 m/kWh. With this higher on-peak purchase rate, expenses could have been as high as $ 171,500. See Table 3, attached.

Lower Actual Purchase Rates -- Purchase prices both onpeak and offpeak were lower than initially estimated, which resulted in lower net expenses for each day in the 4-day period, with significantly lower expenses on Sunday.

Change in Operations At Other CRSP Powerplants -- In the initial estimate, it was assumed that foregone generation at Glen Canyon would be supplemented with purchases, only. However, in actuality, reduced generation at Glen Canyon was accommodated somewhat by adjusting generation at other CRSP powerplants (Flaming Gorge & Curecanti Unit) to more normal generation patterns.

Reduced Loads -- The pattern of load assumed in the initial projections was overestimated, and therefore the need for purchase power was assumed greater than what actually occurred.

Though the actual expenses incurred were less than originally estimated, the $64,000 additional expense resulted in a period representing roughly 1 percent of the total hours in the year and during a period of projected dry hydrologic conditions within the Upper Colorado River Basin. The foregone opportunity sales from the available interchange was not included in the $64,000 expense.

Though interchange was used to reduce purchase power expenses, the availability of interchange can not be assumed over an extended period during future months, particularly in future peak load months.

Our conclusion is that any future special releases at Glen Canyon (and any other CRSP facility) which substantially deviate from normal operations should be prudently evaluated and the potential costs of such temporary changes considered.

Table 1

ACTUAL IMPACT OF 5,000 CFS OCTOBER RELEASES

	FRI	SAT	SUN	MON	TOTAL	
DECREASED OFFPK PURCHASE W/IN PERIOD (E1) (MWH)	1,000	1,000	220	1,000	3,220	
INCREASED ONPK PURCHASE W/IN PERIOD (E2) (MWH)	-1,000	-1,000	-220	-1,000	-3,220	
INCREASED ONPK PURCHASE W/IN PERIOD (E3) (MWH)	-4,416	-4,416	0	-4,416	-13,248	
DECREASED SUBSEQUENT ON-PK PURCHASE (E4) (MWH)	4,416	4,416	0	4,416	13,248	
PREMIUM ONPK PURCHASE RATE (M/K)	21.50	21.50	21.50	21.50		
PREMIUM OFFPK PURCHASE RATE (M/K)	13.00	13.00	13.00	13.00		
AVE ONPK PURCHASE RATE (M/K)	18.70	18.70	18.70	18.70		
DECREASED EXPENSE OFFPK W/IN PERIOD	$13,000	$13,000	$2,860	$13,000	$41,860	'1/
INCREASED EXPENSE ONPK W/IN PERIOD	($116,444)	($116,444)	($4,730)	($116,444)	($354,062)	'2/
DECREASED EXPENSE SUBSEQUENT ON-PK	$82,579	$82,579	$0	$82,579	$247,738	'3/
TOTAL	($20,865)	($20,865)	($1,870)	($20,865)	**($64,464)**	

'1/ = E1*(PREM OFFPK)
'2/ = (-E2+-E3)*(PREM ONPK)
'3/ = E4 *(AVE ON-PK)

Table 2

ESTIMATED IMPACT OF 5,000 CFS OCTOBER RELEASES

	FRI	SAT	SUN	MON	TOTAL	
DECREASED OFFPK PURCHASE W/IN PERIOD (E1) (MWH)	860	859	852	942	3,513	
INCREASED ONPK PURCHASE W/IN PERIOD (E2) (MWH)	-860	-859	-852	-942	-3,513	
INCREASED ONPK PURCHASE W/IN PERIOD (E3) (MWH)	-3,927	-3,731	-201	-5,758	-13,617	
DECREASED SUBSEQUENT ON-PK PURCHASE (E4) (MWH)	3,927	3,731	201	5,758	13,617	
PREMIUM ONPK PURCHASE RATE (M/K)	24.00	24.00	24.00	24.00		
PREMIUM OFFPK PURCHASE RATE (M/K)	17.30	17.30	17.30	17.30		
AVE ONPK PURCHASE RATE (M/K)	19.00	19.00	19.00	19.00		
DECREASED EXPENSE OFFPK W/IN PERIOD	$14,878	$14,861	$14,740	$16,297	$60,775	'1/
INCREASED EXPENSE ONPK W/IN PERIOD	($114,888)	($110,160)	($25,272)	($160,800)	($411,120)	'2/
DECREASED EXPENSE SUBSEQUENT ON-PK	$74,613	$70,889	$3,819	$109,402	$258,723	'3/
TOTAL	($25,397)	($24,410)	($6,713)	($35,101)	**($91,622)**	

'1/ = E1*(PREM OFFPK)
'2/ = (-E2+-E3)*(PREM ONPK)
'3/ = E4 *(AVE ON-PK)

Table 3

IMPACT OF 5,000 CFS OCTOBER RELEASES WITH 28 M/K

	FRI	SAT	SUN	MON	TOTAL	
DECREASED OFFPK PURCHASE W/IN PERIOD (E1) (MWH)	1,000	1,000	220	1,000	3,220	
INCREASED ONPK PURCHASE W/IN PERIOD (E2) (MWH)	-1,000	-1,000	-220	-1,000	-3,220	
INCREASED ONPK PURCHASE W/IN PERIOD (E3) (MWH)	-4,416	-4,416	0	-4,416	-13,248	
DECREASED SUBSEQUENT ON-PK PURCHASE (E4) (MWH)	4,416	4,416	0	4,416	13,248	
PREMIUM ONPK PURCHASE RATE (M/K)	28.00	28.00	28.00	28.00		
PREMIUM OFFPK PURCHASE RATE (M/K)	13.00	13.00	13.00	13.00		
AVE ONPK PURCHASE RATE (M/K)	18.70	18.70	18.70	18.70		
DECREASED EXPENSE OFFPK W/IN PERIOD	$13,000	$13,000	$2,860	$13,000	$41,860	'1/
INCREASED EXPENSE ONPK W/IN PERIOD	($151,648)	($151,648)	($6,160)	($151,648)	($461,104)	'2/
DECREASED EXPENSE SUBSEQUENT ON-PK	$82,579	$82,579	$0	$82,579	$247,738	'3/
TOTAL	($56,069)	($56,069)	($3,300)	($56,069)	**($171,506)**	

'1/ = E1*(PREM OFFPK)
'2/ = (-E2+-E3)*(PREM ONPK)
'3/ = E4 *(AVE ON-PK)