RESULTS OF LAKE POWELL WATER QUALITY MONITORING SURVEY
December 1995

GLEN CANYON ENVIRONMENTAL
STUDIES OFFICE

FEB 1 1996

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William S. Vernieu
Glen Canyon Environmental Studies
January 31, 1996

## Introduction

The Bureau of Reclamation's current water-quality monitoring program on Lake Powell and its tailwaters consists of three main features: (1) quarterly lake-wide surveys of physical, chemical, and biological conditions; (2) monthly water-quality profiles and biological sampling of the Lake Powell forebay; and (3) continuous monitoring of the Glen Canyon Dam tailwater below the dam and at Lees Ferry for temperature, salinity, and dissolved oxygen.

Data from this program is collected and processed by the Glen Canyon Environmental Studies (GCES) office and stored in a relational database for subsequent retrieval and analysis. This database contains 30 years of information from various phases of Reclamation's long-term monitoring effort on Lake Powell. The results presented here are from the most recent quarterly survey, conducted from December 11, 1995, to December 15, 1995.

## Current Conditions

Conditions at Lake Powell during the December 1995 survey show the transition between the strong stratification of late summer and the maximally mixed conditions expected in later this winter.

Lake Powell experienced inflows well above average in 1995 that brought the surface elevation to 3693.75 feet on August 3, 1995. Releases from Glen Canyon Dam were increased on June 1, 1995 and continued above normal through the remainder of the year, bringing the reservoir to an elevation of 3682.34 during the December survey. Figure 1 shows reservoir inflows, releases, and surface elevation for calendar year 1995; values for 1994 are included for comparison.

The higher inflows and outflows have combined to route the summer runoff through the reservoir more quickly than in other years and with less influence from other mixing processes. The depth of the interflow of this runoff volume, coupled with the current winter's convective mixing processes have increased the thickness of the epilimnion in the forebay of the reservoir beyond that experienced in recent years. Because of this, the withdrawal zone for powerplant releases from Glen Canyon Dam is now well into the epilimnion. Consequently, water released from Glen Canyon Dam during January 1996 will have a higher temperature and lower salinity than water released during the past decade. Also associated with this epilimnetic withdrawal is an expected drop in overall nutrient concentrations in Glen Canyon Dam releases.

## Methods

The December 1995 Lake Powell survey was conducted from December 11, 1995, to December 15, 1995. This trip was led by Robert Radtke of the Upper Colorado Regional Office under the direction of the Glen Canyon Environmental Studies (GCES) office. Other crew members were Jeanne Korn, Valerie Saylor and John Nagy of the GCES office. All field work was conducted from the Reclamation's Uniflite 31 foot limnology vessel. Unsettled weather was encountered during the first part of the trip; conditions became calmer and warmer for the remainder of the trip.

Profiles of the physical water quality parameters of temperature, specific conductance, dissolved oxygen, pH and oxidation-reduction potential were conducted at 15 stations on Lake Powell. These stations ranged from the forebay near Glen Canyon Dam to Hite Basin on the Colorado River arm and Upper Piute Bay on the San Juan River arm (Table 1 and Figure 2). Secchi transparency, weather conditions and other observations were recorded at each of these stations.

**Table 1.** DECEMBER 1995 LAKE POWELL WATER-QUALITY MONITORING SURVEY STATIONS

| STATION | KILOMETERS | STATION | KILOMETERS |
|---|---|---|---|
| **Main Channel Stations** | | **San Juan Arm** | |
| Wahweap * | 2.4 | Cha Canyon * | 19.3 |
| Crossing of the Fathers * | 45.3 | Lower Piute Bay | 32.9 |
| Oak Canyon * | 90.5 | Upper Piute Bay * | 43.1 |
| Escalante * | 116.9 | | |
| Iceberg Canyon | 140.0 | **Escalante Arm** | |
| Lake Canyon | 158.9 | Davis Gulch | 11.9 |
| Bullfrog Bay * | 169.2 | | |
| Knowles Canyon | 193.2 | | |
| Lower Good Hope Bay | 208.5 | | |
| Scorup Canyon | 225.5 | | |
| Hite Basin * | 238.7 | | |

**NOTE:** Distances are from Glen Canyon Dam for main channel stations or from the main channel confluence for tributary stations. Sites sampled for chemical analysis are denoted by an asterisk (*).

Chemical samples for major ion and nutrient analysis were collected at eight of these stations to characterize major strata. These samples are being analyzed by Reclamation's Environmental Research Chemistry Laboratory in Denver, Colorado. Alkalinity titrations were performed in the field for each chemical sample collected. Biological samples for phytoplankton, zooplankton,

and chlorophyll concentration were collected at each site selected for chemical analysis. The results of chemical and biological sample analysis were not available as of the time of this report. They will be discussed in a separate annual report summarizing the past year's monitoring.

Data from the water quality profiling effort were collected and stored in data logging equipment in the field. These data were subsequently downloaded, edited, and combined with other field observations for entry into the Ingres WQWM database. The WQWM database resides on the SLCDG1 Data General Avion computer in Salt Lake City, Utah. The information was then retrieved for statistical and graphical analysis using applications based on SAS and SURFER software developed at GCES.

## Results

Information presented here is a summary of the water quality profiles collected on the December trip. Water quality profiles were taken at 15 stations on the Colorado, San Juan, and Escalante arms of Lake Powell (Table 1 and Figure 2). These profiles consist of the measurement of five basic physical parameters (temperature, specific conductance, dissolved oxygen, pH, ORP, and turbidity) at selected depths in the water column.

Isopleth plots of the information gathered by these profiles are shown in this report (Figures 3 and 4). These graphs represent a two-dimensional cross-section of the Colorado River main channel from the dam to the upstream Hite Basin station. Each line or isopleth on the plot represents the same value of a given parameter throughout the lake. This method of representing water quality shows larger scale patterns that exist throughout the lake, such as inflow density currents, thermal stratification, or areas of low dissolved oxygen.

Also included in this report are graphs of individual profiles from the December 1995 Lake Powell survey. Four selected main channel stations and two stations from the San Juan River arm are presented. In addition, two profiles from the Wahweap forebay station taken during late November 1995 and early January 1996 are included to show recent changes at this location with respect to the penstock withdrawal zone.

**Temperature.** Temperatures in the well-mixed surface layer of the reservoir showed little variation, ranging from 13.7 to 14.9 deg C, with the lowest temperatures occuring at the uppermost stations (Figure 3). The depth of mixing of this surface layer ranged from 60 meters at the Wahweap forebay station to 30 meters at the upstream Hite Basin station.

Temperatures in the hypolimnion were uniform at 7.0 to 7.5 deg C in most of the reservoir below depths of 80 meters. This results in a difference of approximately 7 degrees between the epilimnion and the hypolimnion. This difference is much less than that of the strongly stratified conditions of September 1995, which showed a temperature difference of nearly 20 degrees.

**Specific Conductance.** Specific conductance, an indicator of dissolved substances concentration, or salinity, ranged from 500 to 650 $\mu$S/cm (approx. 325 - 450 mg/L TDS) in the well-mixed surface layer of the Colorado River arm

of the reservoir (Figure 3). The lowest values existed in the central portion of the reservoir, near the mouth of Escalante Canyon, probably coinciding with the center of the previous summers snowmelt volume. Specific conductance was lower in the epilimnion of the San Juan River arm, approximately 450 $\mu$S/cm. These levels are much lower than levels seen during the past several years, since the high inflows of the mid 1980's.

Specific conductance in the hypolimnion of both arms of the reservoir below 80 meters was from 950 to 980 $\mu$S/cm (approximately 625 to 675 mg/L TDS). This level has remained constant through the past several years, showing a slight decrease, mostly from the gradual entrainment of inflow density currents. Overall, this bottom layer of the reservoir, below the level of the penstock withdrawal zone, has remained isolated from upper layers.

A body of water with specific conductance between that of the epilimnion and the hypolimnion exists at depths of 60 to 70 meters in the area upstream of Escalante Canyon. This is most likely due to cooler early winter inflows of intermediate density that interflow between the upper and lower layers.

**Dissolved Oxygen.** Dissolved oxygen values were high in the surface layer of the reservoir, essentially at full saturation due to atmospheric mixing; these values ranged from 6.5 to 8.0 mg/l (Figure 3). Locations exhibiting higher values result from increased oxygen solubility due to cooler temperatures at those sites.

In contrast, dissolved oxygen values in the hypolimnion drop steadily with depth below 100 meters, with values ranging from 4.5 to 1.5 mg/L. These low values represent a gradual and continual decrease in the oxygen concentrations of the hypolimnion. This decrease has been most notable during the last three years, further evidence of the isolation of that body of water.

Corresponding to the interflow of water with intermediate conductance noted above, higher dissolved oxygen values are observed at depths of 60 to 70 meters in the area upstream from Escalante Canyon. These oxygen values represent the fresh, well-oxygenated waters of the early winter's inflows of intermediate density. Also of interest is the zone of hypoxic water directly below this layer, centered around Bullfrog Bay. This is most likely due to increased concentrations of sediment and organic matter of higher oxygen demand that occur below the zone of interflow.

Complete anoxia, or absence of dissolved oxygen, was observed at two locations on Lake Powell in December 1995, Lower Piute Bay, on the San Juan River Arm and Davis Gulch, on the Escalante River Arm. Lower Piute Bay was without dissolved oxygen in the hypolimnion below 68 meters. Downstream of this station at Cha Canyon, hypolimnetic oxygen values were higher, approximately 2 mg/l, but still depressed. This hypolimnetic layer did not extend to the shallower upstream station at Upper Piute Bay, which was 60 meters deep and well oxygenated throughout the water column. The Davis Gulch station was anoxic below 66 meters. Complete anoxia has frequently been observed in recent years on the Escalante arm of Lake Powell; however, this phenomenon has rarely been seen in the San Juan arm and is possibly due to the increased sediment load to the hypolimnion from the high inflows of 1995.

**pH.** As expected, pH concentrations follow dissolved oxygen concentrations in an inverse manner (Figure 4). This is due to respiration processes that produce carbon dioxide ($CO_2$) besides consuming oxygen. $CO_2$, in turn, forms carbonic acid which acts to reduce pH values.

**Turbidity.** Turbidity patterns show the higher values of the dense inflow currents that are traveling along the reservoir bed in the upstream reaches of the reservoir (Figure 4). They also show the separation of this inflow current as an interflow of intermediate density well into the reservoir, supporting the similar pattern seen with specific conductance and dissolved oxygen.

Discussion

Throughout most of the reservoir, the epilimnion was mixed to a depth of approximately 50 meters. This depth ranged from a maximum of 60 meters at the Wahweap forebay station to a minimum of 30 meters at the Hite Basin station. This may be the result of the previous summer's high volume of snowmelt runoff, assisted by high releases from Glen Canyon Dam (Figure 1). As of the September 1995 survey, this runoff had extended to the downstream reaches of the reservoir and existed at depths from 10 to 30 meters, flowing below the warmer epilimnion of lesser density. With the onset of the winter cooling, these two layers have now become homogeneously mixed.

In addition to the profile taken at the Wahweap forebay station on December 11, 1995, profiles from the forebay monitoring program taken in late November and early January are shown. These profiles show that the Glen Canyon Dam penstock withdrawal zone is now within the epilimnion of the reservoir. Data from the continuous monitoring program conducted below Glen Canyon Dam show that releases are now warmer and of lower conductance than they have been for the last decade.

The severity of the winter usually dictates the amount of convective cooling that defines the depth of mixing of the epilimnion. An additional factor is the penstock depth that has been shown to limit the depth of mixing to that of the withdrawal zone. Considering the mild winter conditions of late 1995, it seems unusual that the epilimnion of the forebay is now mixed to below the penstock withdrawal zone. The key to this year's deeper mixing lies in the high volume of 1995 spring runoff and its short retention time.

The warm dilute spring runoff volume is of lesser density than most of the reservoir. In years of smaller inflow volumes and lower releases, this water overflows the surface of the reservoir and travels downstream a certain distance before its velocities are dissipated at the end of the runoff period. The thickness of this layer and its longitudinal extent are determined by its volume. This runoff volume is then subject to mixing with other reservoir water by various processes such as diffusion, wind mixing, and convection as the reservoir cools in the fall.

In 1995, the volume of spring runoff into Lake Powell was much larger than in past years (Figure 1). This large volume of water moved through the upper layers of the reservoir creating a thick layer of low density water. As releases from Glen Canyon Dam were increased in June 1995, this water was

carried further downstream in the reservoir and eventually incorporated into the reservoir releases. This has been shown by steadily decreasing specific conductance in the epilimnion at the Wahweap forebay station during 1995 and in the tailwater of Glen Canyon Dam. This thick layer of low density water in the downstream portion of the reservoir, augmented by the smaller layer of overlying surface water, was then subject to the winter's convective mixing processes. This process eventually resulted in mixing to depths below the penstock withdrawal zone.

High releases from Glen Canyon Dam throughout the last half of 1995 allowed the runoff to route through Lake Powell quickly, keeping it isolated from other reservoir mixing processes. This, combined with its large volume, has kept the quality of this water in striking contrast to the more saline water of the hypolimnion. It is expected that releases from Glen Canyon Dam will continue to be drawn from the epilimnion and will be of low salinity for the remainder of the winter months.

Past chemical sampling performed at Lake Powell shows that epilimnetic nitrate nitrogen levels, and possibly those of other nutrients, are approximately three to five times less than those of the lower hypolimnion. Therefore, a further implication of epilimnetic releases at Glen Canyon Dam is the reduction in nutrient concentrations in the tailwater.

While the epilimnion of the reservoir has been routed quickly through Lake Powell in 1995, the hypolimnion has remained isolated. Specific conductance in this layer has remained consistently high in the last decade with little mixing from overlying waters. Infusion of cold saline winter inflow enters this layer, but is of lesser significance due to low winter inflow volumes. As this layer remains isolated, further decreases in dissolved oxygen concentrations in the deep hypolimnion are expected. Hypoxic conditions, as seen in the upper Colorado arm and anoxia, seen in Escalante and San Juan arms may become more prevalent.

The next quarterly water quality monitoring survey will take place in late February or early March. This survey will document the full extent of the winter's mixing process, the continued changes in release water quality from Glen Canyon Dam, and set a baseline for limnological processes in the coming year. This trip will document antecedent conditions on which to evaluate changes occuring from the planned habitat building flows that will occur in late March 1996.

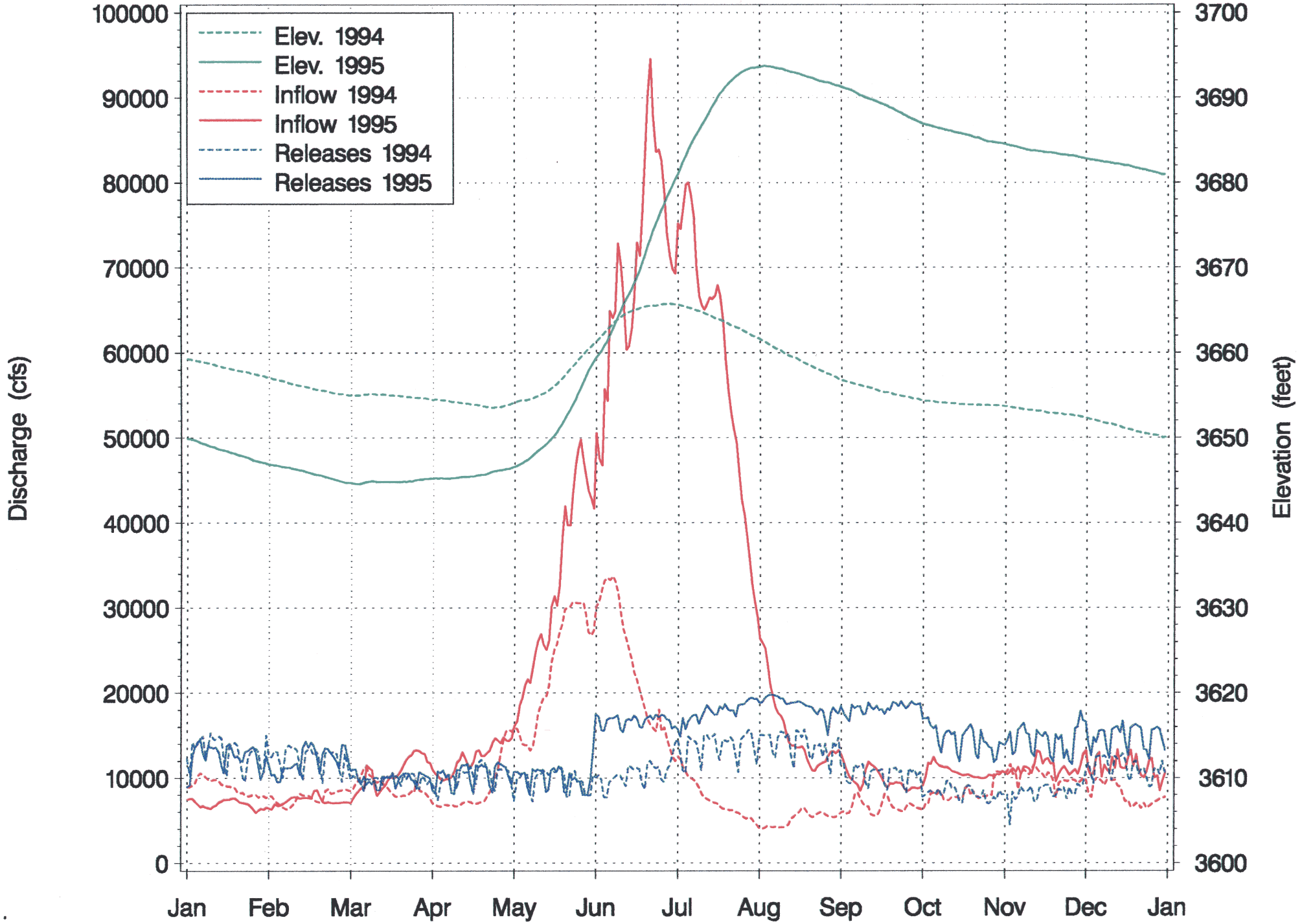



Figure 1. Lake Powell inflows, releases and reservoir elevation, 1994 & 1995

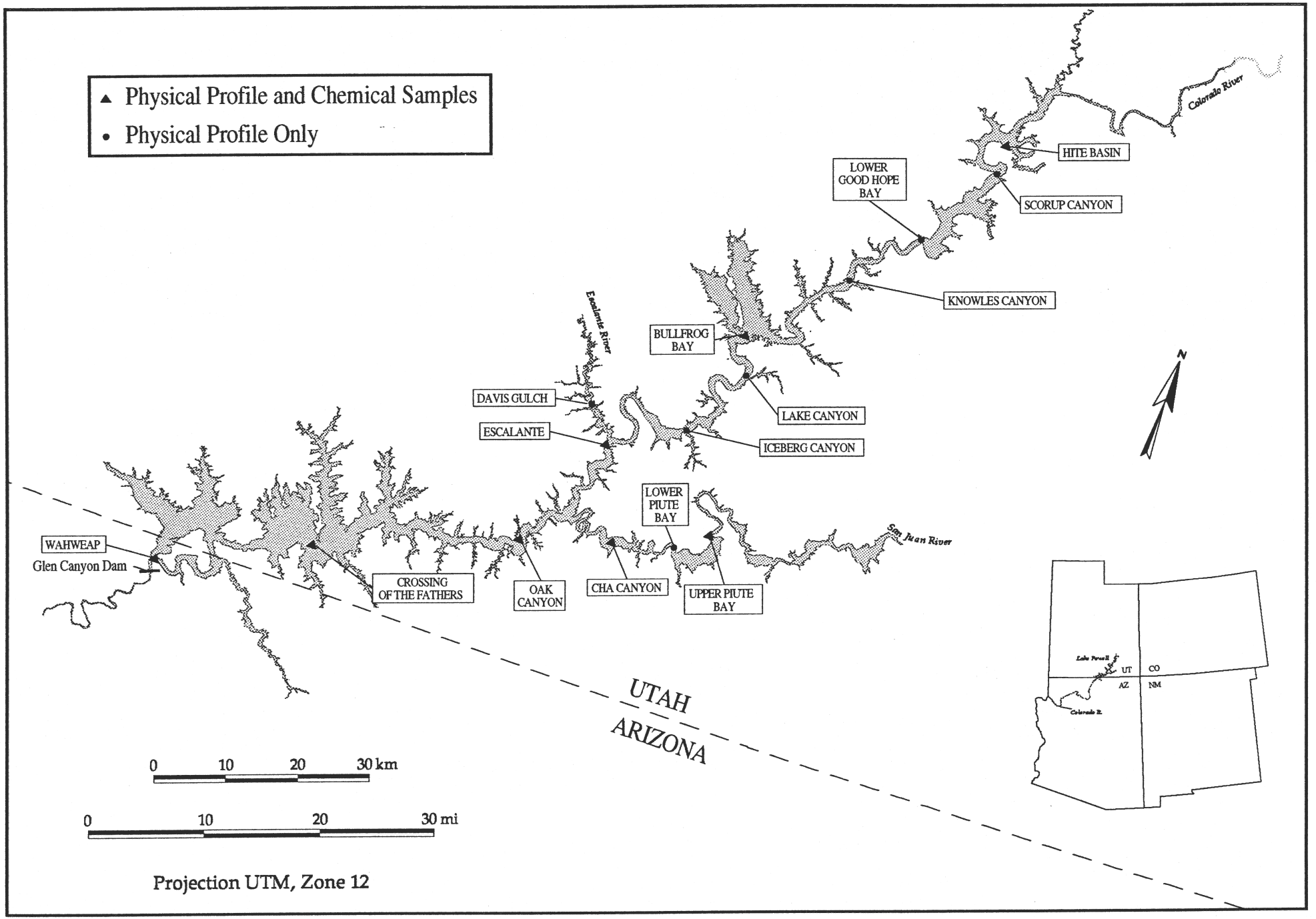



**Figure 2.** December 1995 water quality sampling sites at Lake Powell

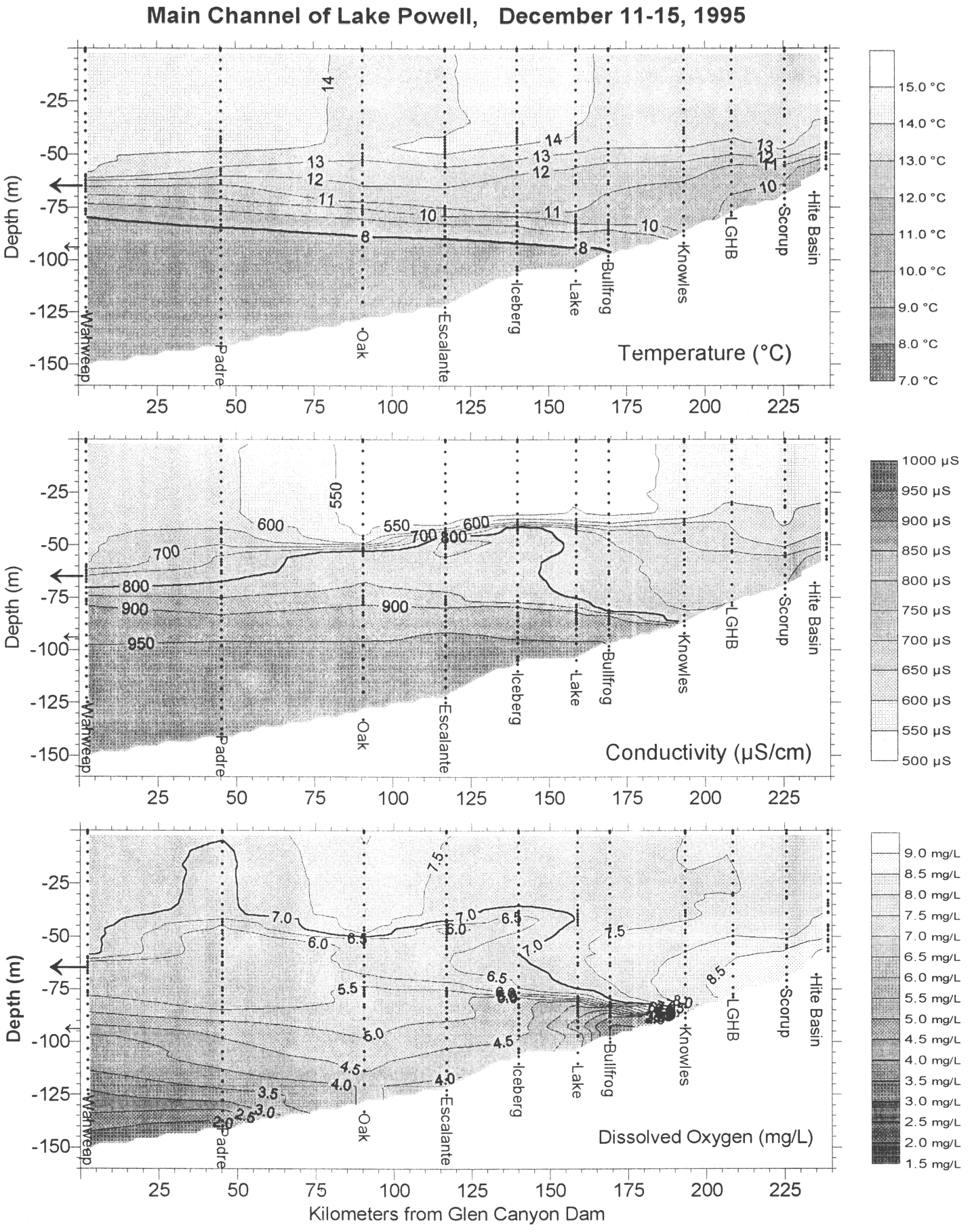



Figure 3: Temperature (°C), conductivity (µS/cm), and dissolved oxygen (mg/L) in the main channel of Lake Powell, December 11-15, 1995. Penstock depth = 64.7 m, river outlet = 94.0 m, lake elevation 3682 feet above sea level.

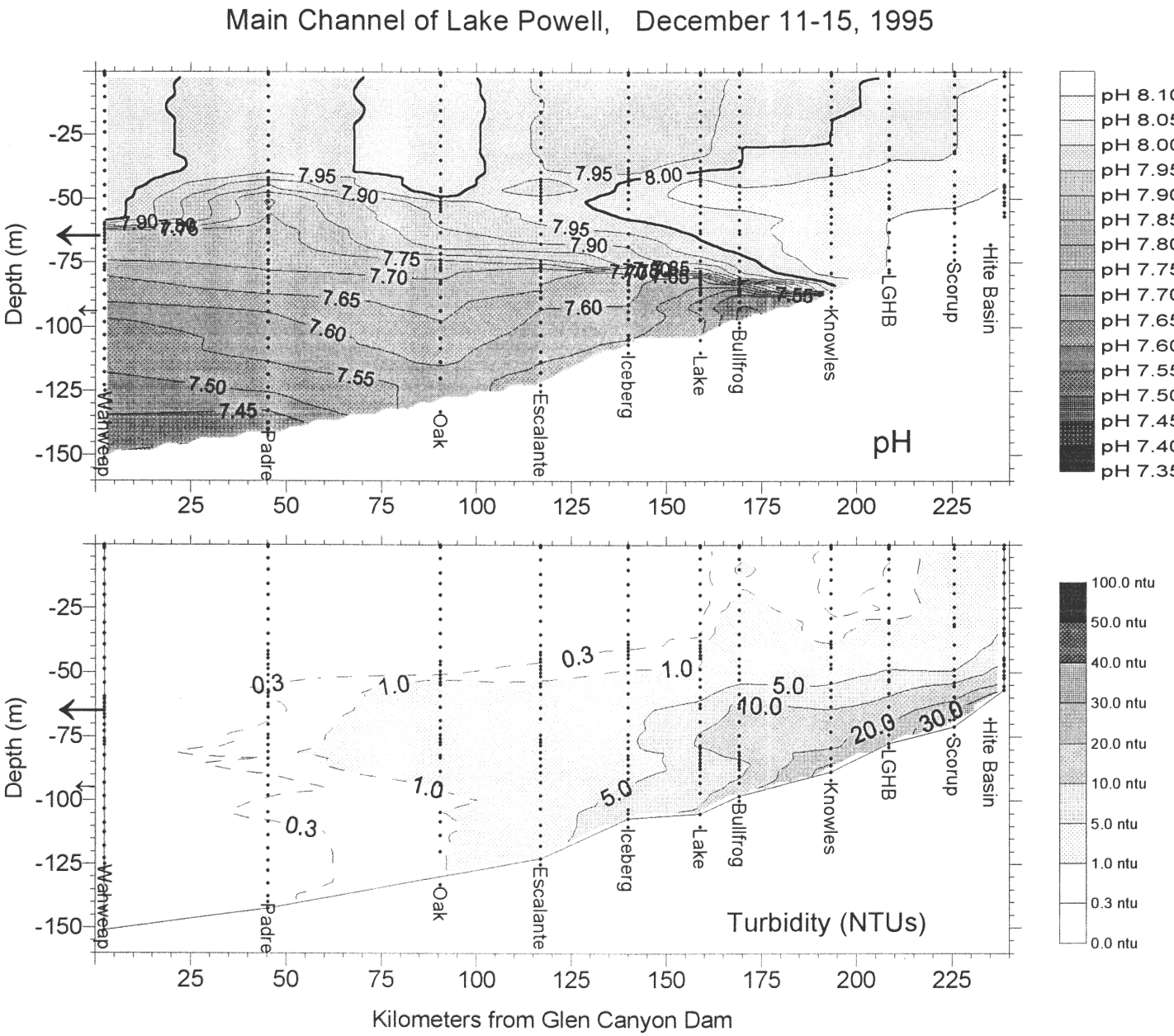
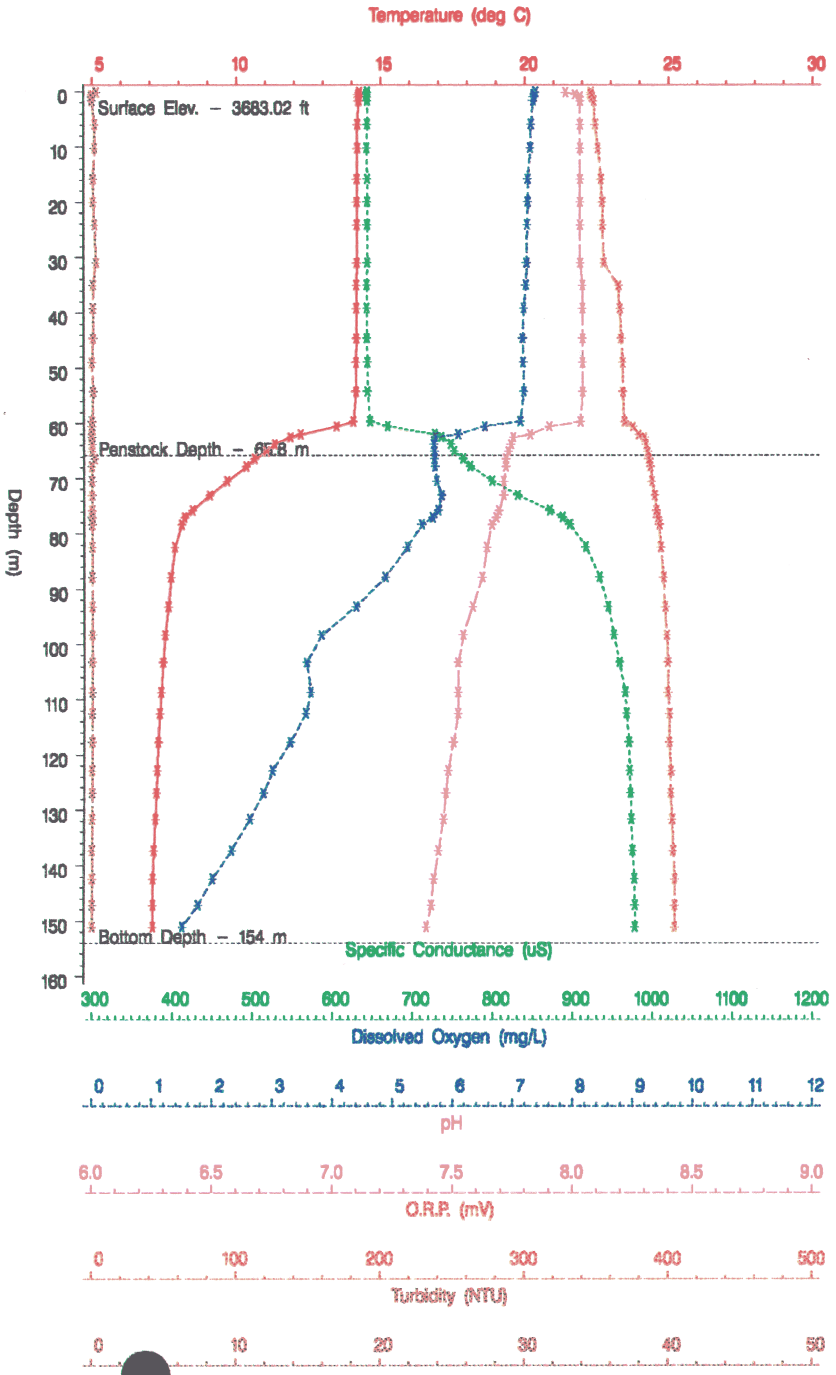



Figure 4: pH and turbidity (NTUs) in the main channel of Lake Powell, December 11-15, 1995. Penstock elevation, 64.7 m and river outlet, 94 m, are indicated by arrows on left axis. Lake elevation is 3682 feet above sea level.

# Wahweap

LPCR0024

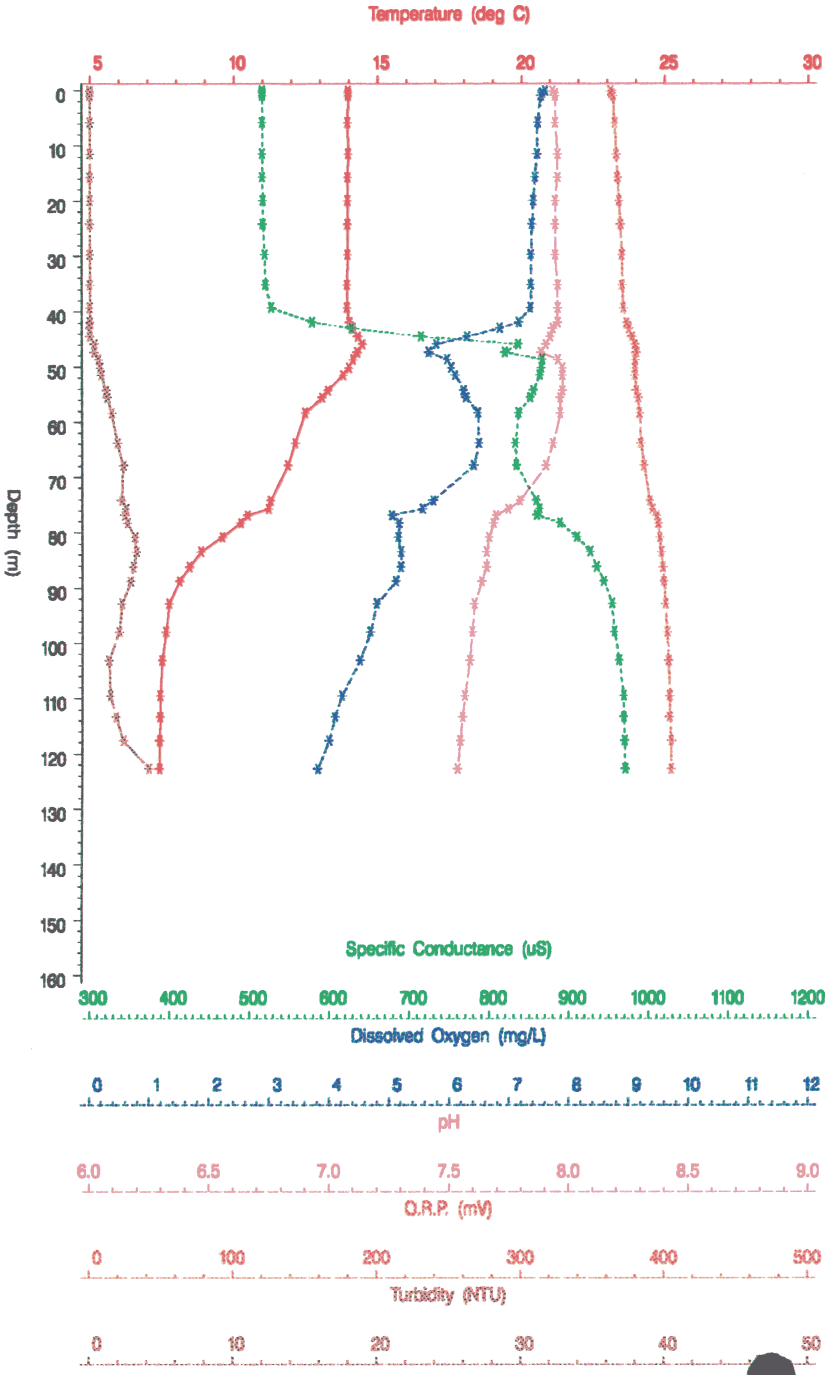
December 11, 1996




# Escalante

LPCR1169

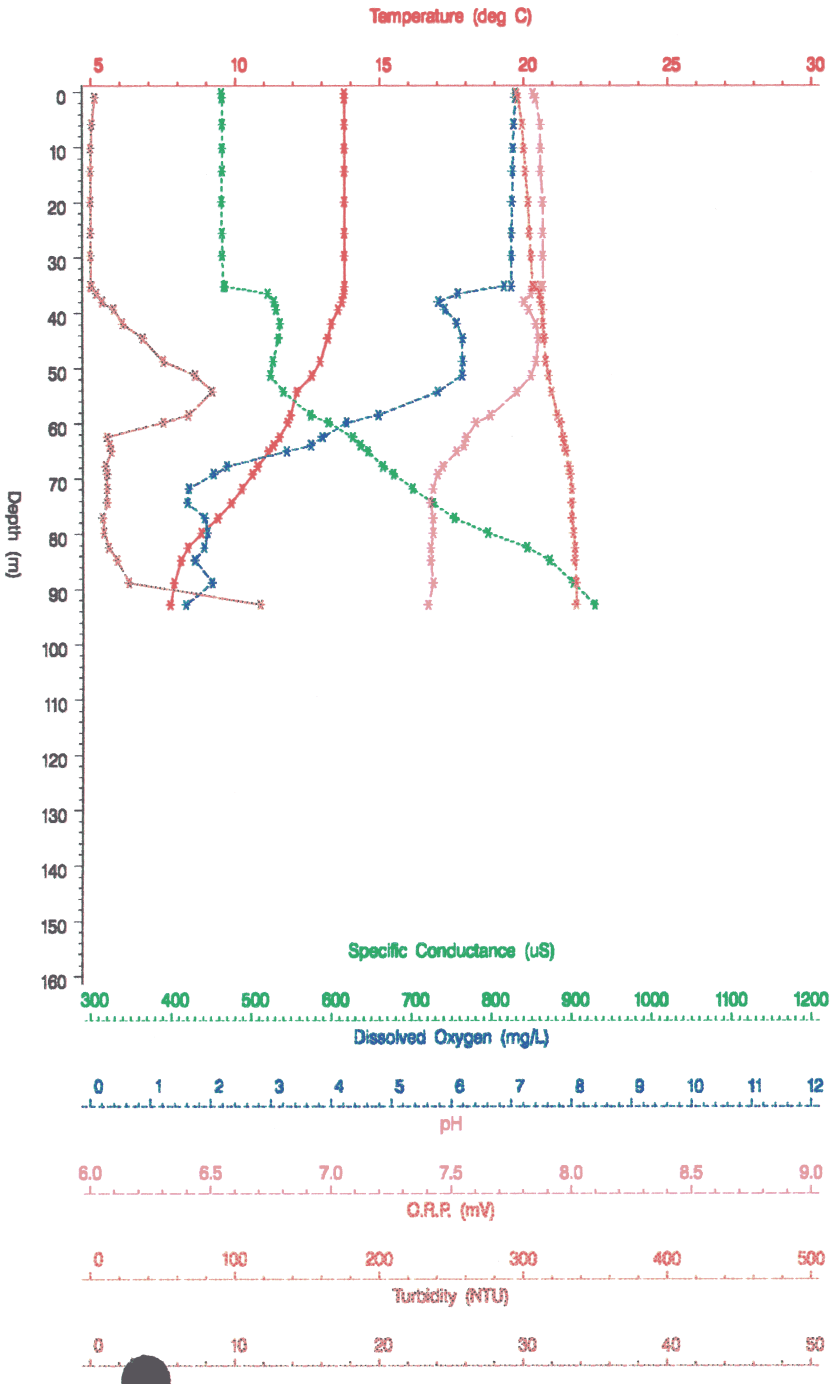
December 12, 1995



# Cha Canyon (SJR)

LPSJR193

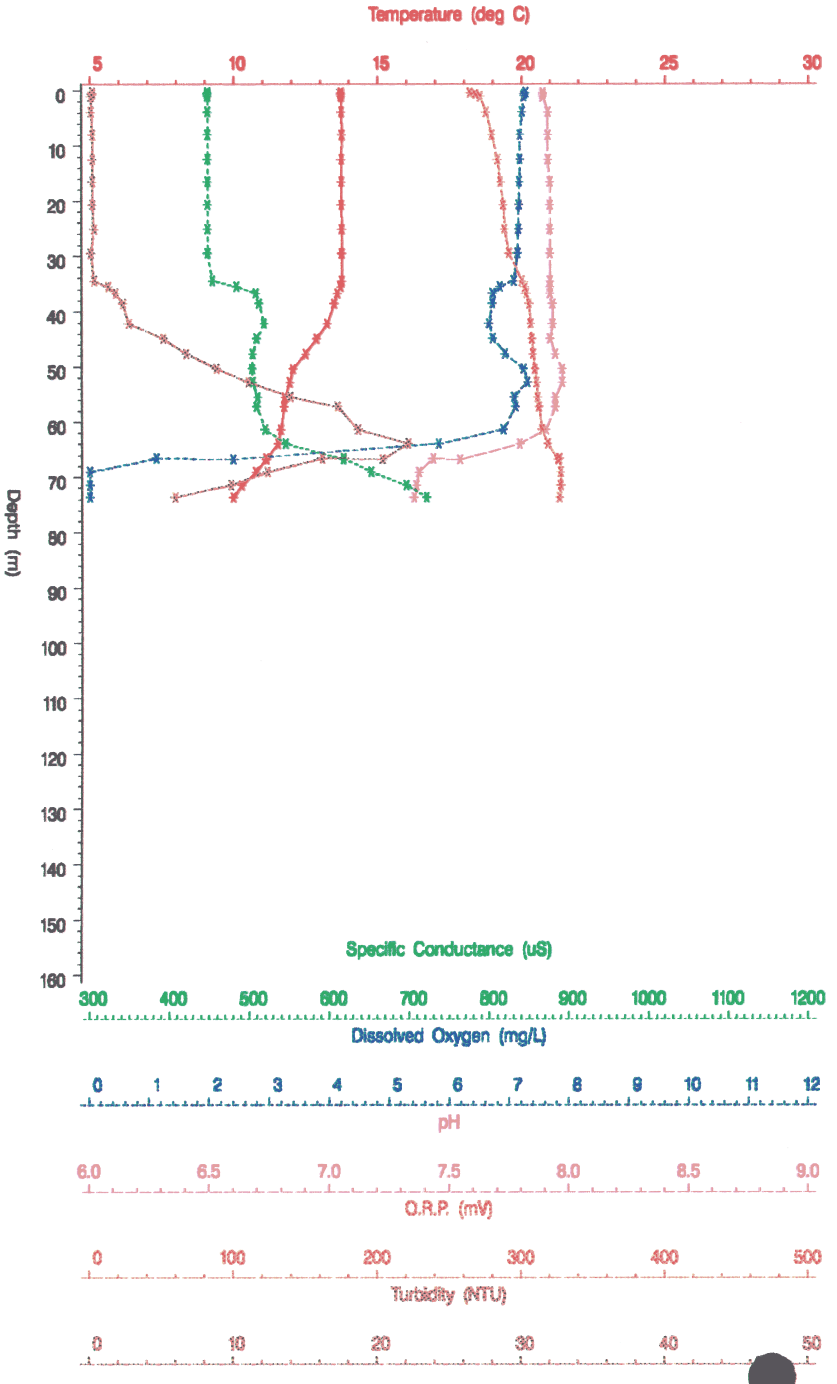
December 15, 1995




# Lower Piute Bay (SJR)

LPSJR329

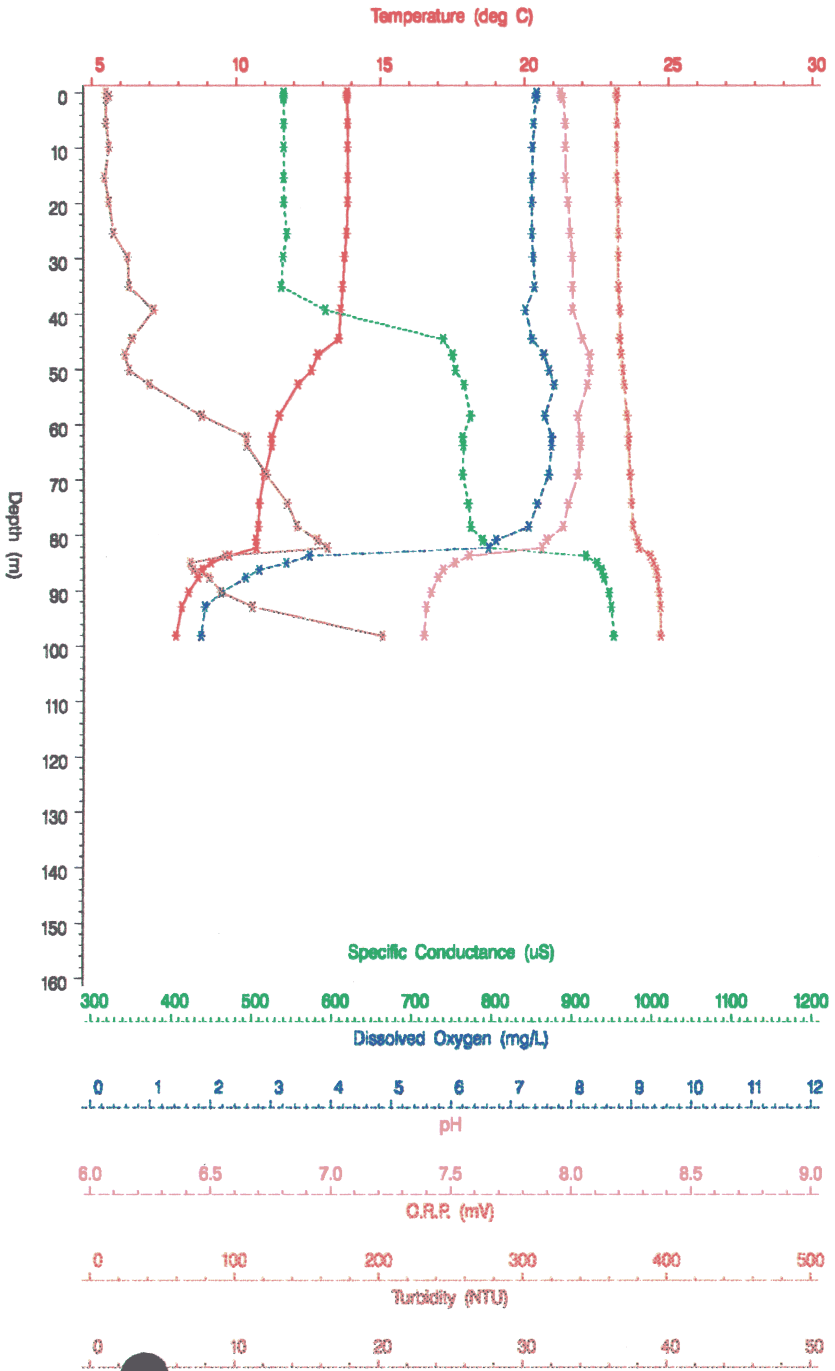
December 15, 1995



# Bullfrog Bay

LPCR1692

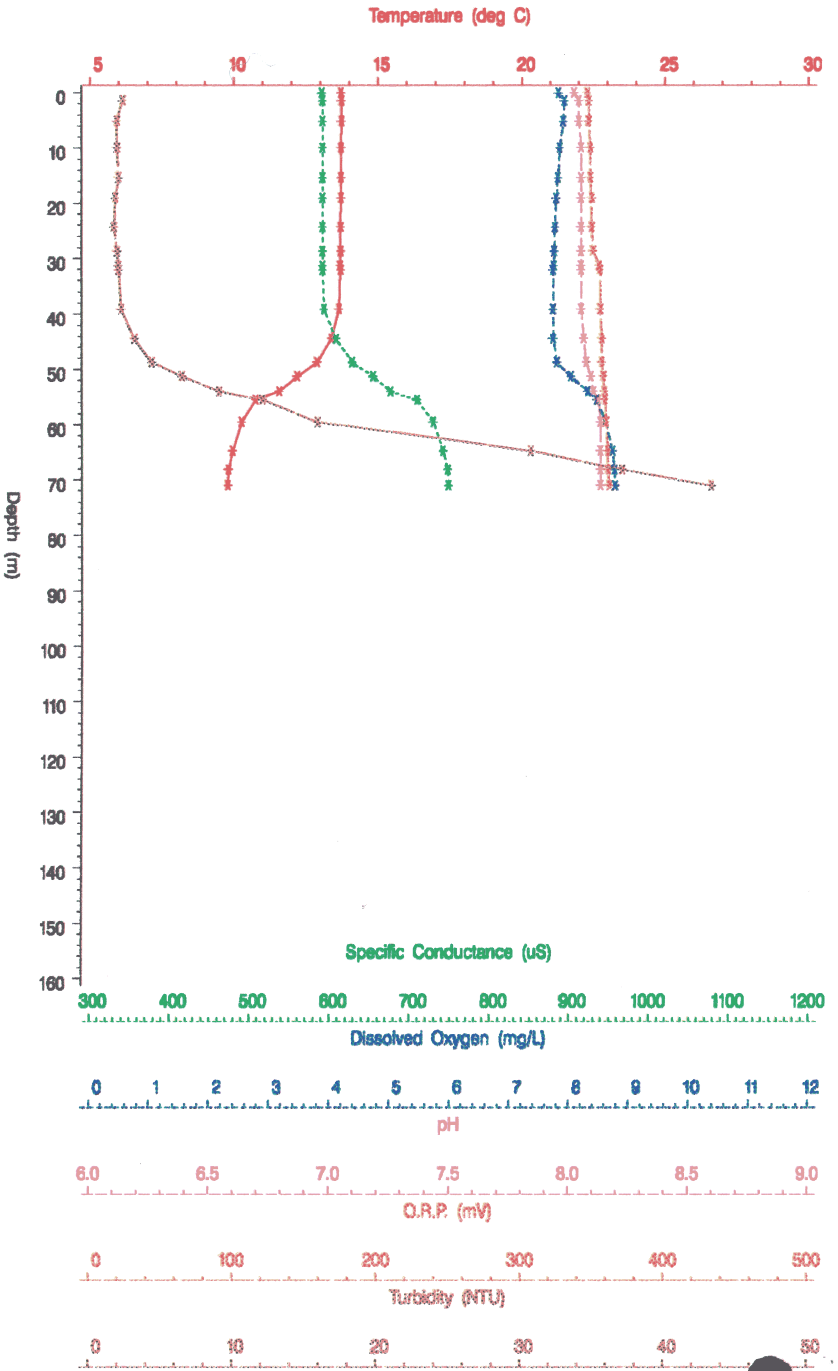
December 13, 1995




# Scorup Canyon

LPCR2255

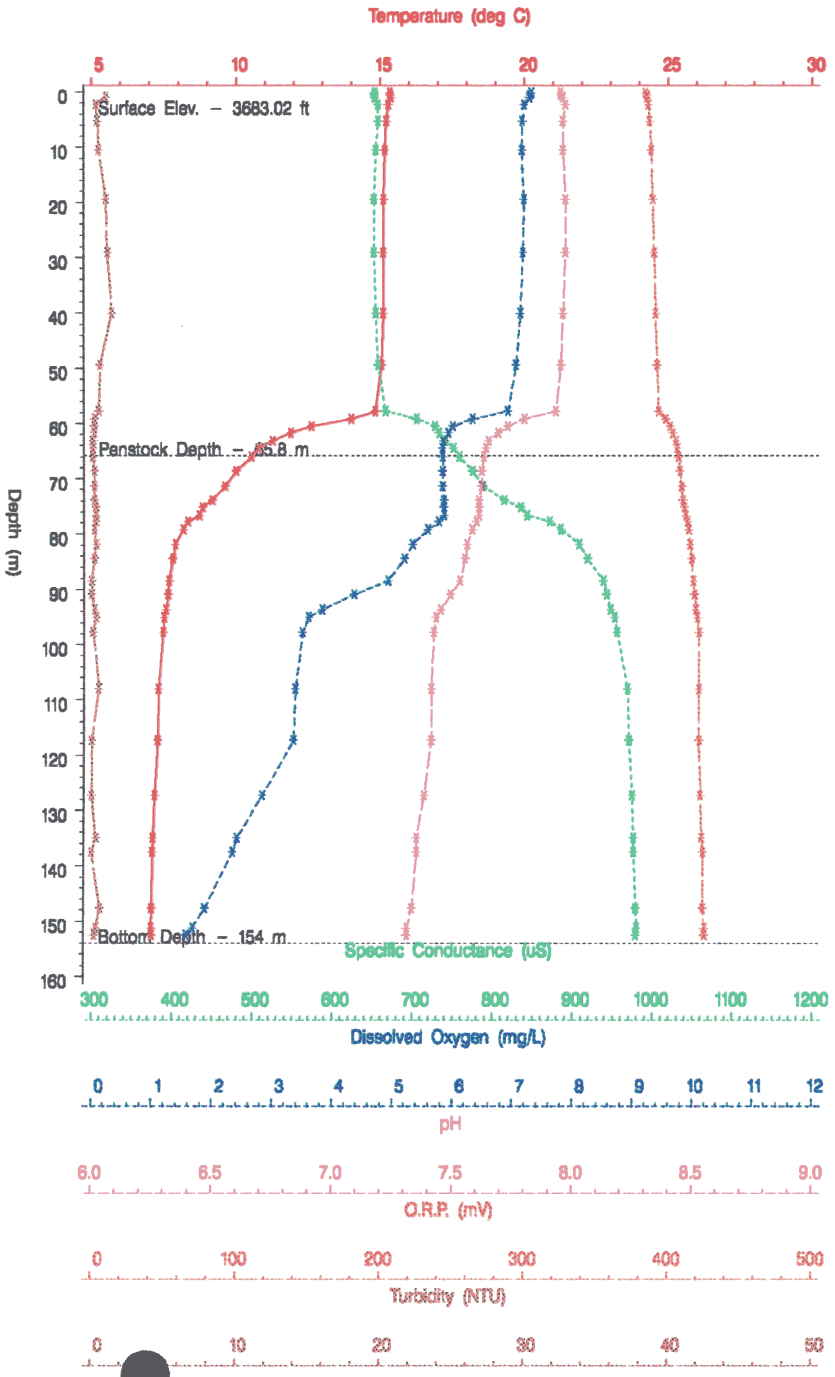
December 13, 1995



# Wahweap

LPCR0024

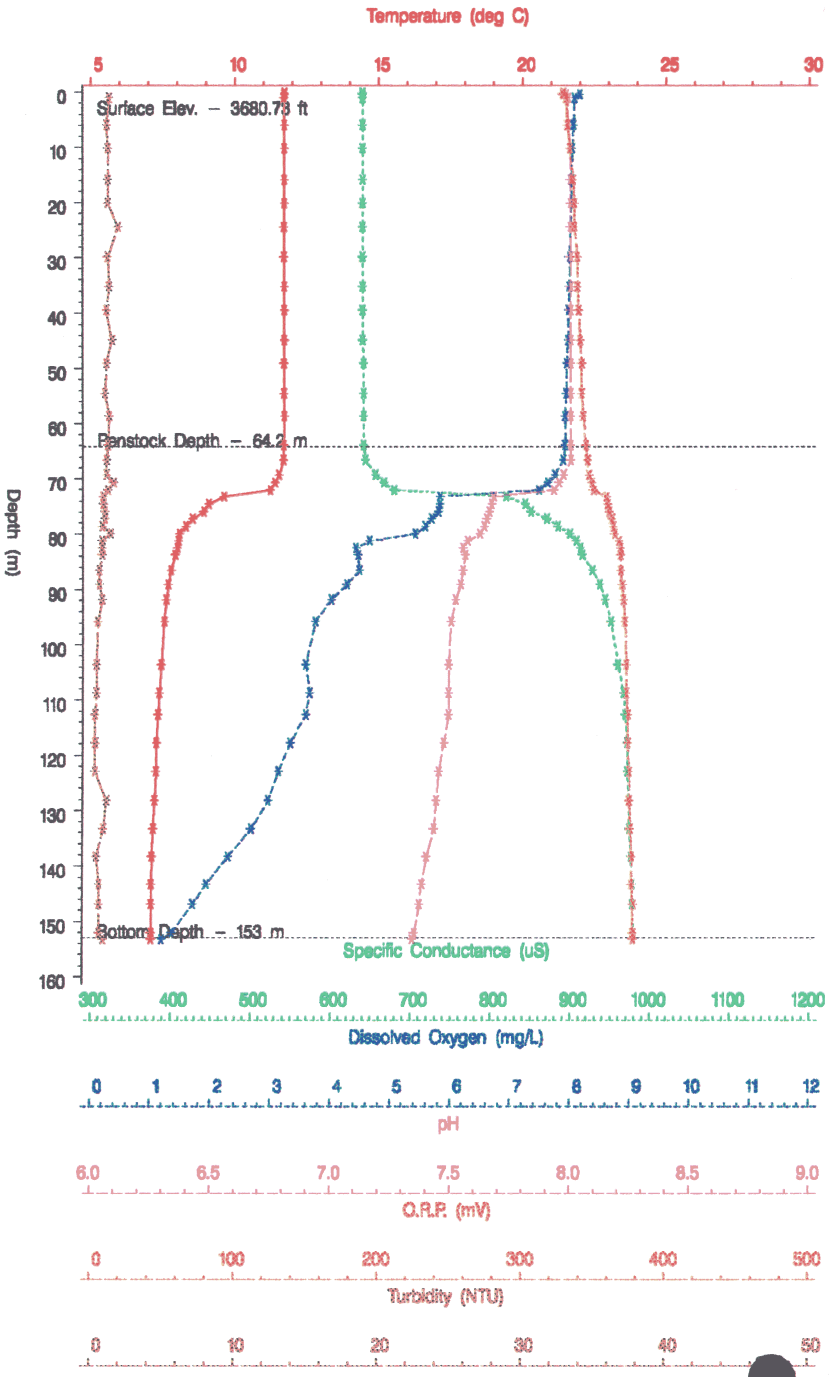
November 29, 1995




# Wahweap

LPCR0024

January 3, 1996



# United States Department of the Interior

BUREAU OF RECLAMATION

Glen Canyon Environmental Studies
P.O. Box 22459
Flagstaff, Arizona 86002-2459

IN REPLY REFER TO:
D-8290
RES-3.20

FEB 1 - 1996

GLEN CANYON ENVIRONMENTAL STUDIES OFFICE

FEB 1 1996

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FLAGSTAFF, AZ

MEMORANDUM

To: All on Attached List

From: David L. Wegner, Manager
Technical Service Center, Environmental Resources Service
Glen Canyon Environmental Studies Group

Subject: Results of December 1995 Quarterly Water Quality Monitoring Survey - Lake Powell

Enclosed for your information are the results of the December 1995 quarterly water quality monitoring survey of Lake Powell conducted by the Glen Canyon Environmental Studies office. The report summarizes mid-winter conditions observed during the survey, conducted from December 11 to December 15, 1995.

Quarterly reservoir surveys are part of the Bureau of Reclamation's long term water quality monitoring program on Lake Powell and its tailwaters. Other features of this program include monthly water quality profiles and biological sampling of the Glen Canyon Dam forebay and continuous water quality monitoring of the tailwater below Glen Canyon Dam and at Lees Ferry.

The objective of this report is to disseminate information collected by Reclamation's Lake Powell Water-Quality Monitoring Program to those interested in Lake Powell conditions and the effects of Glen Canyon Dam's withdrawal patterns on the limnology of the reservoir. In order to eliminate unnecessary mailings of future reports, please indicate your desire to remain on the mailing list by returning the enclosed self-addressed stamped postcard by February 29, 1996.

Please direct any questions or requests for further information to Bill Vernieu (E-mail: bvernieu@slcm03.uc.usbr.gov) or Susan Hueftle (E-mail: shueftle@slcm03.uc.usbr.gov) at (520)556-7363. Your comments, suggestions, and feedback are encouraged and appreciated.

David L. Wegner

Attachments 3:
mailing list
report
postcard

Andrew Ayers
Research Biologist
Arizona Game & Fish
PO Box 342
Flagstaff, AZ 86002

Kevin Berghoff
Hydrologist
Glen Canyon National Recreation Area
PO Box 1507
Page, AZ 86040

Marc Dahlberg
Water Quality Specialist WM-F
Arizona Game & Fish Department
2221 W. Greenway Road
Phoenix, AZ 85023

Dave Garrett
Grand Canyon Science Center
Grand Canyon National Park
PO Box 129
Grand Canyon, AZ 86023-0129

Wayne Gustaveson
Utah Division Of Wildlife Resources
PO Box 1446
Page, AZ 86040

David Haskell
Resource Management Division
Grand Canyon National Park
PO Box 129
Grand Canyon, AZ 86023

Laura Herbranson
Lower Colorado Reion, BOR
Grand Canyon Office
PO Box 61470
Boulder City, NV 89006-1470

Mike Horn, D-8220
Denver Federal Center, BOR
P.O. Box 25007
Denver, CO 80225-0007

Christine Karas, UC-320
Bureau Of Reclamation
125 South State Street Room 6107
Salt Lake City, UT 84138-1102

Gary Kuhstoss
Bureau Of Reclamation
PO Box 1477
Page, AZ 86040

Frank Baucom
U.S. Fish & Wildlife Service
2321 West Royal Palm Road Ste 103
Phoenix, AZ 85021-4951

Dean Blinn, Attn Joe Shannon
Northern Arizona University
Dept. Of Biology & Sciences
PO Box 5640
Flagstaff AZ 86011-5640

Richard Denton
Utah Dept. Of Environmental Quality
Division Of Water Quality
PO Box 144870
Salt Lake City, UT 84114-4870

Rick Gold
Regional Directors Office
Bureau of Reclamation
125 South State Street, Rm 6107
Salt Lake City, UT 84138-1102

Robert Hart
U.S. Geological Survey
2255 North Gemini Drive
Flagstaff, AZ 86001

Norman Henderson
Research Coordinator
Glen Canyon National Recreation Area
PO Box 1507
Page, AZ 86040

Daniel Higgem
U.S. Environmental Protection Agency
EMSL
PO Box 93478
Las Vegas, NV 89193-3478

Dr. William Jackson
NPS, Water Resources Division
1201 Oak Ridge Drive, Suite 250
Fort Collins, CO 80525-5562

John Klein
U.S. Geological Survey
2800 Cottage Way
Sacramento, CA 95825

James F. LaBounty, D-8220
Denver Federal Center, BOR
PO Box 25007
Denver, CO 80225-0007

John Lease, D-8200
Technical Service Center, MR D-7923
Denver Federal Center
PO Box 25007
Denver, CO 80225-0007

Dr. William Lewis, Jr
Chair, EPO Biology
University Of Colorado, Boulder
Campus Box 334
Boulder, CO 80309

Dr. Richard Marzolf
U.S. Geological Survey Water Res Division
3215 Marine Street
Boulder, CO 80303-1060

Jerry Miller, UC-286
Bureau Of Reclamation
125 South State Street Room 6107
Salt Lake City, UT 84138-1102

Bruce Moore, UC-205
Bureau Of Reclamation
125 South State Street Room 6107
Salt Lake City, UT 84138-1102

Gordon Mueller
NBS, Denver Federal Center
PO Box 25007
Denver, CO 80225-0007

Bill Persons
Arizona Game & Fish Department
2221 West Greenway Road
Phoenix, AZ 85023

Randall V. Peterson, UC-288
BOR, Upper Colorado Region
125 South State Street, Rm 6107
Salt Lake City, UT 84138-1102

John Ritenour
Resource Management
Glen Canyon National Recreation Area
PO Box 1507
Page, AZ 86040-1507

Doyle Stephens
U.S. Geological Survey
1745 West 1700 South
Salt Lake City, UT 84104

David Trueman, UC-288
Bureau Of Reclamation
125 South State Street Room 6107
Salt Lake City, UT 84138-1102

Davine Lieberman, D-8220
National Biological Service
Denver Federal Center
PO Box 25007
Denver, CO 80225-0007

Barry Long
National Park Service
Water Resources Division
1201 Oakridge Dr., Suite 250
Fort Collins, CO 80525

Margaret Matter
WAPA Administration
PO Box 3402
Golden, CO 80401

Ed Montoya
Navajo Natural Heritage Program
PO Box 1480
Window Rock, AZ 86515

Tony Morton
Western Area Power Administration
257 East 200 South, Suite 475
Salt Lake City, UT 84111-0606

Steve Noyes, PRO-710
Bureau Of Reclamation
PO Box 51338
Provo, UT 84605-1338

Rob Peterson
Navajo Generating Station
Lab Services Department
PO Box W
Page, AZ 86040

Robert Radtke, UC-289
BOR, Upper Colorado Region
125 South State Street Room 6107
Salt Lake City, UT 84138-1102

Mary Jo Stegman
U.S. Fish & Wildlife Service
P.O. Box 39
Pinetop, AZ 85935

Tom Trent
Arizona Dept. Of Environmental Quality
3033 North Central Ave
Phoenix, AZ 85012

Carol Wiens
U.S. Fish & Wildlife Service
1745 West 1700 South
Salt Lake City, UT 84104