GLEN CANYON DAM
MODIFICATIONS TO CONTROL DOWNSTREAM TEMPERATURES

PLAN AND DRAFT ENVIRONMENTAL ASSESSMENT

January 1999

U.S. Department of the Interior
Bureau of Reclamation
Upper Colorado Region

MISSION STATEMENTS

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering wise use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. Administration.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

EXECUTIVE SUMMARY

Introduction - The U.S. Bureau of Reclamation is considering whether on not to modify Glen Canyon Dam to allow downstream temperatures to be managed. It is believed by the U.S. Fish and Wildlife Service and Reclamation that the cold summer temperatures created by the dam are a constraint to native and endangered warmwater fish, but there are other ecological interactions complicating the issue that cannot be conclusively resolved without physical testing.

Reclamation has developed a relatively inexpensive way to modify the dam to allow temperatures to be controlled and tested. The plan includes a monitoring program to further our understanding of the ecosystem's response to temperature and an adaptive management program to apply this knowledge.

Background - Before Glen Canyon Dam was constructed, the temperature of the Colorado River in the Grand Canyon would increase from near freezing in the winter to about 30°C (86°F) in the late summer. Though several native fish were present in the river system, Leibfried and Zimmerman (1994) reported that the fish community was dominated by warmwater non-native species. Channel catfish comprised 90% of the fish community in Glen Canyon (Woodbury 1959). The dominant forms of non-native fish were channel catfish and carp, with red shiners, largemouth bass, green sunfish, and bullheads present but less abundant (Valdez and Carothers 1998).

Once the dam was constructed, release temperatures became relatively cold during the summer season. Water is now drawn year round from the deep intakes used for power production. Release temperatures vary little and are typically 8°C-10°C (46°F-50°F). Cold mainstem temperatures and high water velocity are thought to have expatriated (or at least greatly limited) most non-native competitors in the mainstem. Of the non-native species, rainbow trout do well in the clear water near the dam. Carp and catfish are abundant further downstream, in and near warm tributaries like the Little Colorado River. Native, warmwater fish have also been greatly limited by cold-water releases. Some are no longer present below Glen Canyon Dam. The endangered humpback chub are essentially limited to the area in and near the Little Colorado River.

Impacts to Fish - Cold-water releases from Glen Canyon Dam are below optimal for the existing trout fishery and far below those temperatures needed to allow native and endangered warmwater fish (such as the humpback chub) to thrive in the mainstem of the Colorado River.

Thermal shock from cold mainstem temperatures has been recognized as a likely cause of mortality for young endangered fish leaving seasonally warmed tributaries (Lupher and Clarkson 1993, 1994; Valdez and Ryel 1995; Thieme 1998). In their integration report on studies in Glen and Grand Canyons, Valdez and Carothers (1998) concluded that, "We believe that most larval flannelmouth suckers, bluehead suckers, and humpback chub descending from warm natal tributaries into the cold mainstem die of thermal shock or from predation elicited by erratic swimming behavior. For those fish old enough to survive the transition, swimming ability may be reduced by as much as 98 percent by cold mainstem temperatures."

In commenting on the proposed plan, Gorman (Arizona Game and Fish) suggested that temperature controls could be an effective tool to reduce this thermal shock problem during the relatively short period of time that the humpback chub are descending into the mainstem (mid to late summer) without greatly favoring their competitors. Furthermore, once recruited, these long-lived native fish would potentially out-live their competitors by well over a decade.

Fish and Wildlife Service Recommendation - According to the Fish and Wildlife Service's (FWS) biological opinion on the operation of Glen Canyon Dam, main channel spawning of endangered fish (critical habitat) is severely limited by cold-water releases from Glen Canyon Dam. In their biological opinion on the operation of the dam, the FWS's reasonable and prudent alternative recommended that Reclamation evaluate methods to control release temperatures and, if viable, implement controls. Reclamation agreed with this recommendation and included it in the U.S. Department of the Interior's (USDI) Final Environmental Impact Statement (USDI 1995) and Record of Decision on the Operation of Glen Canyon Dam.

Plan Development - This report integrates two purposes, planning and an environmental assessment of the alternatives. In Chapter II, the report summarizes Reclamation's study of various methods available to control temperature. Several designs were found to meet the temperature control needs of the project and are technically viable; however, costs varied significantly.

The proposed alternative takes maximum advantage of the existing intake structures to reduce costs, yet meets the performance goals for temperature controls. This innovative approach would cost an estimated $15 million (to modify all eight intakes) and would be within Reclamation's spending authority. More traditional designs like those used at Flaming Gorge Dam and Shasta Dam would cost up to $149 million at Glen Canyon Dam, would have far exceeded Reclamation's spending authority, and would have required returning to Congress for legislation. The least costly method (the 4-intake modification at $10 million) was rejected by Reclamation because it lacked the flexibility needed to meet the downstream temperature objectives.

Environmental Assessment - In Chapter III, the report compares the effects of the proposed warm(er)-water releases to those of the no action alternative (continued cold-water releases). It should be noted that although the proposed alternative is discussed as warmwater releases, in effect temperature controls would actually release water that is only about 5°C (10°F) warmer than the existing condition. To most rafters and recreationists, the water would still seem quite cold (59°F vs. 46°F).

The goal of the proposed alternative would be to modify Glen Canyon Dam to allow release temperatures to be controlled to improve conditions for endangered fish while at the same time protecting other important resources like the Lees Ferry trout fishery.

The proposed plan would create a tiered (cold/warmwater) fishery. Release temperatures would be increased from the existing levels (8°C-10°C) to about 15°C during the summer months. This would improve temperatures for rainbow trout in the reach immediately below the dam (first 16 miles to Lees Ferry). Then, as the water flows downstream and warms, it would quickly reach temperatures preferred by native and endangered (warmwater) fish. Warmwater releases may not be made in every year to help control competitors to the humpback chub. Release periods might be as short as a month to prevent thermal shock as the chub descend into the main channel, or as long as the May through September season to promote better growth rates.

Scoping Issues - Input received at scoping meetings identified several areas of particular interest to the public and scientific community. More detailed discussions are included in Chapter III of this assessment. In summary, this report finds:

- **Lake Powell Fishery -** Temperatures in Lake Powell are already low enough to cause occasional winter-kill of threadfin shad, an important forage fish for the lake (game) fishery. It was recommended that Reclamation carefully evaluate the potential impact on this resource of releasing warm water from the reservoir. Computer modeling of the reservoir shows that temperatures in the surface layer of Lake Powell would be cooled by up to 1°C if warmwater releases were maintained through the entire "summer" season (140 days). Shorter duration releases would have even smaller effects on lake temperatures. Little or no impact is expected to threadfin shad or the lake fishery. However, the existing lake monitoring program would be continued to confirm or refute these predictions.

- **Primary Productivity -** Field and laboratory experiments conducted for Reclamation by Northern Arizona University indicate that the existing macroinvertebrates in the downstream environment can tolerate warmwater releases of 20°C for at least 30 days (the duration of the study). Release temperatures for the proposed action would normally be limited to a maximum of 15°C. Computer modeling of Lake Powell shows that surface withdrawals from the reservoir would increase nutrient and detritus release levels below the dam by up to 300 percent; thus, potentially improving the productivity of the river ecosystem. Studies of warmwater releases at Flaming Gorge Dam suggest that some minor changes (increases) may occur in diversity and abundance. The effects would be carefully monitored through the adaptive management process and the Grand Canyon Monitoring and Research Center.

- **Endangered Fish -** Under present conditions (the no-action alternative), endangered fish do not reproduce in the river, young fish thermal shock while entering the main channel from warm tributaries, and those that survive are easy prey due to their reduced swimming efficiency. The proposed temperature control alternative would allow releases to be made to improve the reproductive success of humpback chub by reducing thermal shock with late-summer, warmwater releases. Additionally, summer-long warmwater releases may be used in an attempt to further improve conditions for endangered species; however, non-native fish may also benefit from sustained releases.

  Of primary concern is competition between carp/catfish and humpback chub. Summer-long, warmwater releases would likely cause carp and catfish populations to increase in the mainstem (along with other non-native species).

However, this does not necessarily mean that humpback chub will be unable to find opportunities once the cold-water restraints are eliminated. For example, it is a well know fact that the humpback chub thrive in the warm water of the Little Colorado River and that they compete very successfully against carp, catfish, and other competitors in that warmwater system. Clear, summer-long, warmed releases (about 13.5°C) from Flaming Gorge Dam have also improved conditions for native fish populations even though non-native fish are present in great numbers.

- **Predator Controls -** Modeling studies underway by the Grand Canyon Monitoring and Research Center suggest that carp and channel catfish populations may need to be controlled by methods beyond the timing and duration of temperature controls. Physical controls (harvesting) may be needed to reduce predation on native fish in specific areas. Careful monitoring of these competitors would be an important part of the proposed alternative. If physical controls are needed, the Adaptive Management Work Group may recommend to the Secretary of the Interior actions that would be appropriate given the details of the monitoring results and the problems that are identified.

- **Rainbow Trout -** Numerous experiences at other dams strongly suggest that the proposed warmwater release of up to 15°C would benefit the rainbow trout fishery below Glen Canyon Dam by removing temperature stresses. The current 8°C (46°F) releases are well below the 15°C (59°F) optimum for rainbow trout. Reservoir modeling studies also suggest that nutrient and detritus releases from the dam would increase, potentially improving the food base for trout in the Lees Ferry reach of the river.

Adaptive Management - Adaptive management is an essential component of the proposed alternative. Because of the complexity of the ecological interactions in the Grand Canyon, no one (fixed) plan of operation could be expected to optimize the goals of the proposed temperature control alternative. Modeling and predictions are of limited usefulness when dealing with complex environmental systems. It is clear that temperature release patterns (operations) will need to be adjusted and evolve as our knowledge increases from each successive year of testing. Carefully monitored experiments are necessary to assure that these adaptations help (not harm) the resources. The testing and monitoring program would be developed by the Glen Canyon Technical Work Group and Grand Canyon Monitoring and Research Center within the existing adaptive management process. The Glen Canyon Adaptive Management Work Group would then review this work and make recommendations to the Secretary of the Interior for implementation.

Monitoring - The temperature control alternative included in this assessment proposes to avoid or mitigate the potential adverse impacts that have been identified in this assessment. It also includes the Adaptive Management Program and Grand Canyon Monitoring and Research Center to monitor and evaluate management options to avoid unforseen impacts that may occur in the future. And finally, if monitoring shows that warmwater releases do not to benefit endangered species, cold-water releases would be available anytime. With time, the proposed action would be reversible (except for the expense of the modifications).

Decision Process - If, after a public review, Reclamation finds that endangered fish are likely to benefit from warmwater releases and all significant adverse impacts can be avoided or mitigated or reversed, Reclamation would then consider proceeding with a Finding of No Significant Impact and would begin modifying the intakes in fiscal year 2000. On this schedule, temperature controls would potentially be available as early as the summer of 2002.

If for some unforseen reason significant adverse impacts are identified through the public review process which cannot conceivably be avoided or mitigated or reversed; then, Reclamation may choose to reconsult with the FWS on this issue and pursue the no-action alternative.

This report is available upon request at the address below or on the interne at the Bureau of Reclamation's Upper Colorado Regional Office homepage:

http://www.uc.usbr.gov

Comments on this draft environmental assessment are due on or before March 26, 1999. Please mail your comments to:

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TABLE OF CONTENTS

CHAPTER I - PURPOSE OF AND NEED 1
INTRODUCTION 1
LOCATION 2
PURPOSE AND NEED FOR ACTION 2
AUTHORITY 4
PERMITS REQUIRED 5
SCOPING SUMMARY 5
PREVIOUS AND RELATED EXPERIENCES 6
- Glen Canyon Dam Outflow Temperature Control Study 6
- Flaming Gorge Outflow Temperature Control 6
- Shasta Dam Outflow Temperature Control Study 7
- Hungry Horse Dam Selective Withdrawal System 8
- Other Selective Withdrawal Systems 8

CHAPTER II- DESCRIPTION OF ALTERNATIVES 9
NO-ACTION ALTERNATIVE 9
ACTION ALTERNATIVE (Temperature Control Modifications) 9
- Role of Adaptive Management in Operations 10
- Glen Canyon Adaptive Management Process 12
- Proposed Operation 13
- Proposed Schedule for Construction 14
- Annual Operation and Maintenance Costs 14

ALTERNATIVES CONSIDERED BUT ELIMINATED 15
- Navajo Powerplant Alternative 15
- Hold the Reservoir at Minimum Pool 15
- Minimize Summer Releases to Increase Warming of the River 15
- Dam Removal 15
- Fund other Recovery Efforts 16
- Reservoir Destratification 16

DESIGN ALTERNATIVES CONSIDERED 16

CHAPTER III - AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES 23
COLORADO RIVER ECOSYSTEM RESOURCE LINKAGES 23
CONSTRUCTION 24
WATER QUALITY AND AQUATIC RESOURCES 24
- River Temperatures 25
- Lake Temperatures 25
- Reservoir Evaporation 28
- Salinity 28
- Selenium 29
- Nutrients and Their Effects on Primary Productivity 29
- Native and Endangered Fishes 33
- Non-Native Fishery Below Dam 35

Fish Parasites 38
Entrainment of Fish into Releases 38
Lake Mead Fishery 38
Lake Powell Fishery 38
Wintering Waterfowl 39
OTHER ENDANGERED AND SPECIAL STATUS SPECIES 39
Peregrine Falcon 40
Southwestern Willow Flycatcher 40
Bald Eagle 40
Kanab Ambersnail 41
Southwestern River Otter 41
Osprey and Belted Kingfisher 41
Northern Leopard Frog 42
CULTURAL RESOURCES 42
RECREATION 43
Fishing in Glen Canyon 43
Fishing in Lake Powell 43
Fishing in Lake Mead 43
Day Rafting 43
White-Water Boating 43
Lake Activities and Facilities 43
Net Economic Value 43
Regional Economic Activity 44
HYDROPOWER 44
AIR QUALITY 45
CUMULATIVE IMPACTS 46
UNAVOIDABLE ADVERSE IMPACTS 47
IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS 47
INDIAN TRUST ASSETS 47
INDIAN SACRED SITES (EXECUTIVE ORDER 13007) 48
INTERNATIONAL IMPACTS 48
ENVIRONMENTAL COMMITMENTS 48
ENVIRONMENTAL JUSTICE IMPLICATIONS 48

CHAPTER IV - CONSULTATION AND COORDINATION 50
PUBLIC INVOLVEMENT 50
PUBLIC MEETINGS AND COORDINATION 50
CONSULTATION 52
Cultural Resources 52
Fish and Wildlife Coordination 52
Glen Canyon Dam Adaptive Management Work Group 52
EXECUTIVE ORDERS 53
DISTRIBUTION LIST 53
Federal Agencies 53
State and Local Agencies 53
Indian Tribes 54
Schools 54
Interested Organizations 54

CHAPTER I - PURPOSE OF AND NEED

INTRODUCTION

As Lake Powell began to fill behind Glen Canyon Dam, water depth increased over the penstock intakes and release temperatures dropped. Deep, cold-water releases (about 8-10°C) from Glen Canyon Dam are believed to be causing serious negative impacts to native and endangered fish which need warm water to reproduce. The evaluation of temperature control was an element of the preferred alternative in the *Operation of Glen Canyon Dam Environmental Impact Statement* (USDI 1995) and contained in the Fish and Wildlife Service's (FWS) reasonable and prudent alternative in their jeopardy opinion under Section 7 of the Endangered Species Act. The proposed temperature control alternative would include modification of the penstocks to allow warmer releases and post-project monitoring and testing to refine its operation.

There are several factors believed to have caused the decline of native fish in the Grand Canyon. With regard to the operation of Glen Canyon Dam, it appears logical that the cold-water releases have added to the decline of native (warmwater) fish and that native fish would benefit from efforts to return the river to a more natural, warmwater release pattern during certain times of the year. There are however, interactions between the river's primary productivity, native and non-native fish, and the habitat that are ecologically linked. An important part of the proposed temperature control alternative would be to test and refine the operation of the temperature control device through the Glen Canyon Adaptive Management process. A post-project monitoring and testing program would be developed as part of the Glen Canyon Dam Adaptive Management process. Monitoring would be conducted by the Grand Canyon Monitoring and Research Center. The results of the tests and monitoring would be reviewed through the adaptive management process. The Glen Canyon Adaptive Management Work Group would recommend further tests and refinements in operations to the Secretary of the Interior

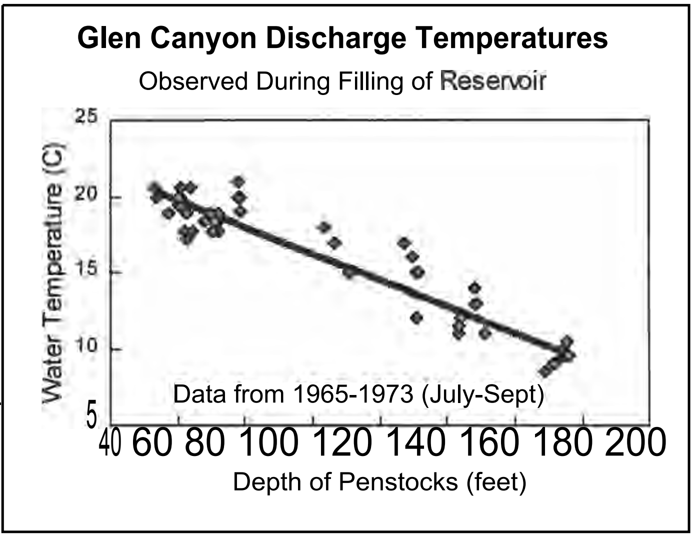

Figure 1 - Release temperatures below Glen Canyon Dam as Lake Powell fill.

Reclamation is considering two alternatives. The proposed temperature control alternative would implement temperature controls at Glen Canyon Dam. The second alternative is the no-action alternative. This environmental assessment will look at each of these alternatives.

LOCATION

This assessment focuses on the Colorado River corridor from Lake Powell, formed by Glen Canyon Dam in northwestern Arizona, southward through Glen and Marble Canyons and westward through the Grand Canyon to Lake Mead. The document will disclose all significant impacts of the alternatives wherever they may occur and plans to avoid or mitigate adverse impacts.

Lake Powell and the 15 miles of the river below Glen Canyon Dam are part of the Glen Canyon National Recreation Area. The remaining 278 miles of the river flow through the Grand Canyon National Park. Regional impacts that may occur outside of the immediate geographic area are also evaluated.

PURPOSE AND NEED FOR ACTION

The purpose of the proposed action is to carry out the FWS's recommendation to implement a selective withdrawal program and determine the feasibility of providing warmer water to remove jeopardy and help recover endangered fish below Glen Canyon Dam. This would include modification of the existing penstocks to allow warmwater releases and a monitoring and adaptive management program to refine operations.

Cold-water releases from Glen Canyon Dam limit recruitment of native and endangered (warmwater) fish in the mainstem of the Colorado River in the Grand Canyon. Deep, hypolimnetic releases from Glen Canyon Dam have cooled the temperature of the river in the Grand Canyon. Because its penstocks draw on water from deep in the reservoir, spring, summer, and fall releases are much colder than before the dam. This has created an excellent cold-water (trout) fishery below the dam, but prevents native, warmwater fish from thriving and spawning in the river.

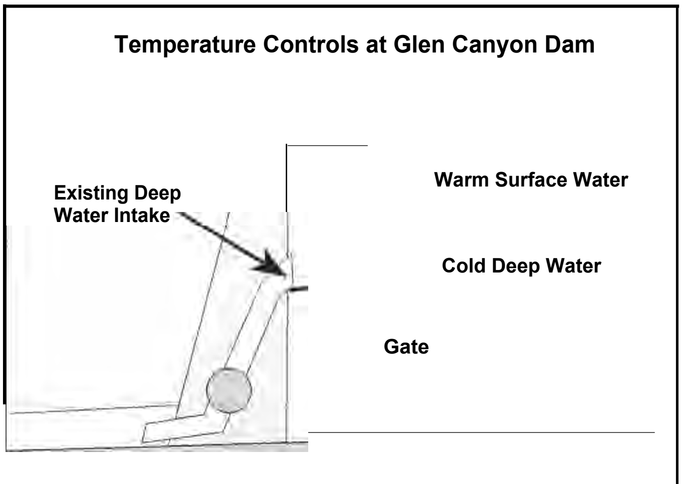

Figure 2 - Schematic of Intake Modifications.

The population of humpback chub in the Grand Canyon is the largest of six in existence. For the most part, the humpback chub only spawn in the Little Colorado River, a warmwater tributary to the Colorado River about 60 miles below Glen Canyon Dam. The fish thrive in the warmwaters of the Little Colorado River, but may be vulnerable to catastrophes because the range of their habitat is extremely limited. Some spawning may occur in the mainstem (near hot springs) and in other small tributaries, but only to a limited extent.

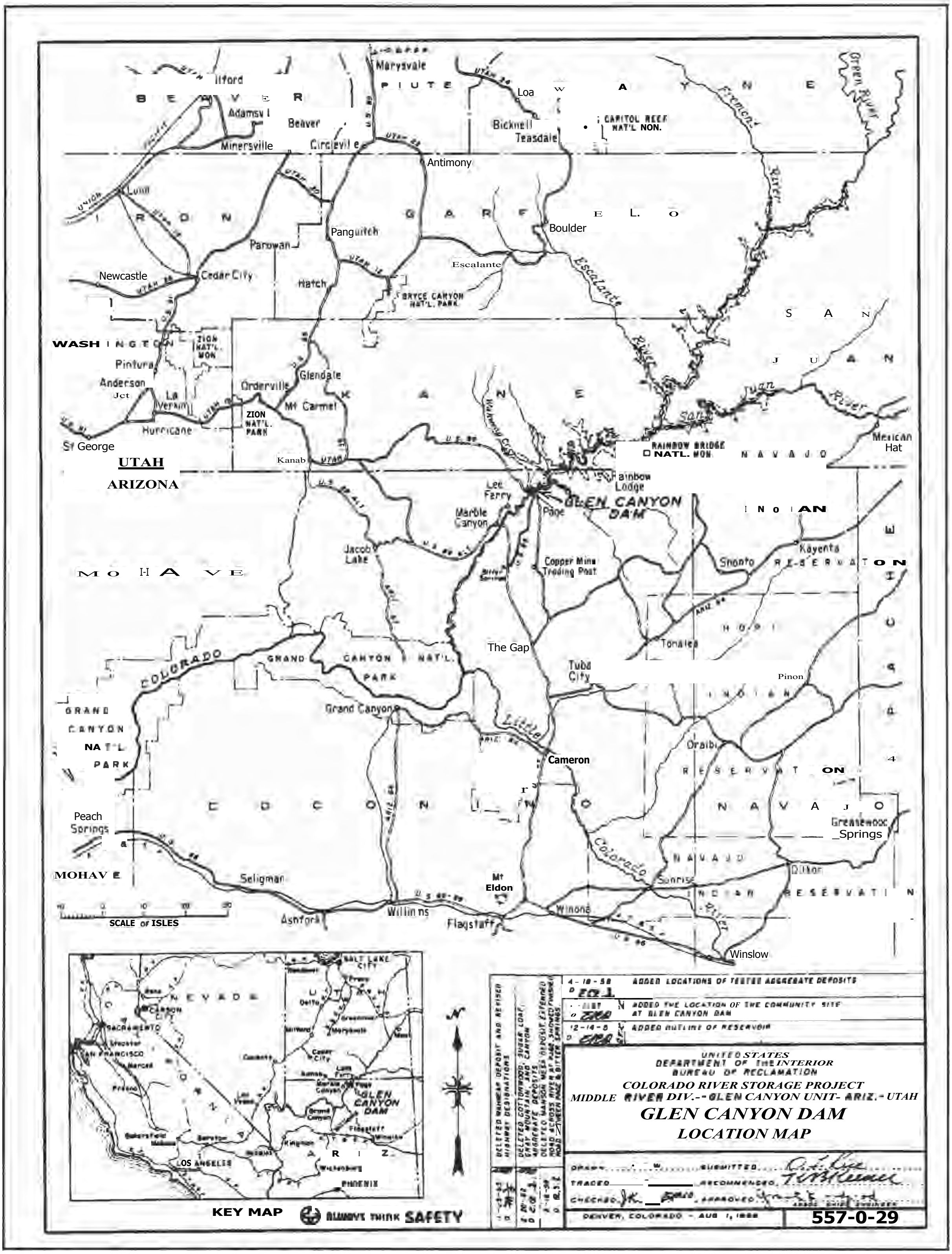

Figure 3 - Location Map

The FWS biological opinion on the operation of Glen Canyon Dam identified outflow temperature control at Glen Canyon Dam as an important component to remove jeopardy for the humpback chub. A goal of the FWS's reasonable and prudent alternative is to develop a second spawning population in the Grand Canyon (below Glen Canyon Dam). Nine aggregations of humpback chub exist below the dam and any one of these could respond positively to thermal modifications and reproduce.

More recent work by Valdez and Carothers (1998) concluded that, "We believe that most larval flannelmouth suckers, bluehead suckers, and humpback chub descending from warm natal tributaries into the cold mainstem die of thermal shock or from predation elicited by erratic swimming behavior. For those fish old enough to survive the transition, swimming ability may be reduced by as much as 98% by cold mainstem temperatures." Gorman of Arizona Game and Fish Department suggested that temperature controls could be an effective tool to reduce this thermal shock during the relatively short period of time that the humpback chub are descending into the mainstem (mid- to late-summer) without favoring their competitors. This concept is recommended as the first step in the testing program for the temperature control device. Then later, after monitoring and consultation with the Glen Canyon Adaptive Management Work Group, longer warmwater.

The proposed temperature controls would be used to create more suitable temperature conditions for humpback chub while protecting the existing blue ribbon trout fishery immediately below Glen Canyon Dam. By coupling warmwater releases from the dam with downstream warming, the Colorado River near the Little Colorado River would reach suitable spawning temperatures for the humpback chub. Outflow and river temperature modeling studies conducted by Reclamation show that this is possible. It has also been proven to work well at Flaming Gorge Dam.

There are ecological interactions in the Grand Canyon which add a degree of risk to the outcome of temperature controls. The potential interactions of native and non-native fish (and the risk to humpback chub) remain somewhat controversial among scientists. In some ways, cold water isolates and protects the habitat of the humpback chub in the Little Colorado River and limits the chub's warmwater competitors. On the other hand, cold water limits the chub's habitat in the main channel of the river. The goal of warming the water in the main channel of the river is to expand the range of habitat available to the chub. However, warmwater may also benefit the chub's competitors. These uncertainties are why Reclamation includes post-project monitoring, verification, and adaptive management as part of the proposed action.

AUTHORITY

Feasibility studies and construction authority is provided under Section 8 of the Colorado River Storage Project Act (CRSP). Section 8 authorizes Reclamation to ". . . investigate, plan, construct,. . . (2) facilities to mitigate losses of, and improved conditions for, the propagation of fish and wildlife. . . ." Use of this authority would be consistent with the retrofit of a temperature control device at Flaming Gorge Dam, another CRSP dam. Federal appropriations (rather than power revenues) were used to prepare this report and would be used to fund construction of the project. As specified by the Section 8, appropriations for the construction of the temperature control project would be nonreimbursable. The CRSP also prohibits the use of power revenues for construction. The Grand Canyon Protection Act of 1992 (Public Law 102-575) authorizes the Secretary of the Interior to use power revenues to fund the ongoing monitoring and adaptive management program. These funds may not be used for construction.

PERMITS REQUIRED

Researchers monitoring the effects of temperature controls would have to obtain permits from the National Park Service to conduct studies in the river corridor. In addition, those working with threatened or endangered species would have to obtain a permit from the FWS and Arizona Game and Fish Department, and researchers working with fish or wildlife species would need an Arizona Game and Fish Department permit. Tribal permits and other permits would be obtained as appropriate.

In a similar temperature control modification at Hungry Horse Dam in Montana, the Army Corps of Engineers stated in their February 1, 1994, letter to Reclamation, ". . . that if the proposed structures are placed inside the trashrack structures, then no Department of the Army permit is required for this project." Reclamation would consult with the Army Corps of Engineers to determine if this project requires a Section 404 permit under the Clean Water Act.

SCOPING SUMMARY

Temperature control has been a topic of discussion among scientists, researchers, cooperating agencies, and other stakeholders in the Glen Canyon Dam Environmental Impact Statement (EIS) process since early 1991. The Glen Canyon Dam EIS Transition Work Group (TWG), which at the time included representatives of virtually all stakeholders in this process, has discussed temperature controls at several of their meetings. In addition to the normal TWG meetings, workshops with representatives of the cooperating agencies and researchers were held in January 1992, April 1992, November 1992, June 1994, and again in October 1994 to discuss temperature controls. These workshops were held to scope the process and issues surrounding the proposed modifications to Glen Canyon Dam. The groups identified a list of resources and issues to be evaluated. The results of these studies and other analyses are included in this report.

There is concern over the ability of science to fully predict the impacts of specific temperature release patterns. Post-project monitoring by the Grand Canyon Monitoring and Research Center and the adaptive management process would be an essential part of the action alternative. Temperature controls at the dam would be another tool to be integrated into the management of the river system. How this temperature control tool will be applied will require an iterative process of thoughtful scientific testing and adaptive management of the facility's operation. A monitoring and adaptive management program is included in the proposed temperature control alternative.

PREVIOUS AND RELATED EXPERIENCES

Glen Canyon Dam Outflow Temperature Control Study - This study conducted by Reclamation (Ferrari 1987) presents an analysis of raising the water release temperatures below Glen Canyon Dam by modifying dam penstocks with multi-level intakes. Predicted temperatures of waters drawn from Lake Powell were calculated with a computer model. The temperature change of this warmer water as it moves downstream was evaluated using both a computer-generated temperature function and a simplified graphical method. The study concluded that multi-level intakes could increase river temperatures by up to 18°F (10°C), depending upon the time of year.

Flaming Gorge Outflow Temperature Control - The retrofit of Flaming Gorge Dam with temperature controls provides the nearest parallel to the proposed temperature modifications at Glen Canyon Dam. Much like Glen Canyon Dam, Flaming Gorge Dam was originally constructed with deep intakes for the power penstocks. The deep intakes released extremely cold water and these cold-water releases limited growth rates in the native and non-native fisheries. Reclamation used the authority of Section 8 of the CRSP Act to retrofit the dam with a series of shutter gates to improve temperatures for trout below the dam.

Mark Vinson, Director of the Bureau of Land Management's (BLM) National Aquatic Monitoring Center has compiled all the available macroinvertebrate data for the Green River below Flaming Gorge under a contract with Reclamation. Vinson found that overall there have been some shifts in species composition that tend to have favored the amphipods or scuds, but little or no change in total abundance of invertebrates and relatively little change in the total taxa diversity or richness at the most upstream sites.

Post-project monitoring shows that the temperature control modifications have been extremely effective at warming the water and producing results. The intakes at Flaming Gorge Dam are set to release temperatures of approximately 13.5°C during the summer. Downstream areas experience some fairly significant warming toward ambient conditions. For example, spring/summer temperatures in 1994 in upper Browns Park ranged between approximately 14°C to 18°C, between approximately 15°C to 20°C in lower Browns Park, and were slightly warmer in Lodore Canyon, approaching 21°C.

The warming of the summer release temperatures from approximately 4°C to 13.5°C had an immediate beneficial effect on trout growth and production in the tailwaters. Annual growth of young trout increased from around 45mm to 150mm during the years immediately following warming. Monthly summer growth of trout fingerlings also increased dramatically with increased temperatures.

Below the immediate tailwater area, several native and non-native fish species appeared to react quickly to the temperature increases. Several species, such as adult red shiners and sand shiners, expanded their range by moving up from the confluence of the Green and Yampa rivers into lower Lodore Canyon. Roundtail chub and channel catfish were also documented 2 moving further up river in Lodore Canyon. As a result of the increased temperatures, flannel mouth sucker, blue head sucker, speckled dace, and red shiner all began reproducing in Lodore Canyon.

As of 1995, there was a fairly extensive native fish community in Lodore Canyon, a number of which were reproducing, including the flannel mouth sucker, blue head sucker, mountain white fish, speckled dace, and mottled sculpin. As of 1995 there was also a fairly extensive non-native fish community in Lodore Canyon. Reproducing species include redside shiner, fathead minnow, and red shiner.

In summary, the measured effects of warming on the fisheries of the Green River include:

- Improved trout growth and reproduction.

- In the period between 1978 and 1995, there appears to be increased use of Lodore Canyon by Colorado (endangered) squawfish.

- Other native fish such as flannel mouth sucker, blue head sucker, mountain white fish, and speckled dace all began to reproduce in Lodore Canyon and lower Brown's Park as a result of raising river temperatures in 1978.

- Non-native red shiners began reproducing in lower Lodore Canyon but have not expanded upstream over the period of 1978 to 1995. Non-native white suckers have also begun reproducing since the inlet modification and there is increasing evidence of various sucker hybrids in the Green River between the dam and the Yampa River.

- Non-native fathead minnows were reproducing in the river throughout Lodore Canyon before the warming of the river and appear to have become more abundant in lower Lodore Canyon during the period of 1978 to 1995.

Shasta Dam Outflow Temperature Control Study - The upper Sacramento River is the largest and most important salmon stream in California and provides more spawning habitat for chinook salmon than any other river in the State. Elevated temperatures negatively impact the fish. In 1987, Reclamation began releasing water from the river outlet works to cool release temperatures in the heat of the summer for salmon. While improving river temperatures, this measure cost nearly $9 million in power generation over 3 years.

A planning report/final environmental statement titled *Shasta Outflow Temperature Control* was prepared by Reclamation and filed in 1991 to evaluate alternatives for retrofitting outflow temperature control to Shasta *Dam* and eliminate bypassing the powerplant. The cost of the shutter device (for temperature control) is about $60 million. The current cost-sharing proposal is 75 percent Federal (50 percent reimbursable by authorized project purposes and 25 percent nonreimbursable) and 25 percent non-Federal. Unlike Glen Canyon Dam, no previous environmental impact statement had been prepared on the operation of the dam. The planning report/final environmental statement was prepared. It concluded that there would be no significant adverse impacts to the environment. The facility has been installed and initial testing is underway.

Hungry Horse Dam Selective Withdrawal System - Near-constant, cold-water releases (4°C) were found to be causing fish losses below Hungry Horse Dam. Temperature modifications at Hungry Horse Dam have been completed. The modifications and temperature objectives are very similar to those proposed for Glen Canyon Dam. River temperatures will be increased to about 17°C in mid-summer to promote higher growth rates in cutthroat trout. The *Hungry Horse Dam Selective Level Withdrawal System Final Environmental Assessment/Finding of No Significant Impact* (Reclamation 1994) states that warmwater releases would increase the downstream trout growth rates by two to five times. Modeling studies indicate that phytoplanton and zooplankton would be entrained in the discharge, but that overall productivity in the reservoir would increase somewhat. Warmwater discharge would destabilize the temperature stratification of the reservoir, promoting a stronger turnover, cycling more nutrients into the surface water. Some minor impacts to the lake fishery are expected, but are thought to be avoidable through careful operation. Fish entrainment in the turbines is not expected because fish stay near shoreline. The report concluded that no adverse impacts would be expected from the addition of temperature controls.

Other Selective Withdrawal Systems - In the Upper Colorado Region of the Bureau of Reclamation, Jordanelle, Stagecoach, and McPhee Dams were all originally designed with temperature controls so that river temperatures could be regulated to maintain natural conditions and sustain trout fisheries. All of these have fulfilled their intended purpose without any known ancillary impacts to either the reservoirs or rivers below them.

CHAPTER II - DESCRIPTION OF ALTERNATIVES

This chapter presents the alternatives considered in detail, the alternatives eliminated from detailed study, and a summary comparison of the alternatives and their impacts. The No-Action Alternative is the continued cold-water release from the penstock elevation. The Action Alternative would modify the intakes of the dam so warmwater could be released from the dam.

NO-ACTION ALTERNATIVE

The No-Action Alternative would continue to release cold water (usually between 8°C to 10°C) through the existing power penstock intake elevation.

ACTION ALTERNATIVE (Temperature Control Modifications)

The Action Alternative would modify the intakes of the dam so warm water could be released from the dam. The proposed modification would make extensive use of the existing (hollow) trashrack structure to convey water from the surface.

As was mentioned earlier in the Scoping section of this report, there are complicated ecological interactions in the Grand Canyon which add a small, but very serious, degree of risk to the outcome of temperature controls. The potential interactions of native and non-native fish (and the risk to humpback chub) and their ecosystem remain uncertain. The goal of warming the water in the main channel of the river is to provide suitable spawning and growth temperatures for the native fish (i.e., humpback chub, flannelmouth sucker, bluehead sucker, and speckled dace). However, warm water may also benefit non-native competitors. Temperature controls are likely to be beneficial, but an adaptive management program would be used to monitor and refine the operation of the facility to optimize its benefits.

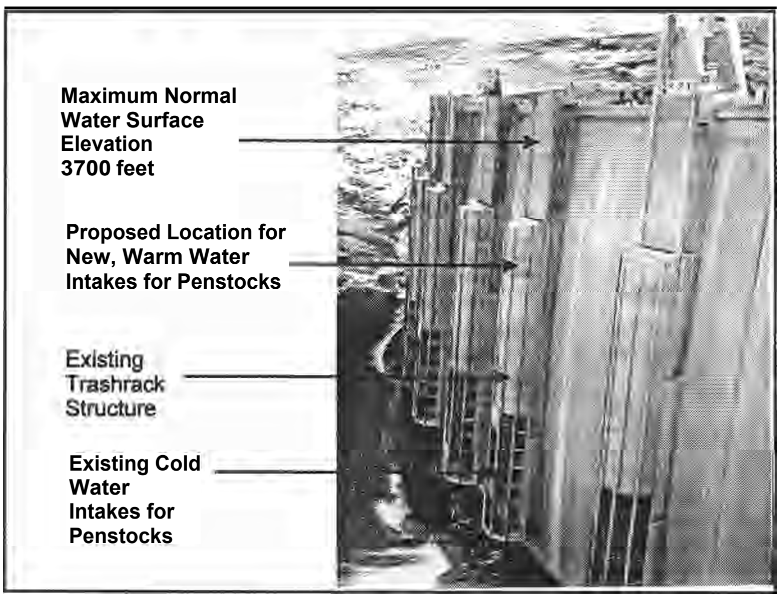

Figure 4 - Photo of upstream side of Glen Canyon Dam showing intakes for power penstocks soon after construction was completed (before the reservoir was filled).

It was this uncertainty that led Reclamation to seek a relatively inexpensive alternative to existing designs. The consensus of those attending the scoping meetings was that the risks were a bit too high to invest an estimated $45 to $150 million in a traditional selective withdrawal structure. Fortunately, the value planning work done by an interdisciplinary team from Reclamation uncovered an alternative design which would use much of the existing structure of the dam to achieve temperature control at a cost of $15 million, yet retain the functionality of a traditional selective withdrawal structure.

The intakes to the dam would be modified to draw water from either the existing penstock intake or through a surface intake at the top of the existing trashrack. Traditional designs usually provide multiple gates or sliding weirs to control intake location and temperature for each individual penstock. This facility would have only two fixed openings (cold and warm). Each of the eight penstocks could be individually set to select either cold or warm(er) water with the new gate system. Blending of water between the penstocks would be used to adjust the resulting downstream (outflow) temperature.

Because the upper intake elevation would be fixed and about 40 feet of submergence would be required to operate the upper intake, warmwater releases would only be made when the reservoir water surface is between 3,700 feet (full) and 3,670 feet. Under present conditions of water development, computer projections of the Colorado River system would show the water surface elevation in Lake Powell to be within this range about 85 out of 100 years during the May-October season. Statistics aside, it can be expected that an extreme dry period would cause operations to be postponed. On occasion, the Colorado River has experienced near decade-long dry periods which could impact the operation. Fortunately, if the reservoir is severely drawn down by an extended drought, the lower intakes will begin to draw some warm water.

Warm water in the reservoir is usually available beginning in the late spring through fall turnover and peaks in the late summer. Release temperatures from the dam would be ramped up to about a 15°C and then limited at that temperature to prevent significant impacts to the "blue-ribbon" trout fishery below the dam. Once these limits are reached, cold water would be blended from one or more of the eight penstocks to prevent impacts to trout fishery. The goal of this management scheme is to increase water temperatures in the lower portions of the river for native, warmwater fish while maintaining near optimal conditions for the "upstream" cold-water trout fishery in the Lees Ferry reach below the dam. Releases of 15°C below the dam should be near optimal for the coldwater fishery and promote better growth rates. Then, as the water flows downstream, it will warm. By the time the water reaches the Little Colorado River (76 miles below the dam), temperatures should be sufficiently warm to meet the thermal needs of native, warmwater fish.

Role of Adaptive Management in Operations - Adaptive management is an approach to natural resource policy that embodies a simple imperative: policies are experiments; *learn from them.* In order to live we use the resources of the world, but we do not understand nature well enough to know how to live harmoniously within environmental limits. Adaptive management takes that concept seriously, treating human intervention in natural systems as experimental probes. Its practitioners take special care with information. First, they are

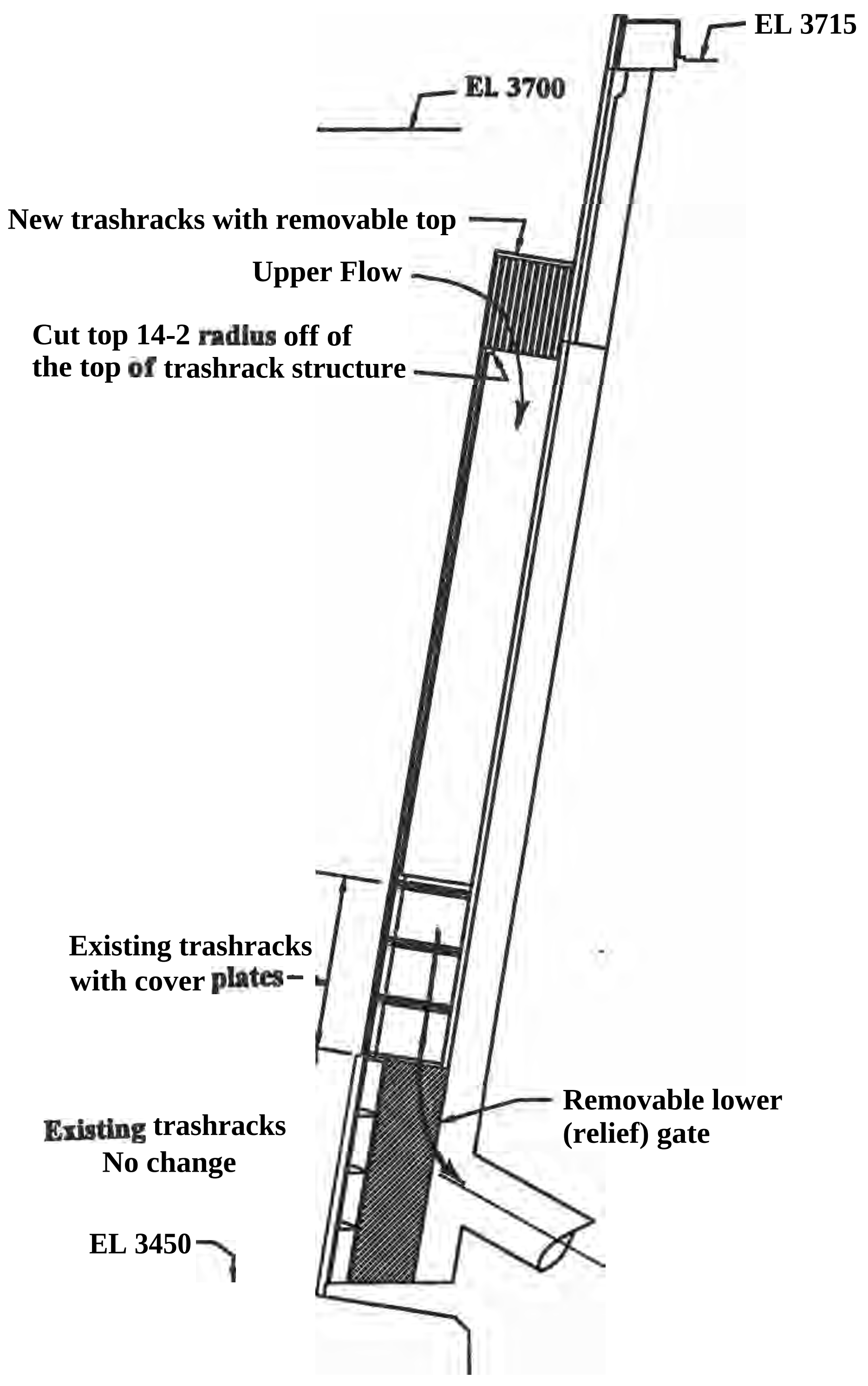

Figure 5-Schematic of temperature control modifications.

explicit about what they expect, so they can design methods and apparatus to make measurements. Second, they collect and analyze information so expectations can be compared with actuality. Finally, they transform comparison into learning—they correct errors, improve their imperfect understanding, and change action and plans. Linking science and human purpose, adaptive management serves as a compass for us to use in searching for a sustainable future.

Adaptive management is an iterative process of action-based planning, monitoring, researching, evaluating, and adjusting with the specific objective of improving implementation and achieving the goals that have been identified. Uncertainty is inherent in this process and the greatest learning may come from unexpected results. Therefore, adaptive management must also be flexible as well as iterative, allowing and providing for change with decreasing uncertainty and increasing knowledge. Knowledge or data on the effects of an action, purposefully collected and used to improve future actions, is fed back into the process. Then, based on that information, the management and research activities are adjusted and adapted as the activities are implemented so the environmental effects fall within the predefined limits identified in the initial analysis. This adaptive management process in not a single act or event, but is a continuing mode of behavior carried out through a process of adaptation.

Because of the complexity of the ecological interactions in the Grand Canyon, no one fixed plan of operation could be expected to fully meet the goals of the proposed temperature control alternative. Refinements in the temperature release patterns (operations) will need to evolve as our knowledge increases from each successive year of testing. The proposed alternative must embrace the basic concepts of adaptive management to become effective. Carefully designed experiments are necessary to assure that these adaptations help, not harm the resources.

The adaptive management tests would follow an iterative process. Managers would design the initial year's experiment to alter the downstream temperature and monitor the effects. After evaluating the results of the experiment, they may modify the temperature release pattern. Any unexpected finding may require adjustments or adaptation. For example, the first year of testing may show an increase in a particular fish species that competes with humpback chub. The following year's release pattern may be shifted to control that species. Each year will be evaluated, and each year a new experimental design will be developed and reviewed. After a number of years, the uncertainties should be reduced and the desirable operational patterns should begin to emerge. Eventually, a reasonable long-term operating and monitoring scenario should become evident.

Glen Canyon Adaptive Management Process - The Glen Canyon Adaptive Management Program was implemented as a result of the Record of Decision (ROD) on the *Operation of Glen Canyon Dam Final Environmental Impact Statement* (USDI 1995) and to comply with consultation requirements of the Grand Canyon Protection Act (PL 102-575) of 1992. The Program provides an organization and process to ensure the use of future scientific information in making decisions concerning Glen Canyon Dam operations and protection of the affected resources consistent with the Grand Canyon Protection Act. The Adaptive

Management Program includes a Federal advisory committee (Glen Canyon Adaptive Management Work Group), a subcommittee (the Technical Work Group), the Interior's Grand Canyon Monitoring and Research Center (GCMRC), and independent review panels.

The Glen Canyon Adaptive Management Work Group evaluates management objectives related to the effects of dam operations on resources within the Glen Canyon National Recreational Area and Grand Canyon National Park. They make recommendations to the Secretary of the Interior related to these issues.

The Department of the Interior's GCMRC was established by the Secretary to develop and administer plans for long-term monitoring and research of the Colorado River and its riverine environment that responds to the short and long-term operations of Glen Canyon Dam. The GCMRC is guided by research needs identified by the Adaptive Management Work Group, the Technical Work Group, and other associated interest groups.

The Glen Canyon EIS established an Adaptive Management Program to study and refine the operation of the dam. Temperature controls would be a new and potent variable available to manage the ecosystem of the river below the dam. The Adaptive Management Work Group, Technical Work Group, and the GCMRC would recommend (to the Secretary) testing and monitoring programs, review monitoring results, and recommend adaptive solutions to manage the system.

Currently, the GCMRC is charged with implementing the monitoring priorities for all the resources impacted by the operation of Glen Canyon Dam. In accordance with the Grand Canyon Protection Act, these studies are funded by power revenues. The proposed addition of temperature controls does not change GCMRC's responsibility to monitor the resources nor does it change the list of resources in the canyon, but it should effect the priority of monitoring needs. For several years now, GCMRC's emphasis has been focused on monitoring sediment transport and beach habitat maintenance as the Adaptive Management Program explores the impacts of floods in the canyon. As this beach habitat work progresses over the next several years, the Adaptive Management Program may place emphasis on monitoring those resources that may be impacted by the use of this powerful new tool (temperature controls).

In summary, the Glen Canyon Adaptive Management Program was developed to provide an organization and process for cooperative integration of dam operations, downstream resource protection and management, and monitoring and research information, as well as to improve the values for which the Glen Canyon National Recreation Area and Grand Canyon National Park were established.

Proposed Operation - Two methods of operation (to achieve different goals) may be tested. The first (somewhat less ambitious goal and test) would be to prevent thermal shock to the young-of-the-year humpback chub as they leave the warm water of the Little Colorado River (mid to late summer) and enter the mainstream of the Colorado River which is presently very cold. Valdez and Carothers (1998) concluded, "We believe that most larval flannelmouth suckers, bluehead suckers, and humpback chub descending from warm natal tributaries into the cold mainstem die of thermal shock or from predation elicited by erratic swimming behavior. For those fish old enough to survive the transition, swimming ability may be reduced by as much as 98% by cold mainstem temperatures." Warming releases in the mid to late summer timeframe would very specifically benefit native fish.

The second more ambitious goal would be to remove the temperature constraint in the river during the summer months to promote new areas of spawning and recruitment. Releases would ramp up to about 15°C over the month of June, sustain 15°C releases through July and August, and then ramp down through the month of September. Monitoring of the resources would be conducted by the Grand Canyon Monitoring and Research Center. Then, given the test results of the monitoring program, changes in the release pattern would be considered through the Adaptive Management Process.

Warmwater releases will need to be limited to 15°C to prevent negative impacts to the tailwater trout fishery. Warmwater releases may also need to be limited in magnitude, duration, timing, and frequency to control competition from non-native fish. Fortunately, humpback chub and other native species are long-lived (20-30 years) while non-native fish tend to be short-lived (2-5 years). If required, infrequent use of temperature controls (possibly as little as once in 5 years) should greatly favor native fish that live for decades. Timing could also be adjusted to favor native fish and discourage the major competitors.

Proposed Schedule for Construction - The FWS biological opinion requires Reclamation to expedite the evaluation and implementation of temperature controls if feasible. Reclamation has scheduled its environmental compliance work and requested funding so that the project could begin construction in fiscal year 2000. The actual construction period would span between 2 to 3 years and would depend upon the rate of funding received from Congress.

Annual Operation and Maintenance Costs - The Grand Canyon Monitoring and Research Center (GCMRC) estimated that a portion of the cost of a monitoring program for temperature controls is already included in their existing monitoring program. The table that follows shows the additional costs for the monitoring program which would either need to be prioritized into GCMRC's existing budget or may require additional fund.

Physically, the intake modifications to the dam are relatively simple to operate and maintain. Because each gate would be operated by an individual hoist, operation would be as simple as pushing a button. Maintenance of the eight hoists, cables, and electrical equipment would be periodic and simple. If the shear pins on the relief gates need to be reset often, this may require a day-long effort on each gate. Special precautions have been designed into the relief gate shear pin mechanism which make this unlikely. The cost of the operation and maintenance was estimated by Glen Canyon Dam maintenance staff to fall well below $100,000 per year. As required by the authorizing legislation, all operation and maintenance costs would be paid by revenues generated by the sale of power.

Operation and Maintenance Costs for Temperature Controls

Fiscal Year	Monitoring	O&M	Total
2000	$200,000	$100,000	$302,000
2001	$1,100,000	$100,000	$1,202,001
2002	$1,600,000	$100,000	$1,702,002
2003	$1,600,000	$100,000	$1,702,003
2004	$1,300,000	$100,000	$1,402,004
2005	$550,000	$100,000	$652,005

ALTERNATIVES CONSIDERED BUT ELIMINATED

Navajo Powerplant Alternative - It was suggested that an alternative to selective withdrawal might be to use waste heat from the Navajo Powerplant. The powerplant currently uses cooling towers to condense their steam. In theory, the powerplant could be modified for flow-through cooling. Water discharged below the dam from a pipeline could be run through a generator(s) to reclaim the power lost (or plumbed into the existing turbine system). The energy produced from a 2,250 MW power plant would be about 810,000 kcal/s (360 kcal/s-MW) and would warm 16,000 cfs by almost 2°C. This alternative would not warm the river sufficiently and would be extremely expensive due to the distances to be traversed.

Hold the Reservoir at Minimum Pool - This alternative would hold the water surface at extremely low elevations so that penstocks could draw from the surface layer of the reservoir during the summer. This alternative would not allow Glen Canyon Dam to meet its statutory purposes. Power revenue losses to the government would exceed $100 million per year. Control of the release temperature would be difficult and would likely impact the downstream trout fishery. This alternative would also not allow the flexibility to quickly return to cold-water releases in case negative effects were seen downstream.

Minimize Summer Releases to Increase Warming of the River - Extremely low summer releases might allow the river to warm more that under existing conditions; however, the loss in power production would likely far exceed the $1.2 million annual cost ($15 million capital cost) of the proposed temperature control alternative. Furthermore, cold-water releases from the dam would continue to be well below optimal for the Lees Ferry trout fishery and nutrient loading to the river would be far less than the temperature control alternative.

Dam Removal - This alternative would likely restore natural temperature regimes to the river but may not help the recovery of endangered species because of the existence of non-native fish species which have been introduced to the river system. These warmwater competitors are suppressed by the existing cold-water discharges from Glen Canyon Dam. Once they reproduce in warm water, humpback chub do very well in cold water. The proposed action would continue to control this competition by the selective discharge of warm and cold water. Warm water would be released to allow the humpback chub to reproduce, the cold-water releases would be used to control competitors. This management option would not be possible if the dam were removed.

Fund other Recovery Efforts - Hatcheries or recovery of other populations of humpback chub are beyond the scope of this study and do not implement the reasonable and prudent alternative of the FWS's biological opinion on the operation of Glen Canyon Dam. The purpose of the action alternative of this environmental assessment is to establish conditions supporting the removal of jeopardy to endangered fish in the Grand Canyon. The Recovery Program participants are reluctant to concentrate all their efforts above Glen Canyon Dam.

Reservoir Destratification - This alternative would mix the reservoir near the dam to warm the water taken into the penstocks. This technique has been used in small reservoirs and ponds to improve water quality, but not in large reservoirs. This alternative could be very expensive and complicated by the size of the reservoir and the complex patterns of winds and currents.

DESIGN ALTERNATIVES CONSIDERED

A value planning study, dated April 24, 1997, was conducted to screen various design alternatives to modify the intakes of the dam to control temperatures and develop appraisal level costs. Proposals 2A, 3, and 4 were recommended for more detailed (feasibility level) analysis. Feasibility level costs were developed for these three design alternatives and reported in a technical memorandum dated September 1997. The feasibility level costs for these alternatives are included below. Proposal 2A is an innovative solution and has become the action alternative. Proposals 3 and 4 are more traditional design solutions, would have similar effects, but are significantly more expensive.

Proposal No. 1 - Use existing spillway structure to release warm surface water from the reservoir: This proposal would use the existing spillway channels to release warm surface water from the reservoir as an alternative to structural modifications to the dam. The appraisal level cost of this proposal was $13,500,000 per year based on lost power revenues and assumes that 8,000 ft^3/s is released through the spillway, which corresponds to two units off-line for 3 months. The clear benefits of this proposal is its lack of structural changes. Its disadvantages are its high annual cost and the potential for dissolved gas problems impacting the downstream trout fishery. In comparing this alternative to others, its capitalized costs would easily exceed $100 million. This proposal might provide a method to test the impacts of warmwater releases, but the costs for even 1 year of operation are about equal to the action alternative. This proposal was not brought forward for more detailed cost analysis.

Fifty percent of the time the water elevation would be above 3,653 feet. When the water surface is at or above 3,653 feet, the spillways would discharge about 8,000 ft /s into the tunnel spillways. The remaining about 17,000 ft^3/s would be released from the turbines with this option. This would mean that the bypassed flow would not generate power. No modifications would be needed to the dam for this option to work, but lost power revenues would occur. During the times when warmer water is needed downstream, the radial gates could be opened and warm water could be skimmed off the top reservoir.

By releasing 8,000 ft /s from the spillway and 17,000 from the turbines downstream, release temperatures at the dam for April, May, June, and July would be 51.0°F, 54.7°F, 60.1°F, and 61.5°F (10.7°C, 12.5°C, 15.6°C, and 16.4°C), respectively, for a starting elevation of 3,653 feet in April. When all the flows are released through the turbines temperatures of 44.3°F, 44.3°F, 44.4°F, and 44.5°F (6.8°C, 6.8°C, 6.9°C, 7.0°C) occur during April to July downstream from the Dam.

There are several potential complications with this proposal. Initial releases may need to be greater than 8,000 ft^3/s to clean debris from the flip bucket. This may cause thermal shock to fish near the dam. Low flows may cause dissolved gas problems if the jet from the flip bucket stays submerged. The ability to control the discharge by adjusting the radial gate may not be very precise using the existing controls. Also, the gate openings would need to be increased as the pool elevation goes below elevation 3,653 feet to maintain 8,000 ft /s.

The range of operation for this option would be from full pool (elevation 3,700 feet) to about 3,653 feet. Below this elevation, the flow from the spillways would decrease until at 3,648 feet; no flow would be released by the spillway in this option. Consequently, all flow would be released through the turbines at about 44.6°F or 46.4°F (7.0°C and 8.0°C).

Costs associated with this option could be significant. According to the operators each turbine generates about $75,000 of power during each day of operation at 4,000 ft^3/s discharge. Power costs based on this rule of thumb would imply that about $150,000/day would be lost by using the spillways and taking two turbines off line.

Proposal No. 2A - Remove top of trashrack structure and install gate at penstock intake. This proposal meets the objectives of warmwater releases at a relatively low cost. It requires the reservoir to be relatively full and would not function every year, but because native fish are long lived and their competitors are not, frequent (annual) warmwater releases are not required. This proposal was determined to be both cost effective and functional. The proposal was brought forward for more detailed cost analysis. The feasibility level cost estimate for this proposal was $15,000,000. This method of temperature control is described in more detail (earlier in this chapter) as the proposed temperature control alternative in this environmental assessment.

Proposal No. 2B - Remove top of trashrack structure and install gate at penstock intake and install a middle level gate. The appraisal level cost of this proposal is $35,000,000. The benefits of this proposal were similar to proposal No. 2A, but would provide the added flexibility of a mid-level withdrawal. The disadvantages of this alternative over proposal No. 2A were its higher cost and complexity. This proposal is functionally similar to proposal No. 2A, but over two times more expensive. It was not considered for more detailed study due to its relatively high cost.

This concept relies on withdrawing water through the top of the trashrack structure and through ports or windows provided in the top 54 feet of the trashrack structure. Proposal No. 2B is very similar to proposal No. 2A except that additional openings are provided in the sides of the trashrack structure to increase the operating range compared to proposal No. 2A. Using underwater construction methods, the top of the trashrack structure, elevation 3,652, would be removed providing a semicircular opening having an area of 318 square feet and a radius of 14.25 feet. Also, 15 ports, 5 per level with 3 levels, that are 13 feet high by 7 feet wide would be cut in the concrete walls of the trashrack structure. The elevation at the bottom of the lower ports would be at elevation 3,598.

To force the flow through the top opening and through the ports, the top 37.5 feet of the existing trashrack opening would be closed and the lower 50 feet blocked by a relief gate. To close the upper portion of the opening, plates would be installed over the existing trashracks. The relief gate, which would be 50 feet high and semicircular in shape, would be installed in the existing stoplog guides. The relief gate would be designed with relief panels to protect the system and trashrack structure from excessive differential head. Unlike Proposal No. 2A, the relief gate would be suspended from wire ropes and operated by a hoist. To accommodate all of the equipment and to provide trashrack slots up to the surface, a hoist deck would be provided at elevation 3,715 and supported by columns down to the top of the existing trashrack structure. Port gates, 8 feet wide and 54 feet high, which would operate up and down in the existing trashrack slots, would be provided to block off the ports when they are not needed. Trashrack panels, 8 feet wide by 60 feet high would be attached to the top of the port gates. Like the relief gates, the port gates would also be operated by hoists.

With the bottom of the existing trashrack structure blocked and the ports closed by the port gates, the warm surface water would be pulled from the top of the reservoir and into the semicircular opening similar to proposal No. 2A. These flows are protected by the raised trashrack panels attached to the port gates. As the reservoir drops and there is not sufficient submergence, the port gates are lowered to provide sufficient intake area. Eventually as the reservoir drops, the level would be below the top of the trashrack structure, elevation 3,652, at which time the total flow would go through the ports. If 40 feet of submergence is necessary, the system would be fully effective down to reservoir elevation 3,638 providing an effective operating range of 62 feet. During periods when selective withdrawal is not needed, the relief gate would be brought up and stored near the surface to conserve the warm water in the lake and minimize head loss.

Proposal No. 3 - Controlled overdraw through existing trashrack structure. The benefit of this proposal was an operating range of 80 feet. The disadvantage of this alternative over proposal 2A was its higher cost and complexity. This proposal was brought forward for more detailed cost analysis. The feasibility level cost estimate for this proposal is $44,500,000. The proposal is functionally similar to proposal 2A, but nearly three times more expensive. It was not considered further because of its relatively high cost.

This concept, using underwater construction methods, removes the top 72 feet of the trashrack structure which would then be at elevation 3,580. To accommodate all of the equipment and provide trashrack slots up to the surface, a hoist deck would be provided at elevation 3,715, and supported by steel columns which connect to the top of the trashrack structure. The columns would also have guides attached for extending the existing trashrack guides up to the surface. Trashracks would then be provided in these slots all the way to the surface.

An alternative to this trashrack arrangement would be to provide a smaller semicircular trashrack mounted to the top of the control gate. The trashrack would travel with the control gate. This guide system, which runs from the surface down to the bottom of the structure, is provided for the relief and control gate.

To force the flow through the top, the top 37.5 feet of the existing trashrack opening would be closed and the lower 50 feet blocked by a relief gate, the same as proposals 2A and 2B. To close the upper portion of the trashrack opening, plates would be installed over the existing trashracks. The relief gate, which would be 50 feet high and semicircular in shape, would be installed in the new guides. The relief gate would be designed with relief panels to protect the system and trashrack structure from excessive differential head. A control gate which acts like an adjustable weir would also be installed in the new guides. It would be semicircular in shape, 80 feet high, and operated by a hoist.

With the bottom of the existing trashrack structure blocked, and the top of the control gate set at the proper submergence, the warm surface water would be pulled from the top of the reservoir and into the semicircular control gate and down the trashrack structure. As the reservoir drops, the control gate is lowered to maintain the proper submergence. If 40 feet of submergence is necessary, the system would be fully effective down to reservoir elevation 3,620 providing an effective operating range of 80 feet. During periods when selective withdrawal is not needed, the relief gate would be brought up, using a lifting frame and mobile crane, and stored near the surface to conserve warm water in the lake and minimize head loss.

Proposal No. 4 - External frame structure with three flat gates. This proposal was brought forward for feasibility cost estimates to define the upper limit of the options available. The feasibility cost for this proposal was $148,500,000. This method was found to be nearly ten times more expensive and yet functionally similar to proposal 2A. This alternative had slightly less impact on power production and unneeded flexibility. It did not offer significant operational benefits over less expensive modifications.

The exterior frames concept consists of a steel truss structure attached to the face of the dam. The structure would encompass the existing trashrack structure. Each structure would be approximately 50-ft wide (cross canyon direction), 50-ft deep (stream direction) and 265-ft high. Each structure would be suspended from a rigid frame attached to the face of the dam by a rigid frame (knee-braced support) at a centerline elevation of 3,710. A separate structure would be provided for each unit. This would allow for staged construction. The structures would be connected to the dam at various elevations as required to resist water hammer, wave, and earthquake loads.

The structure would extend from below the trashrack at approximate elevation 3,445 to the maximum water surface of 3,715. A hoist deck would be provided at the top of the structure at elevation 3,715. A combination of solid, cladding panels and gates would be provided to control the flow of the water into the structure. Cladding panels would be provided on the bottom and along the sides from the bottom elevation of 3,435 feet to elevation 3,670. These cladding panels would seal the bottom and the sides of the structure to the dam and prevent inflow of water during turbine operation.

A series of cladding panels and gates would be provided on the upstream face of each structure to allow selective withdrawal of the water from various elevations. The upstream face of the structure would be configured as follows:

Trashracks would be provided on the upstream face of all gates. Each gate would have a dedicated slot to provide unlimited movement of the gate within its operating range and for removal of the gates. A hoist/operating deck would be provided on the top of the rigid frame. This deck would contain hoists and controls to facilitate individual operation of each of the gates.

Additional trashracks would be provided on the two sides of the structure and on the front of the structure between elevation 3,670 and the top of the structure. This would allow overdraw on all three sides during high water levels.

The external frame structure allows maximum flexibility in the withdrawal of various levels of water from the reservoir. The upper and middle gates can be used to follow the water elevation of the reservoir and allows withdrawal of warm water as required at water elevations from 3,710 feet down to 3,580 feet. The lower gate can be used at any time to withdraw the colder water from the penstock elevation. This would serve to conserve the warmwater pool near the top of the reservoir.

Proposal No. 5A - Air-controlled curtain to direct flow into penstocks. The initial appraisal level construction cost of this proposal is $14,500,000. The life cycle cost of this proposal is $26,000,000. Life-cycle cost was calculated for this proposal due to its short service life. Failure of the curtain could be catastrophic, since the curtain could float into the dam and plug the penstocks. The benefits of this proposal were moderate costs and low head loss. The disadvantages of short service life, potential failure, and high maintenance made this proposal infeasible.

The air-controlled curtain concept consists of a 60-mil fabric reinforced Hypalon-rubber curtain that would span across the canyon approximately 500 feet upstream of the dam. The canyon is approximately 1,000 feet wide at this location. The top of the curtain is at elevation 3,650 and the bottom is at elevation 3,250.

The curtain would be configured in four horizontal sections, each approximately 100 feet wide. The bottom two sections extend from elevation 3,250 to elevation 3,450 and would be moveable to allow low level withdrawals. The intermediate section extending from elevation 3,450 to elevation 3,550 would be fixed and is not adjustable. The top section extending from elevation 3,550 to elevation 3,650 is moveable to allow high level withdrawals with varying water surface elevations.

Support and restraint of the curtain is accomplished with a series of chains, cables, buoys, floatation tanks, and deadweight anchors. The dead weight of the Hypalon curtain is supported by 20-ft-long floatation tanks located at the top of the curtain. When subjected to density and flow loads, the Hypalon curtain would span horizontally to vertical chains spaced on 20-foot centers across the canyon. The vertical chains offer primary support to the curtain and are supported by submerged buoys on the top and dead weight anchors resting on the reservoir bottom. Intermediate support of the vertical chains is provided by cross canyon wire rope cables at elevations 3,450, 3,550, and 3,650. These support cables are anchored to the canyon walls at each end with wedge-type rock anchors. Dead weight lake anchors provide intermediate support to the horizontal cables and breaks them into eight spans of approximately equal lengths. The dead weight of the horizontal cables are supported by 20-ft-long floatation tanks along the entire length of the cables.

The 20-ft-long floatation tanks at elevation 3,650 that support the curtain and horizontal cable are variable buoyant tanks. Air can be pumped into the tanks to raise them or the tanks can be flooded to lower them. The horizontal cable at elevation 3650 is shackled to the vertical chains so the elevation of the top of the curtain can be adjusted from elevation 3650 to elevation 3550 by raising and lowering the variable buoyant tanks. The curtain fabric is attached to the tanks by bolting between flat bars welded to the tanks and fiberglass battens enclosed in sleeves in the fabric.

The primary purpose of the 20-ft-long floatation tanks at elevation 3,550 and elevation 3,450 is to facilitate construction of the curtain. Initially, these tanks would be full of air and then would be flooded to lower the curtain into position. The tanks would be partially filled with floatation foam to support the tank dead weight.

The 20-ft-long floatation tanks at elevation 3,250 are variable buoyant tanks. Air can be pumped into the tanks to raise them or the tanks can be flooded to lower them. This would raise and lower the curtain between elevation 3,250 and 3,450.

Half of the variable buoyant tanks would be operated by an air compressor located on the left bank of the reservoir and half of the variable buoyant tanks would be operated by an air compressor located on the right bank of the reservoir. Engine generators are required to provide power for the air compressors. One-inch air hoses would be run between the air compressors and each variable buoyant tank.

The large size of the lake anchors prevents them from being installed as a single component. First, a 20-ft x 20-ft steel frame with spikes would be lowered in position; then, four 5-ft x 10-ft x 10-ft blocks of concrete would be lowered into the frames to provide the downward force required to secure the anchor. The mooring line would be wire rope with a heavy chain leader at the anchor to ensure the load is transferred horizontally to the anchor. The weight of the mooring line would be supported by spar-buoys floating on the surface. The spar-buoys dampen the effect of wave forces.

Proposal No. 5B - Hoist-controlled curtain to direct flow into penstocks. Failure of the curtain could be catastrophic, since the curtain could float into the dam and plug the penstocks. The cost of this proposal was not estimated. The disadvantages of short service life, potential failure, and high maintenance made this proposal infeasible.

CHAPTER III - AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

This chapter describes the resources of the Colorado River through Glen and Grand Canyons and the impacts of the proposed action on these resources. The conditions that currently exist are the baseline for analysis of effects. The affected resources are broadly categorized into water and water quality, aquatic resources, endangered and special status species, cultural resources, recreation, hydropower, and air quality. More detailed information on the affected resources can be found in the final *Operation of Glen Canyon Dam Final Environmental Impact Statement* (USDI 1995) and the *Aquatic Ecosystem of the Colorado River in Grand Canyon,* Grand Canyon Data Integration Project Synthesis Report (Valdez and Carothers 1998).

For the purposes of the analysis presented here, it was assumed that the temperature controls may be used whenever warm water is available (typically May through September). Warmer release temperatures would be provided to improve conditions for the warmwater native fishes.

COLORADO RIVER ECOSYSTEM RESOURCE LINKAGES

Resources downstream from Glen Canyon Dam are inter-related or linked, and many are associated with, or dependent on, water temperature. In such a linked system, changes in a single process can affect many resources. For example, the proposed temperature modification may directly or indirectly affect water quality, aquatic organisms, and fish. Threatened and endangered species can be affected through their linkages to other resources (non-native predators/competitors) and the effects of temperature on those resources. These changes may be adverse or positive. These linkages play a preeminent role in the development of the proposed alternative and the resource analyses presented in this document. The goal in preparing the proposed alternative was to achieve needed positive effects for endangered species while avoiding adverse impacts.

Glen Canyon Dam has altered many characteristics of the Colorado River. Historically, the river and its larger tributaries were characterized by heavy sediment loads, variable water temperatures, large seasonal flow fluctuations, extreme turbulence, and a wide range of salinities. The dam has dramatically altered the temperature of the river. Before the dam, river water temperature varied on a seasonal basis from a monthly average high of about 26°C (78°F) to lows near freezing. Now, water released from the dam averages about 8°C (46 °F) and varies little year round. The dam releases are clear and cold. The cold releases from the dam now support aquatic communities that did not exist before Glen Canyon Dam.

The ecosystem now contains a mixture of native and non-native plant and animal communities that began developing (prior to the dam) with the introduction of non-native fish and vegetation (Carothers and Brown 1991). Dam construction and operation further modified this mixture and created the current system that is supported by post-dam conditions. This region of the Colorado River is forever changed.

The pre-dam aquatic ecosystem supported an array of native and non-native fish species. At the time of dam closure in 1963, eight species of native and eight species of non-native fish were present. By 1968, non-native fish species outnumbered native species, with trout dominating the now cold-water system immediately below the dam, and native species declining or becoming extirpated. The reasons for extirpations or declines of the native fishes are undoubtedly complex, but principal known factors are competition and predation by non-native fish, habitat changes including temperature changes, and a fragmented ecosystem brought about by construction and operation of Glen Canyon Dam.

Prior to the dam, the principal source of energy to the river was the large quantities of woody and organic material and nutrients washed from the surrounding landscape. There was little primary productivity in the river because of reduced light penetration from consistent turbidity. In the post-dam river, the biological foundation (primary producers) of the aquatic system below Glen Canyon Dam is *Cladophora glomerata,* a filamentous green alga. Clear river conditions created by the dam make possible the abundant growth of *Cladophora.* Together, *Cladophora,* diatoms, and associated invertebrates *(Gammarus* and insects) provide an important food source for other organisms in the aquatic food chain.

CONSTRUCTION

Work activities directly associated with installation of the temperature controls at Glen Canyon Dam would not adversely impact resources in Lake Powell or downstream in the Colorado River. The existing concrete caps on the trashracks towers would be saw-cut underwater. A relatively small amount of concrete (about 715 cubic yards) would be left in the bottom of the reservoir. The operating components of the system would be made mostly of structural steel, assembled off-site, hauled to the dam, and lowered into place from the top of the dam by a mobile crane. Some assembly and connection of the trashrack sections and trashrack cover plates would be completed underwater by divers. No coffer damming would be necessary to dewater the trashrack tower work locations.

The main staging area, equipment storage, assembly, and construction yard would probably be located off-site at Federal facilities near the dam and the City of Page. There would be no ground disturbing activities at the construction yard that would put sediment into nearby water bodies. There would be protective measures included in the construction specifications to prevent possible water pollution from toxic materials, such as solvents, fuels, paints, hazardous materials, or other contaminants.

WATER QUALITY AND AQUATIC RESOURCES

The pre-dam aquatic ecosystem in Glen and Grand Canyons supported an array of native and non-native fishes. At the time of dam closure in 1963, eight species of native and eight species of non-native fish were present. By 1968, non-native fish species became more abundant than native species, with trout dominating the now cold-water system immediately below the dam, and native species declining or becoming extirpated. The reasons for extirpations or declines are undoubtedly complex, but principal known factors include competition and predation by non-native fish, and cold-water releases and habitat fragmentation from Glen Canyon Dam.

The biological foundation of the aquatic system in the post-dam Colorado River below Glen Canyon Dam is *Cladophora glomerata*, a filamentous green alga. Clear river conditions created by the dam make the abundant growth of *Cladophora* possible. Together, *Cladophora*, diatoms, and associated invertebrates *(Gammarus* and insects) provide an important food source for other organisms in the food chain.

River Temperatures - Average monthly river temperatures predating the dam ranged from just above freezing to about 26°C (78°F). Records show that present release temperatures from the existing power intakes vary little from 8°C (46°F). As the river flows downstream through the warm summer desert environment, water temperatures increase about 1°C for every 30 miles traveled. During the summer, temperatures increase from 8°C near the dam to about 16°C (61°F) at mile 240. This is below the last aggregation of chub near Diamond Creek and far downstream of most of the known aggregations of humpback chub.

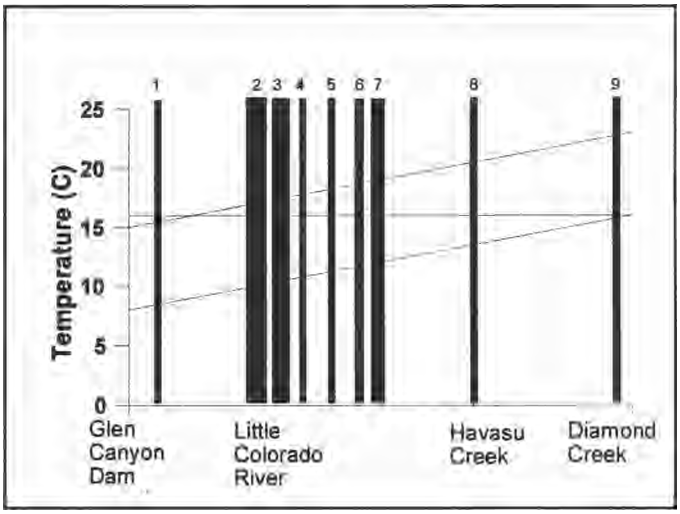

Figure 6 - Water temperatures increase with distance below Glen Canyon Dam (for 8°C and 15°C release temperatures). Also shown are the locations of the 9 aggregations of endangered, humpback chub.

The proposed temperature control alternative would allow a summertime release of 15°C (59°F). It is expected that this would greatly improve growth rates for rainbow trout in the river reach between the dam and Lees Ferry. Then as the water flows downstream, temperatures would increase into the range (16°C-22°C) where they are suitable for most all of the nine known aggregations of humpback chub.

Lake Temperatures - A computer modeling study of Lake Powell was conducted by Reclamation's Denver Technical Service Center to evaluate potential changes which might impact critical resources in Lake Powell. Surface temperatures during the winter are critical to the survival of the threadfin shad, an important forage fish for the Lake Powell sport fishery. Threadfin shad are very near their temperature tolerance during the winter season. Surface temperatures in Lake Powell vary from about 10°C (50°F) in winter to over 25°C (77°F) in summer. Surface temperatures in the winter below 10°C (50°F) could cause problems for threadfin shad.

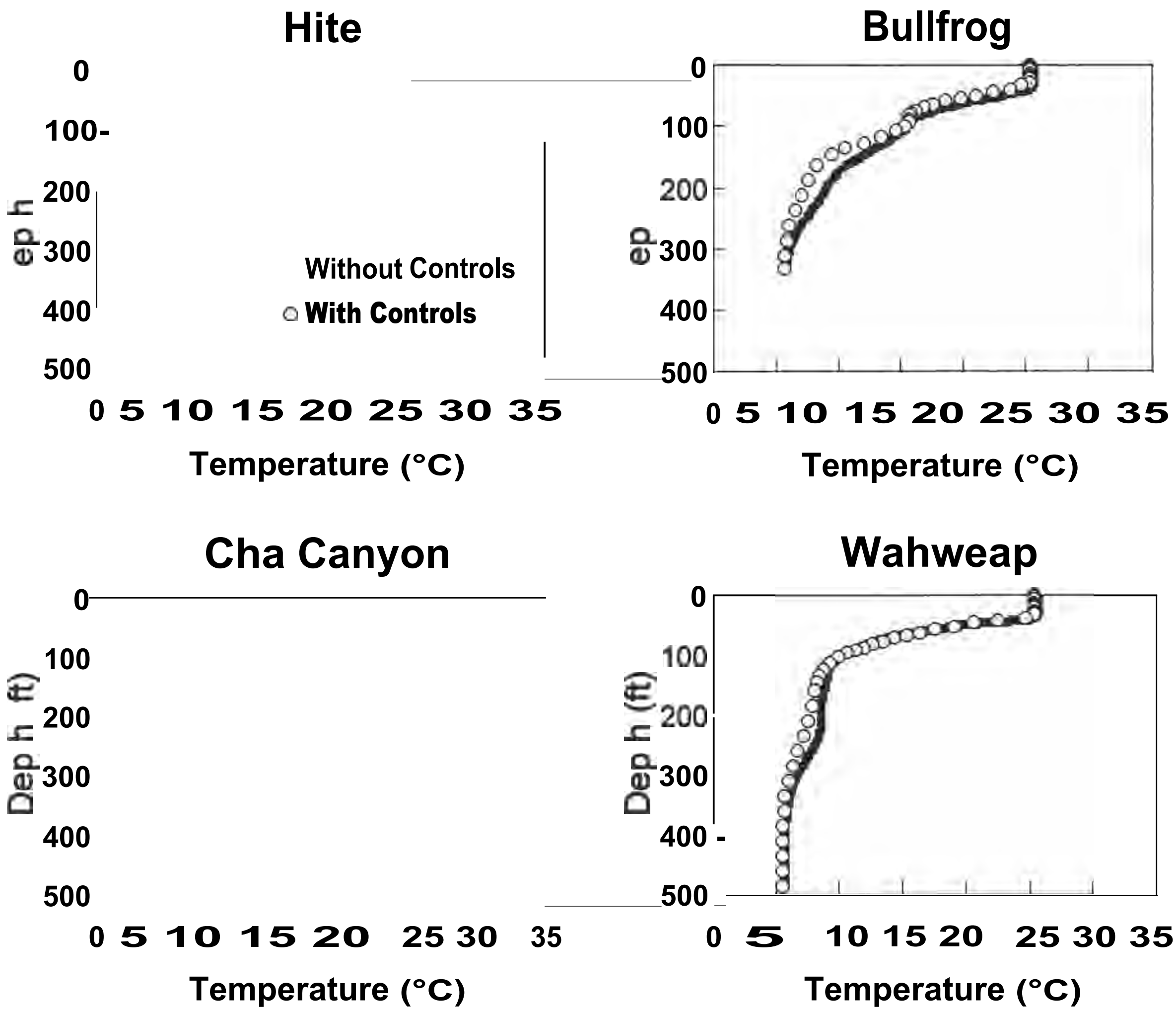

Figure 7 - Lake Powell temperatures in August assuming the release of 15°C water for 140 days to assess maximum impact. Actual releases would likely be much less (30-60 days). The locations in Lake Powell include: Hite (mainstem inflow area), Bullfrog main arm), Cha Canyon (San Juan arm), and Wahweap (near dam).

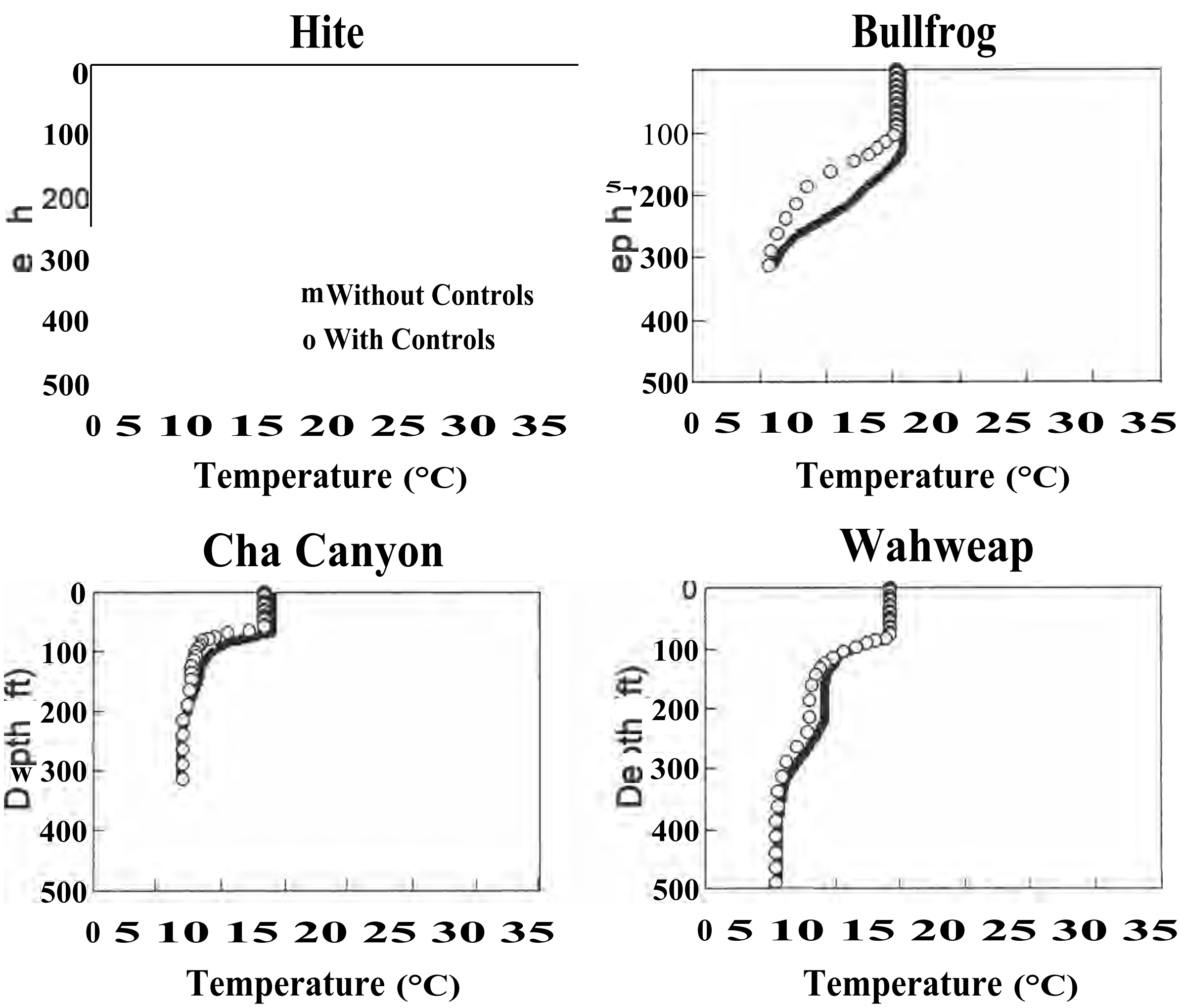

Figure 8 - Lake Powell temperatures in December assuming the release of 15°C water for 140 days to assess maximum impact. Actual releases would likely be much less (30-60 days). The locations in Lake Powell include: Hite (mainstem inflow area), Bullfrog main arm), Cha Canyon (San Juan arm), and Wahweap (near dam).

The results of Reclamation's computer modeling of the Lake, with and without temperature controls are shown in Figures 7 and 8 for the summer and winter seasons, respectively. The analysis includes a series of graphs at various locations in Lake Powell. As can be seen in the two figures, warmwater releases from the lake would have almost no impact on surface water temperatures during the late summer or winter seasons. Of particular interest, Figure 8 shows the modeled impact of warmwater releases on winter temperatures in Lake Powell. Warmwater releases have almost no affect on surface temperatures (less than 1°C) where the threadfin shad winter. Some cooling is observed in the deeper layers. Temperatures would be cooler with temperature controls at depths between 100 feet and 250 feet during the winter. This should have little effect on the fishery.

Reservoir Evaporation - Evaporation in Lake Powell is about 0.5 MAF per year and about 0.7 MAF per year in Lake Mead. The computer modeling studies conducted by the Denver Technical Service Center (TSC) show that the relatively small volume of warmwater releases will have little impact on the heat budget of Lake Powell. With little or no change expected in surface temperatures, no measurable change in evaporation is expected for either Lake Powell or Lake Mead.

Salinity - Salinities in the range typically found below Glen Canyon Dam (400-600 mg/L) have extremely little impact on the environment. The natural ecosystem was well adapted to survive salinities that exceeded 1,200 mg/L. Salinity is a concern further downstream where it can impact plumbing and salt sensitive crops. With closure of Glen Canyon Dam in the mid-1960s, the variation of salinity dropped significantly.

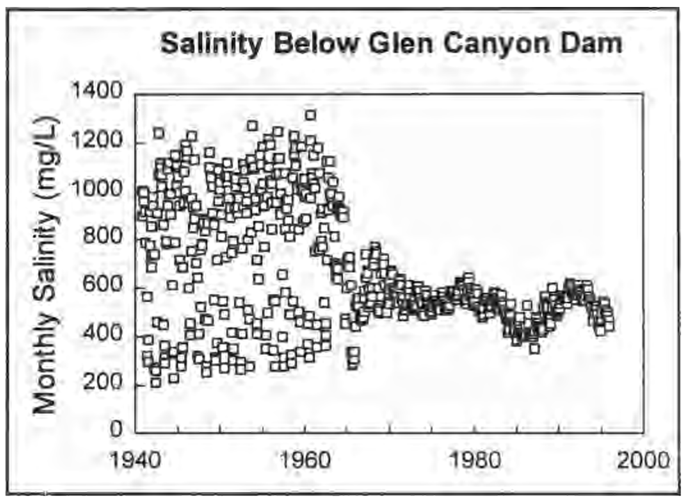

Figure 9-The annual variation in salinity was greatly reduced in the mid-1960s by the buffering effect of reservoir storage.

The surface layer in Lake Powell has the lowest salinity levels found in the lake. The proposed action would release water from the surface during the summer months, reducing downstream salinity. The balance of the year would see slightly higher release salinities. The net effect will be to increase the seasonal variation of salinity releases from the dam. Maximum salinity of the river below the dam would not approach levels which might impact fish and wildlife.

The Colorado River Basin Water Quality Standards require the maintenance of long-term salinity conditions in the Colorado River at three stations: below Hoover Dam, below Parker Dam, and at Imperial Dam. Seasonal, even annual variations in salinity do not impact compliance with this standard. The standard is for long-term trends. The salinity program is designed to offset any long-term effects including those created by Glen Canyon Dam and Lake Powell (or any other project in the Basin).

Under the No-Action Alternative, the goal of the salinity program would be to continue to find cost-effective ways to maintain water quality standards. The Proposed Action alternative would increase the variability of the salinity released from the dam but would not change the long-term discharge of salinity. Salinity is routed conservatively in the reservoir (USDI 1997). Salinity in the Colorado River varies more from changes in hydrologic conditions (e.g., runoff) than from any other single factor. Any change in the operation of the outlets may influence the salinity of the river, but only in temporary ways. Salinities in the Grand Canyon may vary, but mixing in Lake Mead would continue to remove most of the seasonal variation in the system.

Selenium - Water quality data in the reservoir near the dam show that selenium levels are fairly uniform with depth. Values are typically 2 ug/L in summer and may vary +/- 1 ug/L through the year. The USDI (1997) reported average selenium levels below Glen Canyon Dam were 2.5 ug/L. The action alternative would have little or no effect on the value.

Nutrients and Their Effects on Primary Productivity - A balance of nutrients is critical to the ecology of any aquatic ecosystem. Low levels of nutrients generally limit productivity higher in the food chain (fisheries). High levels of nutrients cause systems to strangle on their own wastes, depressing dissolved oxygen levels. Large, long reservoirs like Lake Powell are very efficient at retaining nutrients in the reservoir through biological processes and settling. Nutrients discharged from Glen Canyon Dam under existing conditions are extremely low.

In 1981-1982, an intensive study was jointly conducted by Reclamation and the Lake Mead Limnological Research Center, University of Nevada (Paulson and Baker 1983). The study was conducted to survey nutrient bioavailability, algae productivity, and limnological characteristics of the Lake Powell and Lake Mead.

The study found that total phosphorus concentrations are relatively high coming into Lake Powell. However, a major portion of the total phosphorus load settles out of the water column with sediments in the inflow zone of the reservoirs. This phosphorus is not readily available to biological processes downstream. The high iron oxide content of the Colorado River water gives it the distinguishing red color (for which the basin is famous) and reduces phosphorus concentrations via ion adsorption. Thus, when the sediment settles out, it also removes large quantities of phosphorus. Lake Powell can retain nearly 98 percent of the inflowing total phosphorus (Paulson and Baker 1983; Miller et al. 1983). A similar storage effect is repeated in Lake Mead. The entire mainstem Colorado River Basin remains very phosphorus limited throughout most of the system. Tributaries inflows (example: Paria River, Little Colorado River, and Las Vegas Wash) are an important sources of phosphorus in the river below Glen Canyon Dam.

This settling process can be reversed in Lakes Powell and Mead when the reservoirs are drawn down and the sediment deltas are resuspended. Beneath the water-sediment interface of the sediment delta, dissolved oxygen is quickly depleted and the sediment chemistry changes. Without dissolved oxygen in the interstitial water, bacteria utilize other oxygen sources such as mineralized forms associated with nitrites and nitrates (NO_2-NO_3) and iron oxides. These biochemical interactions result in changes in mineral forms such as iron oxide conversion to iron hydroxide. Since iron hydroxides do not have the same ability as iron oxides to hold (adsorb) phosphorus, it is released into the interstitial water. When the reservoir is filling, the sediment delta forms as the sediment settles out. Then, when the reservoir is drawn down, the river cuts a new channel through sediments of the delta. Thousands of tons of sediment can be moved during this period, releasing dissolved phosphorus into the water column. The iron hydroxide is also reintroduced back into an oxygenated water column and with time is converted back to iron oxide. This iron oxide can readsorb phosphorus again and settle back to a new location further downstream and usually deeper in the water column. This process is not immediate and some dissolved phosphorus escapes into the water column and becomes biologically available. Therefore, drawdown can increase the primary productivity in the reservoir.

In Lake Powell, some increase in bioavailability of nutrients may occur in as the inflow density currents matched up with the depth of withdrawal and are drawn across the reservoir. This could spread inflow nutrients over a larger area of Lake Powell during the summer months. However, only a small increase in nutrient availability is expected and improved primary productivity is expected to be relatively minor. Even a small increase would be beneficial to this relatively nutrient-poor system.

In Lake Mead, the bioavailability of nutrients in the inflow zone are also greatly influenced by inflow temperature. Summer inflows to Lake Mead do not presently warm up to equilibrium temperatures before entering the lake. The inflow to Lake Mead is colder (denser) than the warm surface layer of the lake and quickly plunge below the surface. Nutrients in the inflow are not readily physically available once they plunge below the euphotic zone where photosynthesis can occur. Turbidity also limits photosynthesis in the inflow. Water quality data taken by Reclamation indicates that in August 1996, the inflow plunged to a depth of about 50-70 feet (15-22 meters).

The proposed action would increase release temperatures by about +5°C from Glen Canyon Dam and this would increase inflow temperatures to Lake Mead. This temperature increase would cause the inflow to stay closer to the surface layer of Lake Mead and would increase the water travel time within the lighted portion of the reservoir (called the euphotic zone). This would increase the physical bioavailability of nutrients in the inflow area of Lake Mead until the phosphorus settles out of the euphotic zone. A slight increase in algae productivity may occur in the inflow zone of Lake Mead. Because the system is so non-productive overall, any increases in algae growth would be beneficial to the rest of the food chain, including the fishes.

In the river below Glen Canyon Dam, the proposed action would increase nutrient, algae, detritus released into the tailwater. The results of Reclamation's reservoir modeling studies are shown in figure 10. Releases from the dam due to surface withdrawals would increase detritus concentrations in the river by about 300 percent. Similar increases can also be seen in both phosphorus and nitrogen (ammonia) levels. These increases in the food base of the river should increase the primary productivity of the river system during the summer months when temperature controls are in operation. When not in operation, releases would return to pre-existing conditions which are typically very low.

The cycling and amount of nutrients in the tailwaters and lower reaches below Glen Canyon Dam are not well known. While nutrient levels are often at or below detection limits, the fact that there is high biomass of *Cladophora glomerata* below the dam suggests that nutrients are may not be a limiting factor. The uptake and cycling of nutrients may be quick enough that there is very little opportunity to sample free dissolved nutrients in the water column of the river. Another hypothesis is that delivery rates of low nutrient levels are sufficient for *Cladophora glomerata.* Nutrients may also be provided by sediment inputs from below the dam, even in the Lees Ferry reach. Nutrient levels are important to the ecosystem below Glen Canyon Dam.

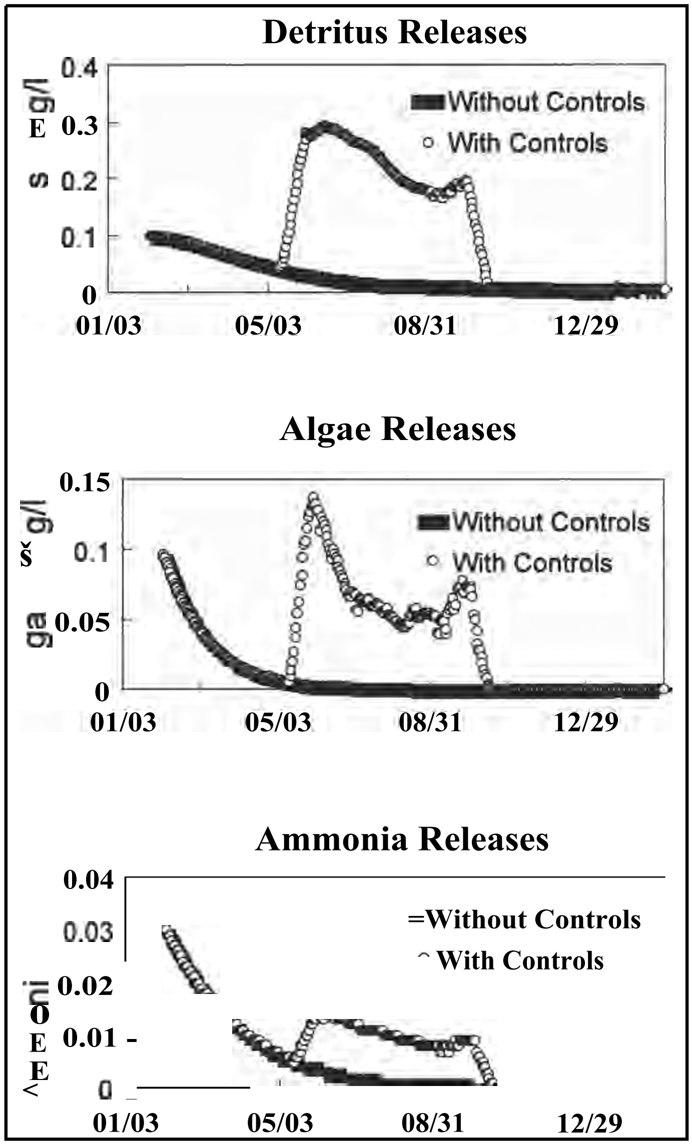

Figure 10-Extremely low nutrient releases from the dam to the downstream environment would increase with temperature controls.

The existing, post-impoundment, aquatic system is characterized by constant year-round releases of about 8°C (46°F) water that contain low nutrient and low sediment levels. Discharges of clear, cold water from Glen Canyon Dam have permitted the filamentous green alga *Cladophora glomerata* to capitalize on the few available nutrients released through the dam and other tributary sources. *Cladophora* and the diatoms depend on these nutrients and form the habitat and food base for an important community of aquatic invertebrates dominated by the amphipod *Gammarus lacustris,* midges (Chiromomidae), and other aquatic insects. *Cladophora,* along with the organisms that live on it, forms the basis of a highly productive food chain below Glen Canyon Dam (USDI 1995).

Since inception of interim flows, the plant component of the aquatic food base has begun to change. The relative dominance of *Cladophora* in the Glen Canyon reach may already be declining as other algae (e.g., *Chara* spp. and other filamentous, muscilagenous green algae) and submerged aquatic plants become established on sediment deposits from canyon wall "pour overs". It is important to note that substrates for these plants differ. *Cladophora* grows on rock and cobble, while *Chara* and other vascular aquatic plants grow best in sand or silt substrate. Higher minimum flows have permitted algae and other aquatic plants to become established above minimum reliable flow levels (5,000 cfs).

The prolific growth of *Cladophora,* and recently *Chara* spp. and other aquatic plants, has resulted in a high flow zone below the dam becoming established as an important production area that feeds immediate downstream reaches. Drift from Lees Ferry reach is quickly pulverized by rapids and probably contributes very little to higher trophic levels. Drift in lower reaches originates within those reaches with particulate organic matter in the form of plant debris and aquatic invertebrates in the current as drift. Much of the drift that feeds fish and other aquatic organisms is *Cladophora* (either dead from desiccation or scoured loose by waterflow) and invertebrates forced to move to avoid drying. Drift is also entrained and settles to the bottom in eddies and backwater areas where it is fed on by organisms and recycled.

Haden et al. (1997) investigated three main topics for Reclamation as part of a research project conducted by Northern Arizona University (NAU). The first study objective was to identify the mass and structure of the existing benthic community above and below Lake Powell. The Green and Colorado Rivers above Lake Powell were used as an analogue to pre-dam conditions. They found that the composition of primary producers and consumers were dramatically different. Differences in community structure were attributed to both food source availability (detritus vs algae) and temperature. Although macroinvertebrate composition was different between the two systems, total macroinvertebrate mass was not significantly different in a comparison of the most productive reaches (above and below Lake Powell) during their July 1996 survey.

Haden's second study objective was to evaluate how *Gammarus lacustris* would react to warmer water temperatures. The post-dam food base is dependent upon *Gammarus lacustris* and midges. Their laboratory experiments compared growth and survivorship at 10°C and 20°C over a 30-day incubation period in experimental circulation chambers. The report concluded that survivorship at both temperatures were very similar. Growth rates were somewhat lower at 20°C. Though statistically significant, the report noted the growth difference between the two temperatures were small and might be attributed to experimental error or temperature driven changes in phytobenthos that caused a reduction in epiphyton food base. The study did not evaluate the effects of higher nutrient loading that would be expected from the temperature control alternative, though higher nutrient loading should increase productivity.

Haden's final study topic was to evaluate the possibility of other macroinvertebrate populations becoming established below Glen Canyon Dam as a result of warmer releases. Low temperatures have been speculated to be a barrier to many other macroinvertebrates. Haden's report states that colonization by other macroinvertebrates would probably be limited by several factors: lack of a specific food source, competition with introduced species of invertebrates, predation by fish, and specific temperature requirements during the entire life cycle.

If a change were to occur, there are some indications that the system is fairly resilient to short disturbances. Reclamation found that even though the 1996 Beach Habitat Building Test Flows strongly scoured the benthic foodbase in the mainstream, recovery was extremely rapid.

Native and Endangered Fishes -The native fishes of the Colorado River make up one of the most unusual assemblages of fish specially adapted to their environment found anywhere in the world. However, recent history has introduced new challenges by modifying the fish's evolutionary environment. Major dams have modified streamflow extremes, cleared and cooled the waters, converted rivers to lakes, blocked natural movement corridors, and permitted the introduction of non-native fish that compete with and/or prey upon the natives. Of the eight species of native fish, three (Colorado squawfish, bonytail, and roundtail chub) have been extirpated from Glen and Grand Canyons, two (humpback chub, and razorback sucker) are listed as endangered, one (flannelmouth sucker) is a candidate species for listing under the Endangered Species Act. One (bluehead sucker) is common only in tributary inflows and one (speckled dace) is relatively common throughout the canyon.

Cold water temperature is thought to be an overriding constraint for larval and young of the year native fish in the Colorado River mainstem. Cold temperatures prevent spawning or, if spawning occurs, limit egg and larvae survival in both native and warmwater non-native fishes. Clarkson et al. (1994) suggests that temperature modification is the only way to alleviate the known restriction by cold-water temperatures to successful mainstem reproduction and recruitment of native fishes. Releases of 15°C (59°F) in the late summer should warm as the water flow downstream and provide optimum temperatures of 16°C to 22°C for spawning, incubation, and growth in the mainstem.

Valdez reported that humpback chub, flannelmouth sucker, bluehead sucker, and speckled dace require 16°C to 22°C for spawning, egg incubation, and survival of larvae, while razorback sucker spawn successfully at 10°C to 22°C. Temperatures released from the dam are about 8°C (46°F) and warm longitudinally (240 miles downstream) to about 16°C (61 °F) in summer. These temperatures are not quite sufficient for spawning of native fish. All documented spawning of native fishes has occurred in warm tributaries and springs.

Humpback Chub - Humpback chub is a native fish which evolved in the Colorado River before water development and regulation by dams. Studies report that the Little Colorado River is the main spawning area for the humpback chub in Grand Canyon. The Little Colorado River is a small, unregulated (natural) tributary to the Colorado River located about 77 miles below Glen Canyon Dam. Spawning is suspected in warm springs and warm tributary inflows.

Adult chub in the mainstem spawn in the lower 9 miles of the Little Colorado River from March through May. Adults stage in large eddies in February and March and make spawning runs up the Little Colorado River from March through May as flows decrease, warm, and clear (Valdez and Ryel 1995). Young humpback chub either remain in the Little Colorado River or move into the mainstem, where mortality is believed to be high because of cold-water temperatures, thermal shock, and predation. Small numbers of chubs spawned the previous year may be present in the mainstem the following spring.

Limited humpback chub spawning occurs among other aggregations in the mainstem. Valdez and Ryel (1995) documented limited spawning success at 30-Mile Spring (a warm riverside spring) in upper Marble Canyon, and young chubs have been recorded at Kanab Creek. However, such sightings are insignificant when compared to the relative success of humpback chub in the Little Colorado River.

The proposed temperature control alternative would warm the releases from the present 8°C to a maximum of 15°C. As shown in the figure 11, the river warms as it flows downstream. Without temperature controls, cold temperatures cause thermal shock to young fish as they descend into the mainstem from warm tributaries. Without controls, temperatures rarely reach levels suitable for spawning and recruitment of humpback chub (above 16°C) in the mainstem. With temperature controls, the river would reach suitable temperatures to greatly reduce or prevent thermal shock and increase growth rates. Temperatures would also be suitable for spawning and recruitment of humpback chub if other environmental factors permit.

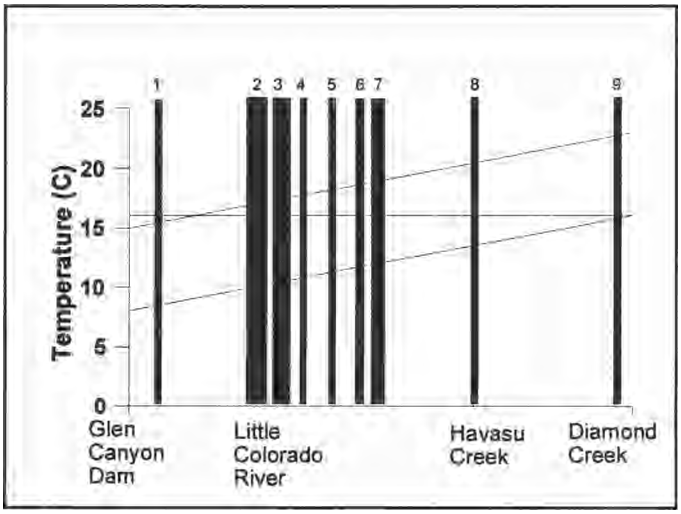

Figure 11 - Humpback chub prefer temperatures above 16°C. Graph shows warming of river as it flows downstream for releases of 8°C (without controls) and 15°C (with controls). Also shown are the locations for the 9 known aggregations of humpback chub.

Razorback Sucker - The razorback sucker is extremely rare in Grand Canyon, with only 10 specimens reported between 1981 and 1990 (Valdez 1996). All individuals were old, and no reproduction is known to have occurred. Critical habitat for the razorback sucker in Grand Canyon includes the Colorado River from the confluence with the Paria River to, and including, Lake Mead.

In other systems, razorback suckers spawn earlier than other Colorado River native fishes. In Lake Mohave, where the largest population of suckers occur, razorback suckers spawn from November into May. In Upper Basin riverine situations, razorback suckers begin spawning when flows increase in the spring and spawn through spring runoff. Razorback suckers evolved under a water regime featuring high spring flows. There is no indication that young razorback suckers occur in Grand Canyon. The temperature control alternative may relieve one environmental constraint, but others may exist.

Flannelmouth Sucker - The flannelmouth sucker is a candidate for listing under the Endangered Species Act of 1973, as amended, but this fish is locally common and reproduces in several tributaries in Grand Canyon. The species is found in the Paria River and Little Colorado River; Shinumo, Bright Angel, Kanab, and Havasu Creeks; and inhabits various locations in the mainstem (USDI 1995). Valdez and Carothers (1998) thought that, "Low survival of young flannelmouth descending from seasonally warmed tributaries into the cold mainstem appeared to be limiting recruitment in the 1980's and 1990's. Possibly hatching success was low, or young were unable to find food in the tributaries, succumbed to cold-shock in the mainstem, or were exposed to predation." Flannelmouth sucker is a warmwater fish and would likely benefit from increased temperatures during the summer or reductions in thermal shock as the young-of-the-year descend into the mainstem.

Non-Native Fishery Below Dam - Non-native warmwater fish such as channel catfish and carp have a long history in the Colorado River (USDI 1995). As water temperatures declined following construction and operation of Glen Canyon Dam, both native and non-native warmwater fish populations have declined. Rainbow trout now dominate the fish biomass for 50 miles below the dam (Valdez and Ryel 1995).

Non-native warm- and cool-water fish face the same water temperature-related problems with main channel reproduction as described for native fish. Because of temperature constraints, backwaters and near-shore habitats are also believed to be important for non-native warmwater and cool-water fish growth in the main channel.

In their report, Clarkson et al. (1994) suggested that a lack of important environmental requirements, other than water temperatures, may serve to restrict nonnative fishes. These conditions may limit the invasion and expansion of the non-natives under the Proposed Action.

Trout - Trout are a non-native resource found throughout Glen and Grand Canyons. Rainbow trout were originally introduced by various agencies for sport purposes (USDI 1995). Rainbow trout make up a major part of the sport fishery in the 15-mile reach below Glen Canyon Dam. Brook, brown, and cutthroat trout have also been stocked in the river. Brook trout and cutthroat trout have nearly disappeared from the system. Current practices call for stocking approximately 80,000 rainbow trout annually between Glen Canyon Dam and Lees Ferry. Natural spawning occurs where trout find suitable conditions. Arizona Game and Fish Department (1993) estimated that 78 percent of the juvenile trout sampled in August 1992 were naturally reproduced.

The figure 12 on the following page shows rainbow trout preferences provided by Arizona Game and Fish Department. The cold-water discharge from Glen Canyon Dam has created an excellent trout fishery, but current release temperature levels are at the bottom of the optimal range (8°C to 10°C). The proposed action is likely to have positive effects for the rainbow trout fishery in the 15-mile reach below the dam. Release temperatures would be increased during the summer season from the existing 8°C to a peak of near 15°C in the late summer, introducing some seasonality into the temperature regime of the river and providing near optimal temperature conditions. The optimum spawning temperature for rainbow trout is 10°C to 16°C. Warmer release temperatures would also increase growth rates in the tailwater fishery. Rainbow trout growth rates are limited by cold water. An 8.25% decrease in growth can be expected for each degree Celsius below 15°C. Warmwater releases would greatly improve growth rates in the upper portions of the river. Farther downstream (near the mouth of the Little Colorado River and major humpback chub populations), rainbow trout would be limited by temperature as the river warms beyond their preference. Brown trout have higher temperature preferences and tolerances than rainbow trout and would continue to do reasonably well throughout most of the Grand Canyon above the Little Colorado River. They would continue to be more limited by turbidity than temperature. Because trout are site predators, few trout are found in the river below the Little Colorado River due to high turbidity (Valdez, personal communication).

Although whirling disease has not yet been observed below Glen Canyon Dam, it is becoming more common in the West and has become a major concern for all trout fisheries. Richard Vincent, Whirling Disease Research Coordinator, Montana Fish, Wildlife and Parks, summarized field experiments exploring the relationship of temperature to infection rate of whirling disease. Vincent pointed out that once the disease has become established in a body of water, there is little chance that it can be eradicated. The studies found severe infections in young of the year rainbow trout begin at about 9°C, peak at about 14°C, and decline to near zero at 18.5°C. Under the no-action alternative, release temperatures would continue to range between 8°C to 10°C. Cold-water releases in this range would not prevent whirling disease from becoming established. If whirling disease existed below Glen Canyon Dam, the warmwater releases would have the potential to increase the severity of infection. Brown trout and wild trout tend to be more resistant to whirling disease than rainbow trout.

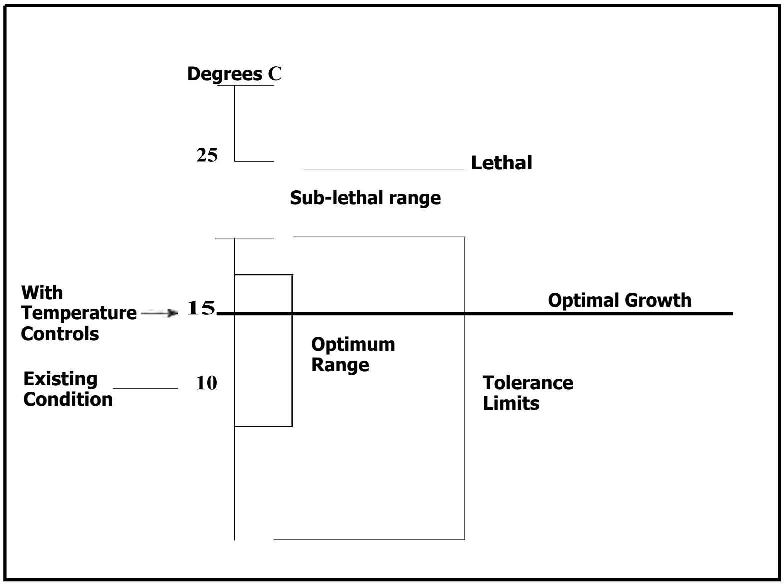

Figure 12 - Temperature tolerance of rainbow trout showing optimum range and preferred temperature from Michigan Hatchery Manual, 1968.

Channel Catfish - One of the greatest potential threats to endangered fishes is from channel catfish which prey upon and compete with native species. Channel catfish have been documented feeding on humpback chub at the mouth of the Little Colorado River (Valdez and Ryel 1995). Under either alternative, channel catfish would continue to exist and reproduce in the river. The proposed alternative would improve temperature conditions for channel catfish. Optimum growth temperatures of 26°C to 30°C may occur in the lower reaches of the river near Lake Mead. Competition with the humpback chub by channel catfish would need to be carefully monitored.

Carp - The effect of carp on native fishes under the proposed temperature control alternative is expected to be negligible. Native fishes typically deposit their eggs over cobble in deep, swift currents where the eggs drop into protected crevices, removed from the suction feeding of carp. Carp are likely to have suitable spawning temperatures in the mainstem under temperature modification, but since carp require vegetation or structure for attaching their eggs, spawning sites are likely to be limited to warm quiescent areas such as flooded lowlands or stable, vegetated backwaters. These features are likely to be available to carp under flow management scenarios that favor long-term stability of backwaters, even without temperature modification.

Fathead Minnows - The small numbers of fathead minnows that occur in the Grand Canyon could be expected to increase in abundance and distribution with warm flows, but because of the inability of this species to tolerate even moderate currents and swift riverine conditions, its numbers could be easily controlled with flow management (e.g., beach/habitat-building flow), possibly even of the magnitude seen under existing flows.

Red Shiners - Red shiners may exclude other species through competition and predation (Ruppert et al. 1993), although the mechanisms are not fully understood. Red shiners were abundant in Glen and Grand Canyons before the dam, but declined dramatically after dam construction, presumably because of cold-water temperatures and because high fluctuating releases from the dam prevented stable backwaters, the primary habitat for this species (Minckley 1991; Valdez and Ryel 1995). Like fathead minnows, red shiners experience dramatic decreases in density during high flows (Valdez 1990), but this species is more tolerant to swift currents and riverine conditions.

Plains Killfish and Mosquitofish - These species are not expected to increase in the mainstem. They are relatively intolerant of high velocity conditions.

Striped Bass - Thermal augmentation may allow for greater numbers of striped bass to ascend into the Grand Canyon from Lake Mead, but it is unlikely that these would become resident any further upstream than their current distribution in the lake inflow. It is likely that high stream velocity and the absence of deep lentic habitat limits upstream distribution of striped bass in the Grand Canyon, not cold-water releases.

Walleyes - Walleyes are a highly predaceous predator. Although the present (no action) releases provide optimum spawning temperatures for this species, walleyes have not expanded into the Grand Canyon. Other factors are presumed to be limiting their range. Warmer temperatures from the proposed alternative would have no effect.

Lentic Fish - Other lentic fish species that pose a possible threat to native fishes in the Grand Canyon are black bullhead, green sunfish, smallmouth bass, and largemouth bass. These species are highly predaceous if they gain access to backwaters. Except for smallmouth bass, these species are relatively weak swimmers and are unlikely to gain access into the Grand Canyon in large numbers. They rarely occur in the main river channel in the upper basin, and rely almost exclusively on backwater habitats.

The other lentic species—bluegill, black crappie, and threadfin shad—are extremely weak swimmers, very intolerant of swift riverine conditions, and would not be expected to invade Grand Canyon.

Flathead Catfish - This species is common and problematic as a predator of native fishes in many tributaries below Hoover Dam, but has not been reported in Lake Mead. This species prefers warmer temperatures (spawns at 24°C-28°C) and more quiescent flooded lowlands than are available in Grand Canyon.

Fish Parasites - Valdez and Ryel (1995) reported that two parasites are of particular concern in Grand Canyon. The Asian tapeworm *(Bothriocephalus acheilognathi)* was found in humpback chub in Grand Canyon. The absence of the tapeworms in 1989 suggests that this parasite has only recently entered the region, or that the parasite had been present and stressful conditions for the fish allowed for the proliferation of individual cestodes. Asian tapeworms are typically host-specific of cyprinids (minnows) and have been found in fathead minnows, red shiners, and mosquitofish in Grand Canyon (Brouder and Hoffnagle 1996). Valdez and Ryel (1995) noted that egg maturation occurs at 25°C to 30°C, a temperature that could be reached under either alternative in backwater habitats. Warmer releases would likely increase the amount of warm backwater habitat and would likely lead to the spread of Asian tapeworm; however, under the no action alternative, the majority of humpback chub would still be exposed since the Asian tapeworm is now well established in warm water of the Little Colorado River. Under the proposed temperature control alternative, stresses on the chub might be reduced by warmer releases, allowing them to cope more effectively with this ongoing infection.

The second parasite of concern is the anchor worm *(Lernaea cyprinacea)* which occurs in native and nonnative fishes in the seasonally-warmed river above Lake Powell. Valdez and Ryel (1995) reported that infestation is common in the upper basin (31 percent of adults). Infestation in the Grand Canyon is less that 1 percent. It is thought that mainstem temperatures below Glen Canyon Dam fail to reach maturation requirements for the anchor worm of 25°C. Warmer releases would be expected to increase the infestation of anchor worms. Valdez and Ryel reported that none of the fish in the upper basin showed signs of stress or illness, although open lesions had formed at some anchor points. Infestation does not appear to lead to significant numbers of fish mortalities in the seasonally-warmed river system above Lake Powell.

Entrainment of Fish into Releases - Deep, cold-water (power) releases are usually below levels where fish aggregate near the dam and lake fish are not normally entrained into the outflow of the dam by penstock operation; however, spillway releases near the surface of the reservoir probably have entrained lake fish into the outflow in the past. Warmwater releases from the proposed temperature control modifications would also entrain lake fish into the discharge. Normally large adult fish would be killed by the pressure changes that occur in the penstock, but smaller fish may survive. However, small disoriented fish in the outflow would be easy prey for rainbow trout in the Lees Ferry reach. Furthermore, cold-water releases during the balance of the year have and would continue to greatly limit smallmouth bass if they were to survive.

Lake Mead Fishery - Lake Mead supports a warmwater sport fishery. Summer inflows to Lake Mead are cool enough in summer to dive below the surface layer making any nutrients unavailable to photosynthetic algae. Warmer summer inflows from the proposed action would remain on the surface in the inflow zone making these nutrients available to algae in the summer and potentially increasing productivity of the lake.

Lake Powell Fishery - Threadfin shad were introduced into Lake Powell as a forage base for the sport fishery. The shad already experience occasional winterkill from low reservoir water temperatures. During the winter, shad reside in the relatively warm surface layer of the reservoir. Figure 13 shows the results from a computer modeling study where warm water

(15°C) was released for 140 days. It shows that the temperatures in the surface layer would be reduced by about 1°C. Shorter periods of warmwater releases are envisioned and would have proportionally less impact on surface temperatures. This relatively small decrease in water temperature should not impact threadfin shad.

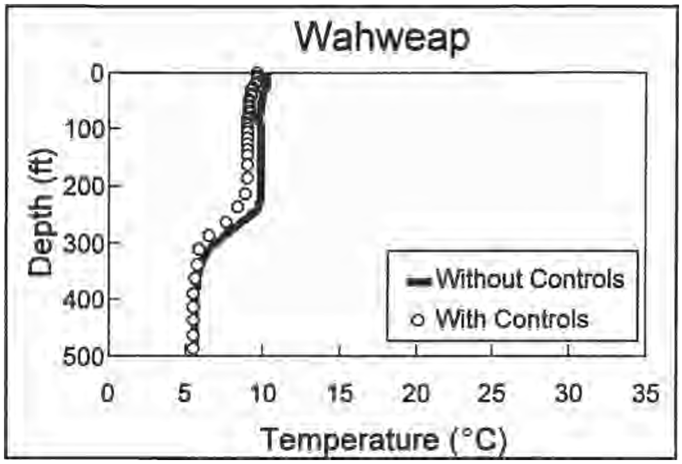

Figure 13 - Comparison of late winter temperature profiles in Lake Powell near dam.

Wintering Waterfowl - Waterfowl are evaluated by analyzing effects on the aquatic food base, because it is assumed that the birds are attracted to the open water and abundant food resources. No specific information on feeding is available for wintering waterfowl in Glen and Grand Canyons. However, the diets of individual species are well known from other studies and indicate that foods taken from the river would range from plants through invertebrates to small fish. The variety and abundance of waterfowl using the river during winter indicate that a productive aquatic ecosystem exists below the dam. The system is supported by clear, cold releases from the dam and is based on linkages between *Cladophora,* diatoms, *Gammarus,* and immature aquatic insects (USDI 1995).

The number of waterfowl using the river corridor increases in late November, peaks in December and early January, and then decreases in February, March, and April (Stevens and Kline, written communication 1991). During peak winter concentrations in 1990-1991, some 19 different species of waterfowl used the river between Lees Ferry (RM 0) and Soap Creek (RM 11) at a density of 136 ducks per mile. An average density of 18 ducks per mile occurred over the entire upper Grand Canyon (RM 0-77) during the same period. In addition, over 34 species of waterfowl have been recorded in Glen Canyon, with densities of 150 to 200 per mile.

Most wintering waterfowl would have left Glen and Grand Canyons by late March and would not be affected directly by summer temperature controls. Mallard, late migrating gadwall, and American widgeon may still be common (USDI 1995). The proposed action would cause little or no change in wintering waterfowl.

OTHER ENDANGERED AND SPECIAL STATUS SPECIES

The Federal special status species evaluated in this EA include the endangered peregrine falcon, southwestern willow flycatcher, humpback chub, razorback sucker, and Kanab ambersnail. The bald eagle is threatened, and the flannelmouth sucker is a candidate (category 2) species. Arizona species of concern include the southwestern river otter, osprey, belted kingfisher, and northern leopard frog.

Peregrine Falcon - The Grand Canyon and surrounding areas are believed to support the largest known breeding population of peregrine falcons in the conterminous United States (Carothers and Brown 1991) and appear to be part of an increasing Colorado Plateau peregrine falcon population. Population estimates are 96 pairs at Grand Canyon National Park, with another 50 peregrine breeding areas located around Lake Powell (USDI 1995).

Peregrine falcons may be indirectly linked to river operations through the aquatic food chain. This species feeds on waterfowl, swifts, swallows, bats, and other species that derive some of their insect and other invertebrate food from the river. Peregrine falcons generally nest on ledges on cliff faces in Grand Canyon, and these sites are not affected by river operations. The breeding season extends from February to July in Grand Canyon.

No measurable decrease in availability or abundance of forage base of the peregrine falcon is expected. The proposed action would likely not effect peregrine falcons.

Southwestern Willow Flycatcher - This species has declined throughout its range in the Southwest. Critical habitat in Grand Canyon has been designated along the Colorado River from RM 39 to RM 71.5. This habitat includes the main river channel and associated side channels, backwaters, pools, and marshes throughout the May-September breeding season, as well as areas within 109 yards of the edges of surface water (USDI 1995).

In Grand Canyon, the southwestern willow flycatcher is a habitat generalist, occupying sites where vegetation is of average height and density (Brown and Trossett 1989). Nesting occurs in non-native tamarisk 13 to 23 feet tall with a dense foliage 0 to 13 feet from the ground. Proximity to water is necessary and correlated with food supplies. Willow flycatchers in Grand Canyon forage in tamarisk stands on sandbars, around backwaters, and at the water's edge. In 1995, five southwestern willow flycatchers were located: three nonbreeding males and one pair that fledged a single young (Sogge et al., 1995b).

Riparian modification, destruction, and fragmentation provided new foraging habitat for brown-headed cowbirds *(Molothrus after)*. Populations of brown-headed cowbirds continue to expand. Brood parasitism, habitat destruction and predation are all major threats to SWWF. Over half the nests in Brown's study contained brown-headed cowbird eggs. Cowbirds may remove prey eggs, their eggs hatch earlier, and the larger nestlings are more competitive in the nest. Cowbirds fledged from Sierra Nevada SWWF nests while SWWF nestlings died shortly after hatching. Brown-headed cowbirds occur extensively around mule corrals on the rim of the canyon and travel down to the Colorado River.

The conditions under which the southwestern willow flycatcher experiences limited reproductive success in Grand Canyon would continue under either alternative. Riparian areas used by nesting southwestern willow flycatchers have stabilized in size, sediment deposition in low-lying emergent marsh vegetation—where the birds forage—would continue. Without periodic disturbance to re-form sites supporting emergent marsh vegetation, these sites would fill with sediment and be replaced by woody riparian vegetation.

Bald Eagle - The Colorado River corridor through Glen and Grand Canyons is used by migrating bald eagles during the winter. Use of the river is opportunistic and currently concentrated around Nankoweap Creek (RM 52.5), where eagles exploit winter-spawning trout as food. Eagles concentrate at Nankoweap Creek in late February, with counts ranging from 6 in 1987 to 26 in 1990 (Sogge et al. 1995a). Eagles preferentially capture rainbow trout in the shallow creek rather than in the mainstem, where foraging success is lower. Eagle density is correlated with trout density in the lower reach of the creek, and trout density is correlated with water temperature in Nankoweap Creek.

The wintering bald eagle population has been monitored since 1988 and occurs throughout the upper half of Grand Canyon, Glen Canyon, and on both Lakes Powell and Mead. Density of bald eagles during the winter peak in late February and early March of 1993 to 1995 ranged from 13 to 24 eagles between Glen Canyon Dam and the Little Colorado River (RM 61.5) (Sogge et al. 1995a).

The proposed action is expected to improve conditions for trout in the tailwater. Further downstream, such as at the Nankoweap Creek confluence, water temperatures may be slightly above suitable growth temperatures for trout in summer, but this action is not expected to be detrimental to these fish and to the food supply of wintering bald eagles. This may provide more opportunities for bald eagles to exploit winter-spawning trout as food.

Kanab Ambersnail - The snails occurring in Grand Canyon are one of only two known populations of Kanab ambersnails. Demographic analyses based on size class distribution indicate that the Kanab ambersnail is an "annual" species, with much of the population maturing and reproducing in July and August, and most snails over-wintering as small size classes (Stevens et al. 1995). Kanab ambersnail habitat includes vegetation supported by a spring in the canyon wall. The primary vegetation used by Kanab ambersnails is crimson monkey-flower and non-native watercress. The total area of primary vegetation/habitat was 0.22 acre in June 1995 (Stevens et al. 1995). Neither alternative is expected to have an impact on the Kanab ambersnail.

Southwestern River Otter - The southwestern river otter is an Arizona species of concern. While never numerous, this subspecies of otter occurred historically in Grand Canyon. Although suitable habitat appears to be present in Grand Canyon, no reliable sightings have occurred since the mid-1980's (Reclamation 1995). This species is assumed extirpated from Grand Canyon. Warmer water temperatures may improve the otter's food base, improving conditions for any potential reintroduction effort.

Osprey and Belted Kingfisher - Ospreys are a State of Arizona candidate threatened species that migrates through the river corridor between Lake Powell and Lake Mead (USDI 1995). Ospreys are most numerous along the Colorado River in Grand Canyon during fall migration and are relatively rare during March and April (Reclamation 1995). Ospreys feed on fish that they generally catch from the mainstem river.

The belted kingfisher is a State of Arizona candidate threatened species that migrates through Grand Canyon between Lake Powell and Lake Mead (Reclamation Reclamation 1995). It is most common in Grand Canyon during spring migration. The belted kingfisher uses the river and its tributaries for feeding and nests in suitable banks. This species has not historically nested in Grand Canyon, since suitable nest sites are probably rare (Stevens et al. in press).

Because of the migratory nature of use of Grand Canyon by ospreys and belted kingfishers, there would be little or no impact from the no action or proposed action on these species.

Increased temperature and its positive impact on the downstream fishery may temporarily benefit fish-eating birds.

Northern Leopard Frog - The northern leopard frog is a State candidate for threatened species in Arizona. This frog is rare in the river corridor, with only two known individuals recorded below Lees Ferry (Stevens, written communication, 1995). A population is currently located in Glen Canyon and in 1993 consisted of 80 to 100 transformed frogs, a large number of individuals less than 1 year old, and tadpoles. This population is genetically similar to Lake Powell populations of northern leopard frogs. The origin of the Glen Canyon population is unknown but may have been natural or received assistance from man (e.g., bait anglers).

The Glen Canyon population is associated with a spring, a perched pool, and rivulets exiting the pool. Dense emergent vegetation consisting of giant reed, cattail, bulrush, and sedge is associated with the site. Most of the existing frog habitat in Glen Canyon lies below the 45,000-cfs stage.

The Glen Canyon population of this species would likely persist under no action and action conditions. More natural temperatures would if anything tend to favor native species. In addition, other nearby sites may be colonized by frogs from this population, as has probably happened in the past. To date, these colonizing groups have been small (one to three frogs) and have not become established at other sites.

CULTURAL RESOURCES

The area of potential effects for operation of Glen Canyon dam covers the 255-mile section of the Colorado River corridor below Glen Canyon dam. Within this corridor, intensive archeological inventory to Secretary of the Interior standards has identified a total of 475 archeological and historical sites, but only 33 of the sites are located on sediment directly affected by post-dam flooding. Elevating the temperature of the river will have no effect on these historic properties.

Reclamation also evaluated the eligibility of Glen Canyon Dam to the National Register of Historic Places. The dam was evaluated within the national historic context of Reclamation's built environment, 1902-present. Within this context, a property may be eligible to the National Register if they embody the distinctive characteristics of a type, period or method of construction (Criterion C). While the dam is classified as thin arch construction, it is not sufficiently old or illustrative of this engineering type to be considered eligible for listing on the National Register.

In consultation with Indian tribes including the Havasupai, Hualapai, and Hopi tribes, Navajo Nation, Paiute Consortium, and Zuni Pueblo, the Grand Canyon as a whole, as well as specific locations within the river corrido,r have been identified as places of traditional concern. The canyon as a whole has also been identified as a sacred site.

RECREATION

Fishing in Glen Canyon - Most fishing occurs from boats, but some anglers wade in the area around Lees Ferry. Angler use in 1991 was approximately 125,000 fishing trips. The Proposed Action is expected to improve thermal conditions for the trout fishery in Glen Canyon by providing more suitable growth temperatures for trout in summer. Similar modifications to Flaming Gorge Dam in 1976 nearly doubled growth rates of trout in the Green River resulting in larger fish caught.

Fishing in Lake Powell - Lake Powell has an excellent warmwater sport fishery. The no action alternative would not impact this. The proposed action may cause a slight cooling of the reservoir at the middle depths. This is not expected to aggravate problems with winter surface (0-100 ft) temperatures for the threadfin shad, the principal midwater forage species.

Fishing in Lake Mead - Lake Mead also has an excellent warmwater sport fishery, though it has declined somewhat with the impoundment by Glen Canyon Dam and the trapping of nutrients and sediments in Lake Powell. Under the no-action alternative, no change is expected. The proposed plan would send warmer water to Lake Mead in the summer months. This may make nutrients more bioavailable in the inflow zone and slightly increase productivity.

Day Rafting - If the pattern of day rafting use is similar to that of 1991, approximately 33,000 day use rafting trips occurred in that year. River temperatures are normally very cold for rafting. Wilderness characteristics of day rafting trips are influenced by fluctuating river stages and by the conditions of beaches, vegetation, and other features of the riparian zone. These would continue under the no-action alternative. The Proposed Action would warm the river and the change would be noticeable to rafters during the summer months. The warmer water would reduce the risk of hypothermia in case of boating accidents.

White-Water Boating - If private and commercial white-water boating use is similar to that of 1991, approximately 3,000 individuals would take private trips and 12,000 individuals would take commercial trips during the year. Wilderness characteristics of white-water boating trips are influenced by fluctuating river stages and by the conditions of beaches, vegetation, and other features of the riparian zone. These would continue under the no-action alternative. The Proposed Action would warm the river. The change would be noticeable to rafters during the summer months. The warmer water would reduce the risk of hypothermia in case of boating accidents.

Lake Activities and Facilities - The proposed action would slightly cool the reservoir surface by less than 1°C in the summer months. This is not expected to impact lake activities and facilities.

Net Economic Value - A measure of the value over and above the costs of participating in a recreation activity, is related to the number of recreationists who participate in each activity, the time of year in which they participate, and the value of each trip taken. The net economic value of recreation in Grand Canyon was estimated for a number of different types of water years in the Glen Canyon Dam EIS (USDI 1995). No net change in white-water boating use or significant change in trip value is expected to result from the no action or proposed action.

Regional Economic Activity - This activity refers to expenditures and their impacts within the study area. River-based recreational users, such as anglers and white-water boaters, spend large sums of money in the region purchasing gas, food, lodging, guide services, and outdoor equipment during their visits. While these expenditures do not represent a benefit measure, they nonetheless are important because they support local businesses and provide employment for local residents.

The regional economic activity that results from nonresident anglers, white-water boaters, and day rafters who visit the region has been estimated (USDI 1995) at approximately $25.7 million (1995 nominal dollars). As discussed in Douglas and Harpman (1995), recreational use in the region comprised of Coconino and Mojave Counties supports approximately 585 jobs. Of this total, there are 21 licensed fishing guides (Gunn, 1996). Recreational use is not expected to change with the either alternative.

HYDROPOWER

Glen Canyon Dam and Powerplant are part of the CRSP, one of the Federal projects from which Western Area Power Administration (Western) markets power. Glen Canyon Dam generates approximately 75 percent of the total CRSP power. The total annual amount of energy produced by the dam is based on actual water conditions. Western's Salt Lake City Area Integrated Project (SLCA/IP) annually markets more than 4 billion kilowatt-hours (kWh) from Glen Canyon Powerplant to 198 entities principally in the six-State area.

Hydropower plants such as Glen Canyon can generate electricity without causing air pollution or using nonrenewable fuels. Also, they are able to rapidly change generation levels to satisfy changes in the demand for electricity. This capability is termed "load following." Power is most valuable when it's most in demand (during the day when people are awake and industry and businesses are operating). Water from Glen Canyon Dam is used for load following as much as possible.

Figure 14 - Power from Glen Canyon Dam is sold over a six-State area.

There are approximately 5.6 million end use retail consumers (residential, agricultural, commercial, and industrial) in the six-State area where power from Glen Canyon powerplant is sold. Approximately 3.9 million (70 percent) of these end users do not receive power from the dam. Nearly 1.3 million (23 percent of the total) end users are served by large systems that have their own generation capability and rely on Federal power for a relatively small proportion of their energy needs. The remaining 0.4 million (7 percent of the total) end users are served by small systems that rely heavily on Federal power to supply their needs.

Retail power rates paid by end use consumers are affected to varying degrees by Western's wholesale rate. The extent of this effect, if any, depends on the proportion of Federal hydropower used by the customer's utility to meet their power needs, the wholesale rate, and the cost of replacement power.

Western's rate-setting procedure differs from that of a profit-making utility. Western's charges are based on a rate which is designed to ensure that revenues are sufficient to repay all costs assigned to the CRSP power function within a prescribed period. These costs include annual power operation and maintenance costs, certain environment-related costs, power facilities construction costs, and irrigation project costs allocated to the power function.

The economic value of the lost power production was evaluated by Reclamation's Denver Technical Service Center based on the 2 foot headloss predicted in Reclamation's September 1997 Feasibility Study. This study describes a reconnaissance level analysis of headloss from which an economic analysis was prepared. Financial costs to specific groups could be less than or greater than those described here. This economic analysis assumed that all eight of the intakes were set to draw warm water and used an estimated headloss of 2 feet. In summary, relative to the without temperature control case, the economic value of the electrical energy produced would be reduced by an average of about $37,000 per month if all eight upper level intakes are used at the same time. Lower impacts would occur during the late summer when cooler water would blended from the lower intakes to control maximum temperatures. This estimate represents an average monthly decline of less than 1 percent. The results described in this analysis are subject to the limitations noted in Harpman (1998). Subsequent studies conducted on a physical model of the intakes suggests that headloss at maximum discharge rates might be as high as 4 feet. In total, these results suggest that the economic impact of lost power production from operating temperature controls will be quite limited.

AIR QUALITY

Glen Canyon Dam is one component of an interconnected utility system. Air quality in Grand Canyon and the surrounding region is affected by emissions of particulates, carbon compounds, sulphur dioxides (SO_2), and nitrous oxides (NO_x) from powerplants and other emission sources. It also is affected by weather, wind, and other environmental factors.

Powerplant emissions result when fossil fuel is burned to provide electric power. Annual powerplant emissions in the region rise and fall with the availability of water to generate hydropower. For example, during an 8.23 MAF year when the reservoir is full, approximately 4 million MW/hr of hydropower is generated at Glen Canyon Dam. During an 11.3 MAF year such as 1996, approximately 5.5 million MW/hr of hydropower is generated at Glen Canyon Dam. There is a difference of 1.5 million MW/hr, or 38 percent between these 2 years.

Differences in the amount of energy generated at Glen Canyon Dam lead to changes in generation levels at other interconnected powerplants. This results in differential emission levels in the six-State marketing area.

The Grand Canyon enjoys some of the cleanest air in the lower 48 States, resulting in a visual range that sometimes exceeds 240 miles. However, haze—consisting of air pollution brought into the Grand Canyon area from urban and industrial areas in the surrounding region—results in a summertime average visibility of only 100 miles.

Regional air quality is comparatively good by national standards. Locally significant degradation of air quality does result from the operation of some fossil-fueled powerplants.

The proposed action would result in a slight decrease in the efficiency of the powerplant while water is drawn from the surface layer during the summer months. In theory, this would have an impact on air quality. This would require increased levels of generation at other powerplants in the region. A least-cost mix of hydro, coal, and gas plants would be used to replace the hydropower that would otherwise have been generated. As a result, there would be an increase in the emission of SO_2 and NO in these months. However, compared to the annual variation in emissions due to water availability, this increase is likely to be negligible.

CUMULATIVE IMPACTS

Physical and biological resources are closely linked in the ecosystem below Glen Canyon Dam. The impacts based on these linkages have been analyzed in the sections on those resources in this chapter. Monitoring programs will be designed and implemented through Adaptive Management Program to evaluate biological responses. Data on native and non-native fishes, macroinvertebrates, and algae would be collected before and after temperature controls to identify both desirable or undesirable responses.

Cumulative impacts on the environment result from incremental impacts of the action when added to other past, present, and reasonably foreseeable future actions. Cumulative impacts can be positive or adverse. For example, there has been an accumulation of impacts on native fish, starting with reduced sediment and colder water as a result of the construction of Glen Canyon Dam. Those impacts were followed by wide-ranging daily fluctuations due to operations of the powerplant in response to changes in electrical loads. Introductions of non-native fish have resulted in predation and other competitive interactions with native fish.

Recently, there have been efforts to produce an accumulation of positive impacts on native fish, beginning with implementation of interim flows in 1991 and continuing with the Record of Decision in 1996. Future actions might include the potential use of temperature controls to deliver warmer water from Lake Powell, measures to directly control non-native fish, and efforts to establish additional populations of endangered fish. The proposed action would implement temperature controls in an attempt to further this restoration effort.

UNAVOIDABLE ADVERSE IMPACTS

The no action alternative would continue to adversely impact native and jeopardize endangered fish. For the proposed temperature control alternative, adverse impacts would be avoided using adaptive management to test and refine operations.

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS

Before Glen Canyon Dam, the river was seasonally warmed in the summer. When the dam was constructed, coldwater releases from the deep outlets modified environment below the dam. The purpose of temperature control alternative is to return a portion of this seasonality to the downstream environment. It is envisioned that cautious, incremental testing of the device would allow early detection of any unforseen problems. Adaptive management would then allow flexible solutions to be developed. And finally, if the adaptive management process fails to find solutions to unforseen problems, the temperature control modifications would allow a return to year-round coldwater releases as a last resort.

Though the cost of the temperature modifications would not be recoverable, the potential effects of warmer releases are expected to be reversible or retrievable. As when the dam was first constructed, the coldwater environment could be reestablished. The proposed temperature control modification is a tool that can release either warmer or cooler water without further modifications, allowing the return to cold-water releases if needed.

INDIAN TRUST ASSETS

Reclamation policy is to protect American Indian Trust Assets from adverse impacts resulting from its programs and activities when possible. Indian Trust Assets are property interests held in trust by the United States for the benefit of Indian tribes or individuals. Although there is no concise legal definition of Indian Trust Assets, courts have traditionally interpreted them as being tied to property. Lands, minerals, and water rights are common examples of trust assets.

The Hualapai Tribe has asserted that there are Indian Trust Assets within its reservation boundary and that these are affected by dam operations. The claimed resources include land, recreation, fish, vegetation, wildlife, and cultural resources. Reclamation does not agree that trust assets are affected because, in Reclamation's opinion, dam operations do not affect reservation lands. However, without regard to jurisdictional boundaries, Reclamation's proposed temperature control alternative seeks to improve and protect conditions for these resources and avoid or mitigate adverse impacts that might occur.

Through this environmental assessment, Reclamation is presenting Indian tribes and individuals with its plan and environmental analysis.

INDIAN SACRED SITES (EXECUTIVE ORDER 13007)

Reclamation policy is consistent with Executive Order 13007, which is to accommodate access to, and ceremonial use of, Indian sacred sites by Indian religious practitioners and to avoid adversely affecting the physical integrity of such sacred sites.

Potential impacts to human remains, objects, and sacred sites would be addressed according to the Programmatic Agreement on Cultural Resources and the accompanying monitoring and remedial action plan in the final Glen Canyon Dam EIS (USDI 1995)

INTERNATIONAL IMPACTS

Under the Mexican Water Treaty of 1944, Mexico receives 1.5 MAF/yr of water from the Colorado River Basin. Minute 242 of the Treaty specifies allowable gains salinity between the Imperial Dam and Mexico. There will be no measurable impact from the proposed action on water or water quality delivered to Mexico under the Mexican Water Treaty of 1944.

Because the small loss of head caused by the proposed action, lost power production at Glen Canyon Dam may be replaced by power generated at other facilities. This loss would be minor. Replacement power would likely be generated by coal and gas plants that use fuels of domestic origin. A small possibility exists that some electrical power could be produced by powerplants which burn oil, and some of this oil could be imported. If so, the amount of imported oil used as a result of the proposed action would be insignificant.

ENVIRONMENTAL COMMITMENTS

The environmental commitments to avoid or mitigate potential adverse impacts would include:

- Limit maximum release temperatures to protect the tailwater rainbow trout fishery below the dam.
- Continued monitoring by the GCMRC to measure the effects of temperature controls and monitor for unforeseen impacts.
- Refine operation of the temperature control device through the ongoing adaptive management process.
- Potential abandonment of warmwater releases if they fail to improve (or at least maintain) conditions for endangered fish.

ENVIRONMENTAL JUSTICE IMPLICATIONS

The proposed action does not involve construction of major new facilities, population relocation, health hazards, hazardous waste, property takings, or substantial economic impacts. Neither of the alternatives analyzed in this EA has an adverse human health or environmental effect on minority and low income populations as defined by environmental justice policies and directives.

CHAPTER IV- CONSULTATION AND COORDINATION

This chapter summarizes public involvement and coordination with State and Federal agencies, tribal governments, and private organizations that occurred during planning and preparation of this environmental assessment. It also includes the distribution list for this document.

PUBLIC INVOLVEMENT

Temperature controls were discussed throughout the Glen Canyon Dam EIS process, which began in 1990 at numerous Cooperating Agency and interested party meetings and was a common element to each of the alternatives in the EIS.

The public process to evaluate temperature controls includes meetings and workshops with numerous Government agencies (both State and Federal), Native American tribes, and private organizations. Participants are identified in the distribution list at the end of this chapter. These workshops were to scope the process and issues surrounding the proposed addition of a temperature controls to Glen Canyon Dam.

The process of evaluating and potentially implementing the temperature controls has been a regular agenda item for the Glen Canyon Dam Transition Work Group (TWG) since about 1995. In a letter dated October 28, 1996, to the TWG, Reclamation summarized past scoping activities and stated its intent to begin an environmental assessment. During these meetings, participants were given the opportunity to present data, discuss potential impacts, and voice opinions about temperature controls. These meetings—along with this document's distribution for review and comment— constitute appropriate public involvement for an environmental assessment.

The Colorado River Basin States have been kept apprised of the progress pertaining to temperature controls. The involved States were sent all information on the TWG meetings and participated in the meetings described above.

PUBLIC MEETINGS AND COORDINATION

Among the more widely attended meetings in the planning process were the following:

December 9, 1991, Tempe, Arizona - Glen Canyon Reservoir Working Group met to identify benefits, objectives, potential impacts of temperature controls and discuss inclusion in GCEIS. The Work Group consisted of representatives from the FWS, USBR, Utah DWR, AGF, Bio/West, and AS.

November 18, 1992, Phoenix, Arizona - GOES sponsored Multi-Level Intake Structure Workshop to identify potential impacts on Lake Powell, Colorado River, and Lake Mead, discuss case histories and unpredicted effects, goals, develop issues and plans, list technical and administrative questions.

February 12, 1993, Phoenix, Arizona - Meeting of the Selective Withdrawal Investigations Group to review and discuss research, issues, resources, objectives, biological opinion, questions, concerns, impacts, prioritize research and monitoring needs, schedules, and adaptive management.

June 23, 1994, Flagstaff, Arizona - GOES sponsored meeting on temperature controls to discuss risk assessment, NEPA compliance, prioritize studies, status of work, and draft appraisal report. Comments by Tribes, USGS, USBR, NPS, AGF, WAPA, and other interested parties.

October 27, 1994, Phoenix, Arizona - Meeting among GOES Endangered Species Researcher and Selective Withdrawal Structure Researchers to discuss status of plan, risk assessment, economics, technical studies needed, and study plans.

May 21, 1996, Phoenix, Arizona - Glen Canyon TWG meeting that included a discussion to temperature controls as one of its agenda items. Discussed status of studies, plans, NEPA procedures, and potential impacts.

August 29, 1996, Phoenix, Arizona - Glen Canyon TWG meeting that included a discussion to temperature controls as one of its agenda items. Discussed status of studies, plans, NEPA procedures, and potential impacts.

October 28, 1996 - Letter to TWG and interested parties announcing the start of studies to determine the feasibility of temperature controls. The letter summarized potential impacts and risks identified in previous meetings.

November 21, 1996, Phoenix, Arizona - Glen Canyon TWG meeting that included a discussion to temperature controls as one of its agenda items. Discussed previous scoping of issues and summary of issues contained in October 28, 1996, letter. Continued discussion of NEPA procedures, magnitude of potential impacts, and design efforts. Reclamation agreed to host a temperature control workshop on January 9, 1997.

December 31, 1996 - Letter to TWG reminding them of the January 9, 1997, Glen Canyon Temperature Control Work Group meeting.

January 9, 1997, Phoenix, Arizona - GC Temperature Control Work Group Meeting to discuss public scoping of issues, potential impacts, status of studies, and NEPA compliance.

February 3-4, 1997, Phoenix, Arizona - Glen Canyon TWG meeting that included a discussion to temperature controls as one of its agenda items

September 11, 1997, Tempe, Arizona - The first meeting of the Glen Canyon Adaptive Management Work Group (AMWG) was held. The agenda included a brief discussion of Reclamation's proposal for temperature controls by modifying the existing trashrack/penstock intake structure and Reclamation's plan to prepare an environmental assessment.

Winter 1998, Phoenix, Arizona - The second meeting of the Glen Canyon Adaptive Management Work Group was held. The agenda included a lengthy discussion of Reclamation's proposal for temperature controls by modifying the existing trashrack/penstock intake structure and Reclamation's plan to prepare an environmental assessment on temperature controls.

March 18, 1998, Phoenix, Arizona - AMWG Technical Work Group was presented summaries on the potential benefits/effects of warm releases on several key topics. These include presentations on rainbow trout by Arizona Fish and Game, native fish by Dr. Richard Valdez, studies of the changes observed from temperature controls at Flaming Gorge Dam and fish and macroinvertebrates by Larry Crist, and Northern Arizona University's research on the effect of warm water on macroinvertebrates.

July 1, 1998, Phoenix, Arizona - Conducted a workshop for the Glen Canyon Technical Work Group to discuss preliminary draft of the environmental assessment.

July 22, 1998, Phoenix, Arizona - The third meeting of the Glen Canyon Adaptive Management Work Group was held. The meeting included a 1 hour review of Reclamation's preliminary draft environmental assessment. The presentation included a review of the design alternatives investigated by Reclamation and a review of the potential impacts of temperature control on Lake Powell, releases from Glen Canyon, and inflows to Lake Mead.

CONSULTATION

Cultural Resources - Through this environmental assessment, Reclamation is notifying the State Historic Preservation Officer, as well as the interested public of the propsal and of Reclamation's determination that raising the temperature of the river should have no effect on cultural resources eligible to the National Register of Historic Places.

Fish and Wildlife Coordination - Consultation with FWS and the Arizona Game and Fish Department was conducted throughout the process and they were included in the formulation of the temperature control plans. Both agencies were represented on the Glen Canyon EIS team, cooperating agencies, the Transition Work Group, Adaptive Management Work Group, and Technical Work Group. The Fish and Wildlife Coordination Act report dated June 28, 1994, and the biological opinion dated December 21, 1994—written in connection with the EIS—both strongly supported the evaluation of the feasibility of temperature controls.

Glen Canyon Dam Adaptive Management Work Group - In a meeting on January 15, 1998, Reclamation requested that the AMWG charge its technical work group and Grand Canyon Monitoring and Research Center with the task of developing monitoring and verification plans for temperature controls. The AMWG accepted this request by a formal vote and agreed to recommend the integration of temperature control operations into the adaptive management process.

EXECUTIVE ORDERS

Executive Order 11988 requires Federal agency avoidance of long- and short-term adverse impacts to flood plains; and Executive Order 11990 requires minimization of the destruction, loss, or degradation of wetlands and preservation and enhancement of the natural and beneficial values of wetlands. The proposed action is part of the ongoing adaptive management process to improve the ecological health and well-being of the flood plains and wetlands of Glen and Grand Canyons. The public review required by both Executive Orders has been achieved through the EIS, public scoping, TWG, and the environmental assessment processes.

DISTRIBUTION LIST

Federal Agencies

Department of the Army
- Corps of Engineers, Dallas, Texas; Salt Lake City, Utah; Phoenix, Arizona

Department of Energy
- Western Area Power Administration, Sacramento, California; Golden and Loveland, Colorado; Salt Lake City, Utah; Phoenix, Arizona

Department of the Interior
- Bureau of Indian Affairs; Hopi Agency, Keams Canyon, Arizona; Truxton Canon Agency, Valentine, Arizona; Navajo Area Office, Gallup, New Mexico; Southern Paiute Field Station, St. George, Utah
- U.S. Fish and Wildlife Service, Phoenix, Arizona; Flagstaff, Arizona; Pinetop, Arizona
- U.S. Geological Survey, Tucson and Flagstaff, Arizona; Boulder, Colorado; Menlo Park, California
- National Biological Service, Fort Collins, Colorado
- National Park Service, Washington, DC; Fort Collins, Colorado; Flagstaff, Arizona; Grand Canyon National Park, Grand Canyon, Arizona; Lake Mead National Recreation Area, Boulder City, Nevada; Glen Canyon National Recreation Area, Page, Arizona; Canyonlands National Park, Moab, Utah
- Office of Environmental Policy and Compliance, Washington, DC
- Office of the Field Solicitor, Phoenix, Arizona

Environmental Protection Agency, Region VIII, Denver, Colorado; Region IX, San Francisco, California

State and Local Agencies

Arizona State Government, Phoenix
- Governor
- Commerce Department
- Environmental Quality, Department of
- Game and Fish Department
- State Historic Preservation Officer

Parks Recreation Council
Water Resources, Department of
California State Government, Sacramento
Governor
Colorado River Board of California, Glendale
Colorado State Government, Denver
Governor
Colorado Water Conservation Board
Nevada State Government, Carson City
Governor
New Mexico State Government, Santa Fe
Governor
Interstate Stream Commission
Utah State Government, Salt Lake City
Governor
Water Resources, Division of
Wyoming State Government, Cheyenne
Governor
State Engineer

Indian Tribes

Havasupai Tribe, Supai, Arizona
Hopi Tribe, Kykotsmovi, Arizona
Hualapai Tribe, Peach Springs, Arizona
Navajo Nation, Window Rock, Arizona
Paiute Tribe of Utah, Cedar City, Utah
San Juan Southern Paiute Tribe, Tuba City, Arizona
Southern Paiute Consortium, Pipe Springs, Arizona
Zuni Pueblo, Zuni, New Mexico

Schools

Arizona State University, Tempe, Arizona
Northern Arizona University, Flagstaff, Arizona
Utah State University, Logan, Utah

Interested Organizations

American Fisheries Society, Bethesda, Maryland; Olympia, Washington; McCall, Idaho; Albuquerque, New Mexico
America Outdoors, Flagstaff, Arizona
American Rivers, Washington, DC
Argonne National Laboratory, Lakewood, Colorado; Argonne, Illinois
Arizona Municipal Power Users Association, Phoenix, Arizona
Arizona Nature Conservancy, Tucson, Arizona

Arizona Power Authority, Phoenix, Arizona
Arizona Power Pooling Association, Phoenix and Mesa, Arizona
Arizona River Runners, Phoenix, Arizona
Arizona Wildlife Federation, Mesa, Arizona
Audubon Society, Coordinating Counsel of Utah, Clearfield, Utah; Maricopa, Phoenix, Arizona; Napa-Sonoma, Napa, California; Northern Arizona, Flagstaff and Sedona, Arizona; Prescott, Prescott, Arizona; Yosemite Area Chapter, Mariposa, California
Bio/West, Inc., Logan, Utah
Bountiful City Light and Power Department, Bountiful, Utah
Canyoneers, Inc., Flagstaff, Arizona
Colorado River Resource Coalition, Salt Lake City, Utah; Desert Hot Springs, California
Colorado River Energy Distributors Association, Salt Lake City, Utah; Phoenix, Arizona
Dixie Escalante Rural Electric Association, St. George and Beryl, Utah
Desert Flycasters, Chandler, Arizona
Eco-Plan Associates, Mesa, Arizona
Environmental Defense Fund, Inc., New York, New York; Oakland, California; Boulder, Colorado; Austin, Texas
Friends of the Colorado River, Flagstaff, Arizona
Friends of the River, Inc. (and Foundation), San Francisco and Sacramento, California
Grand Canyon River Guides Association, Flagstaff, Arizona
Grand Canyon Trust, St. George, Utah
High Country River Rafters, Golden, Colorado
Intermountain Consumer Power Association, Sandy, Utah
Los Angeles Department of Water and Power, Los Angeles, California
Maricopa Water District, Waddell, Arizona
Murray City Power, Murray, Utah
Natural Resources Defense Council, Inc., New York, New York; San Francisco, California
Sierra Club Southwest Office, Phoenix, Arizona
SWCA, Inc., Flagstaff, Arizona
Tri-State Generation and Transmission Association, Inc., Denver, Colorado
Trout Unlimited, Vienna, Virginia; Rocky Mountain Region, Wheat Ridge, Colorado; West Coast Region, Fairfax, California; Arizona Council, Flagstaff, Glendale, and Phoenix, Arizona
Upper Colorado River Commission, Salt Lake City, Utah
Wilderness Society, The, Bethesda, Maryland

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