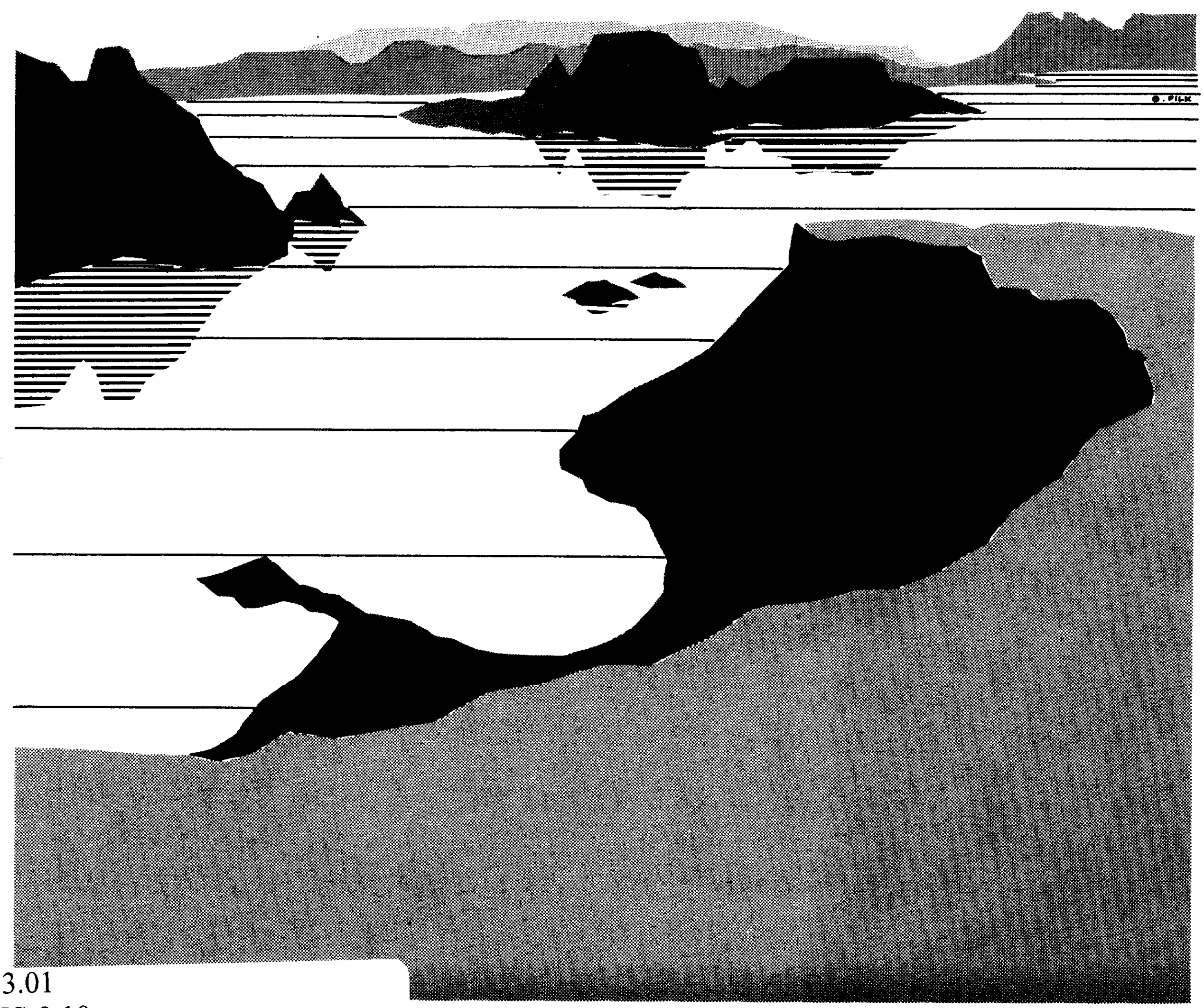
WATER RESOURCES MANAGEMENT PLAN

GLEN CANYON NATIONAL RECREATION AREA
UTAH / ARIZONA



WATER RESOURCES MANAGEMENT PLAN
and
ENVIRONMENTAL ASSESSMENT

GLEN CANYON NATIONAL RECREATION AREA
Arizona/Utah

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FOREWORD

This Water Resources Management Plan, the first for Glen Canyon National Recreation Area, is intended to serve as a management action plan for water resources for the next ten years. It is complementary to, and consistent with, other existing management documents such as the General Management Plan (NPS 1979), Lees Ferry Upriver Recreation Plan (NPS 1984b), Statement for Management (NPS 1985f), Natural Resources Management Plan (NPS 1986), and Cultural Resources Management Plan (NPS 1987). The present plan discusses water resources management issues that currently are significant and in need of management action within the next ten years. As new problems arise or unanticipated alternatives appear, the plan will be subject to revision from time to time. 10 years

Because management actions are proposed, an Environmental Assessment is incorporated into this plan. Alternatives are evaluated for addressing each problem, impacts are compared, and a specific action is recommended. Circulation of the draft plan for public review and subsequent comment resolution by the National Park Service will complete full compliance with the National Environmental Policy Act of 1969. EA

I. INTRODUCTION

I.A. Purpose of the Plan

Glen Canyon National Recreation Area (NRA) in Utah and Arizona (Fig. 1) was established as a unit of the National Park Service by Public Law 92-593 on October 27, 1972 ". . . to provide for public outdoor recreation use and enjoyment of Lake Powell and lands adjacent . . . and to preserve scenic, scientific, and historic features contributing to public enjoyment of the area. . . ."

Among the natural resources essential to public use and enjoyment of the recreation area are the waters of 163,000-acre Lake Powell, its five major tributaries, and the waters of adjoining lands, including springs, seeps, ephemeral streams, and ground water. To ensure adequate management of these extensive resources, this Water Resources Management Plan was prepared to evaluate significant issues and develop a management program. It is consistent with existing development plans for recreation and administrative facilities.

This plan incorporates water resources planning for Rainbow Bridge National Moument, which is administered by Glen Canyon NRA management. The monument's water resources are covered by the problem statements for the recreation area.

I.B. Legislative and Planning Relationships

The Act establishing the recreation area placed the unit under the National Park Service to be administered for public recreation purposes in accordance with the National Park Service Organic Act, and ". . . for the conservation and management of natural resources . . ." (P.L. 92-593; 86 Stat. 1311). This general directive is supplemented in the Act by provisions that permit mineral leasing, grazing, hunting, fishing, and trapping to the extent that these activities are consistent with the purposes and administration of the recreation area. A further legislative directive provides that nothing in the Act shall affect the authority of the Secretary of the Interior to operate the reservoir.

The operation of Glen Canyon Dam and Reservoir for water storage, electric power generation, and flood control (Colorado River Storage Project Act, April 11, 1956 [P.L. 84-485]) is the responsibility of the Bureau of Reclamation, U.S. Department of the Interior. Those activities and their management are not discussed in this plan except where they affect recreation programs.

The National Park Service (Service) and Bureau of Reclamation (Bureau), by Memorandum of Understanding dated August 28, 1973, agreed that:

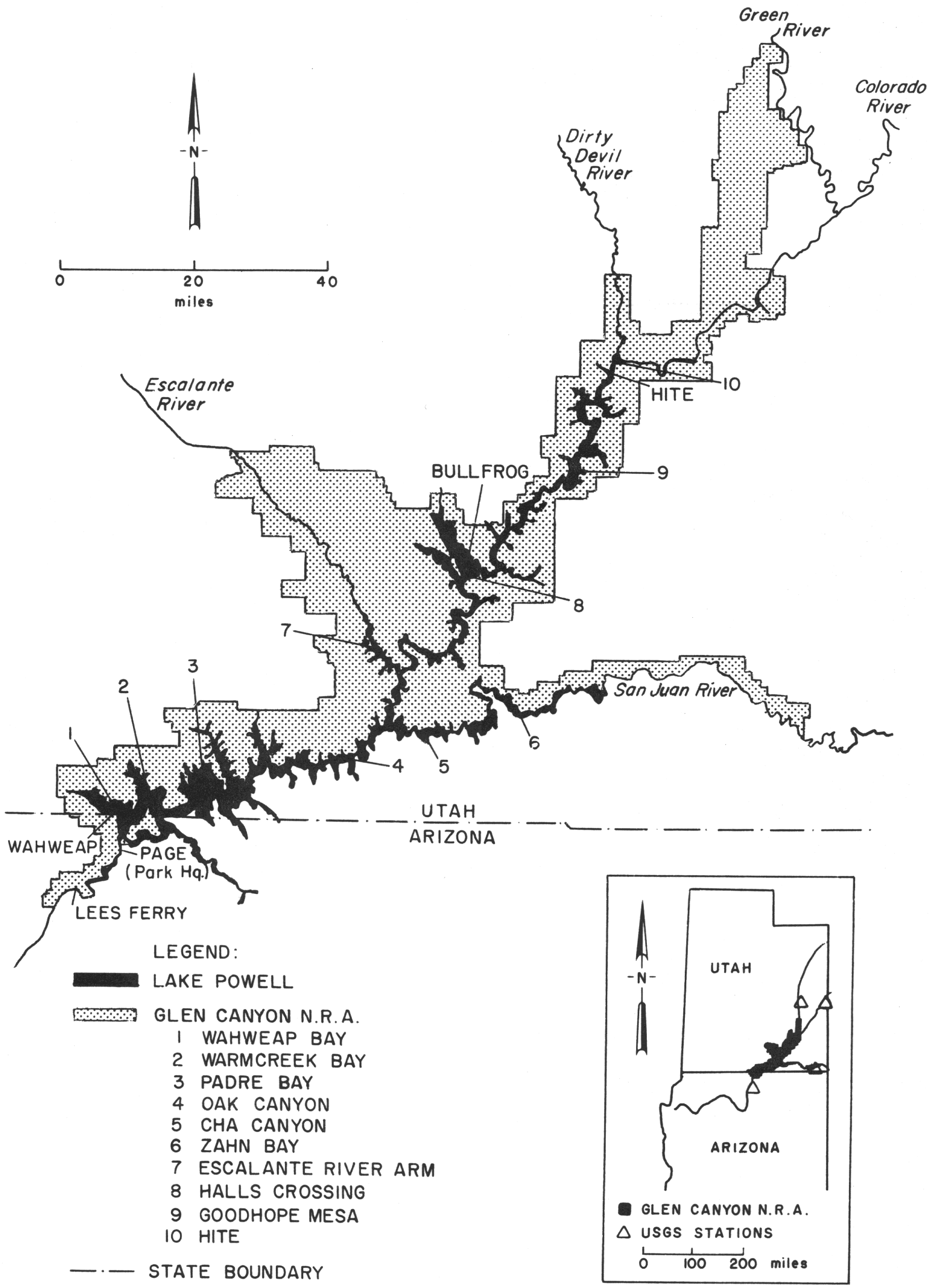

Fig. 1. Glen Canyon National Recreation Area.

- The Bureau administers the dam and appurtenant facilities, and the Colorado River to 2,500 feet downstream of the dam.

- The Bureau will vary the water level in Lake Powell to the extent necessary for the purposes of the Glen Canyon storage unit. In keeping with Interior policy, the Bureau will provide "full consideration of public recreation and conservation" in its decisions on reservoir management. The Bureau is required to keep the Service continuously informed of changes in reservoir operation schedules. (The fluctuation in water level in Lake Powell is typically in the 20- to 25-foot range over the course of a year, with highest water during summer. The Colorado River Basin Project Act of 1968 [P.L. 90-537] established 3700 feet above mean sea level as the full pool elevation for Lake Powell.)

- The Service manages all other federal lands and waters within the recreation area boundary. It also administers licenses, permits, and contracts to provide public services, such as developed recreation facilities, and regulates public use of the lake and lands.

Glen Canyon NRA's enabling legislation provides for fishing in the recreation area in accordance with federal and state law. The National Park Service may designate areas of closure for the purposes of "public safety, administration, or public use and enjoyment," and may regulate Lake Powell fisheries after consultation with the state. The only areas closed to fishing by the Service are marina dock areas and the Bureau of Reclamation administrative zone near the dam, which is closed for safety reasons.

The Arizona Department of Health Services and Utah Division of Environmental Health have promulgated water quality standards for primary uses (drinking, recreation, and aquatic resources) pursuant to the Clean Water Act of 1977 (P.L. 92-500). As a federal land management agency, the National Park Service must "adhere to all . . . applicable Federal, State, and local laws regarding avoidance, amelioration or elimination of environmental pollution" (including water pollution) and comply with Executive Order 11752, which requires the prevention and control of pollution at federal facilities. In addition, Section 404 of the Clean Water Act requires that the U.S. Army Corps of Engineers issue permits for disposal of dredged or fill materials in waters of the U.S. or for structures affecting waters of the U.S., which include Lake Powell and the Colorado River.

WQ STDS.

Other legislation and executive orders influencing water resources management include the following:

- The National Park Service Organic Act (1916) directs NPS to preserve park resources for future generations while allowing for public enjoyment of park lands.

- The Resource Conservation and Recovery Act (1976) regulates solid and hazardous waste disposal. It protects ground water from waste disposal activities on land and provides "cradle-to-grave" standards for handling of hazardous waste.

- The Safe Drinking Water Act (1986) applies to developed public drinking water supplies. It sets national minimum water quality standards and requires regular testing of drinking water.

- Executive Order 11988 (1977) requires planning and review of projects that may affect floodplains, and it establishes federal policies for minimizing floodplain hazards.

- Executive Order 11990 (1977) orders federal agencies to avoid impact to wetlands and establishes a policy of recognizing and enhancing wetland values.

I.C. Land Status, Land Use, and Political Boundaries

Glen Canyon National Recreation Area encompasses portions of Kane, Garfield, Wayne, and San Juan Counties in Utah and Coconino County in Arizona. Eighty-one sections of state land are included within NRA boundaries in Utah.

The NRA is bordered on the south by the Navajo Indian Reservation and elsewhere primarily by federal lands. Adjacent NPS units include Grand Canyon, Capitol Reef, and Canyonlands National Parks. Most of the remaining boundary adjoins BLM land, including two Wilderness and Primitive Areas at Paria Canyon and Grand Gulch.

The General Management Plan (NPS 1979) designated four management zones for the NRA. The Natural Zone (668,670 acres) is managed to maintain natural processes and to conserve land, water, and cultural resources. Mineral leasing and use of motorized vehicles are prohibited in this zone, although grazing is permitted and backcountry recreational use is encouraged.

The Recreation and Resource Utilization Zone (557,890 acres), which includes Lake Powell and most of the land not included in the Natural Zone, provides for a variety of recreational activities. Motorcraft are permitted on Lake Powell and vehicles are allowed on established roads. Utility and transportation systems may be installed where appropriate. Mineral leasing is also permitted except on the lake or where leasing would be incompatible with recreation area purposes.

The Development Zone encompasses 19,270 acres of existing and potential recreational developments and certain road corridors, including the area around Glen Canyon Dam. Land in this zone is designated for the location of facilities and services.

The Cultural Zone (25 acres) is managed to preserve, restore, and interpret identified cultural resources.

I.D. Water Resources Management Objectives

It is the policy of the National Park Service to maintain the quality of all waters originating within or flowing through or along the boundaries of NPS areas. This policy establishes one of the most important objectives for water resources management at the recreation area: to maintain existing water quality and quantity. According to NPS *Management Policies*, this can be accomplished by:

- providing adequate sewage treatment and disposal for all facilities, including the requirement for self-contained sewage storage units in boats
- controlling erosion induced by human activities
- preventing direct pollution of natural waters by livestock
- regulating fuel-burning watercraft
- avoiding contamination by toxic substances
- regulating use as necessary to maintain water quality
- establishing cooperative agreements with other agencies or governing bodies to prevent water pollution

Because the waters of the recreation area are recognized as important resources to be conserved, another important objective is to avoid unnecessary withdrawal and depletion of federally-managed water resources by permitting water developments only as necessary to operate public and park facilities.

Additional water resource management objectives at Glen Canyon include:

- identifying and remaining current on issues that may affect the water resources in the NRA
- maintaining high water quality for water-oriented recreation and the protection of natural resources
- establishing consistent monitoring programs
- documenting and filing federal reserved and appropriated water rights

- perpetuating the natural flow of free water
- protecting natural riparian and aquatic ecosystems
- assessing floodplain hazards and minimizing the flood hazard to facilities and to the public
- regulating the recreational and consumptive use of park waters in accordance with the above goals
- maintaining cooperative programs with federal, state, and local governments and private entities to further the above objectives

I.E. Identification of Water Resource Issues

Significant water resource issues for the recreation area were identified through meetings between park and regional office staffs, the Water Resources Division of the National Park Service, and Bureau of Reclamation and state agency personnel. The following fifteen issues require development of management alternatives and are discussed individually in Section III:

- Identification of Outstanding National Resource Waters
- Water rights
- Floodplain identification and management
- Shoreline water quality
- Gray water
- Water quality of rivers for recreational use
- Springs, seeps, and waterpockets
- Water resources of riparian ecosystems
- Water resources as habitat for fish
- Heavy metals in fish flesh
- Range management practices
- Mineral extraction
- Tar sand operations
- Energy-related wastes
- Management of hazardous materials spills

II. THE HYDROLOGIC ENVIRONMENT

II.A. Introduction

Glen Canyon National Recreation Area comprises a number of diverse water resources. The largest of these is Lake Powell, which was formed with the completion of Glen Canyon Dam on the Colorado River. As part of the extensive Colorado River Basin, Lake Powell receives water from sources in Wyoming, Colorado, New Mexico, Arizona, and Utah.

II.B. Description of the Area

II.B.1. The watershed. Glen Canyon NRA is centrally located in the Colorado River Basin in southeastern Utah (Fig. 2). The major tributary rivers flowing into Lake Powell are the San Juan, the Colorado, the Dirty Devil, and the Escalante. The watershed is extremely varied in ecosystem type and land use and therefore is influenced by many different factors. The total drainage area above Glen Canyon Dam is 111,700 square miles, which includes 3,959 square miles in the Great Divide Basin in southern Wyoming that are noncontributing to flow (USGS 1984). A fifth major river, the Paria, enters the recreation area fifteen miles below Glen Canyon Dam, at the unit's boundary with Grand Canyon National Park.

II.B.2. Climate. Although the Colorado River drains some areas receiving more than 50 inches annual precipitation, the Glen Canyon region is classified as semi-arid to arid. Glen Canyon NRA receives an average of only six to seven inches of precipitation per year, although high plateaus typically receive several inches more and canyon bottoms several inches less. Annual precipitation extremes of four inches (low) and ten inches (high) have been recorded in the recreation area. Snowfall occurs in the area, but it normally remains on the ground only a few days below about 7,000 feet (USDI 1984). Brief, intense thunderstorms produce virtually all of the moisture received during the summer. March, August, and September are generally the wettest months, and June is the driest.

Summer thunderstorms that sweep through the area pose a dual threat to visitors. First, the brief but intense rains can cause flash floods in canyon bottoms, producing dangerous, fast-flowing water that carries large amounts of debris and in extreme cases extends to both walls in the canyons. Second, severe winds, often gusting to 70 miles per hour or more, have been known to capsize small craft on Lake Powell (NPS 1979).

Evapotranspiration in the Glen Canyon area greatly exceeds annual precipitation during all but the winter months, and is estimated to be

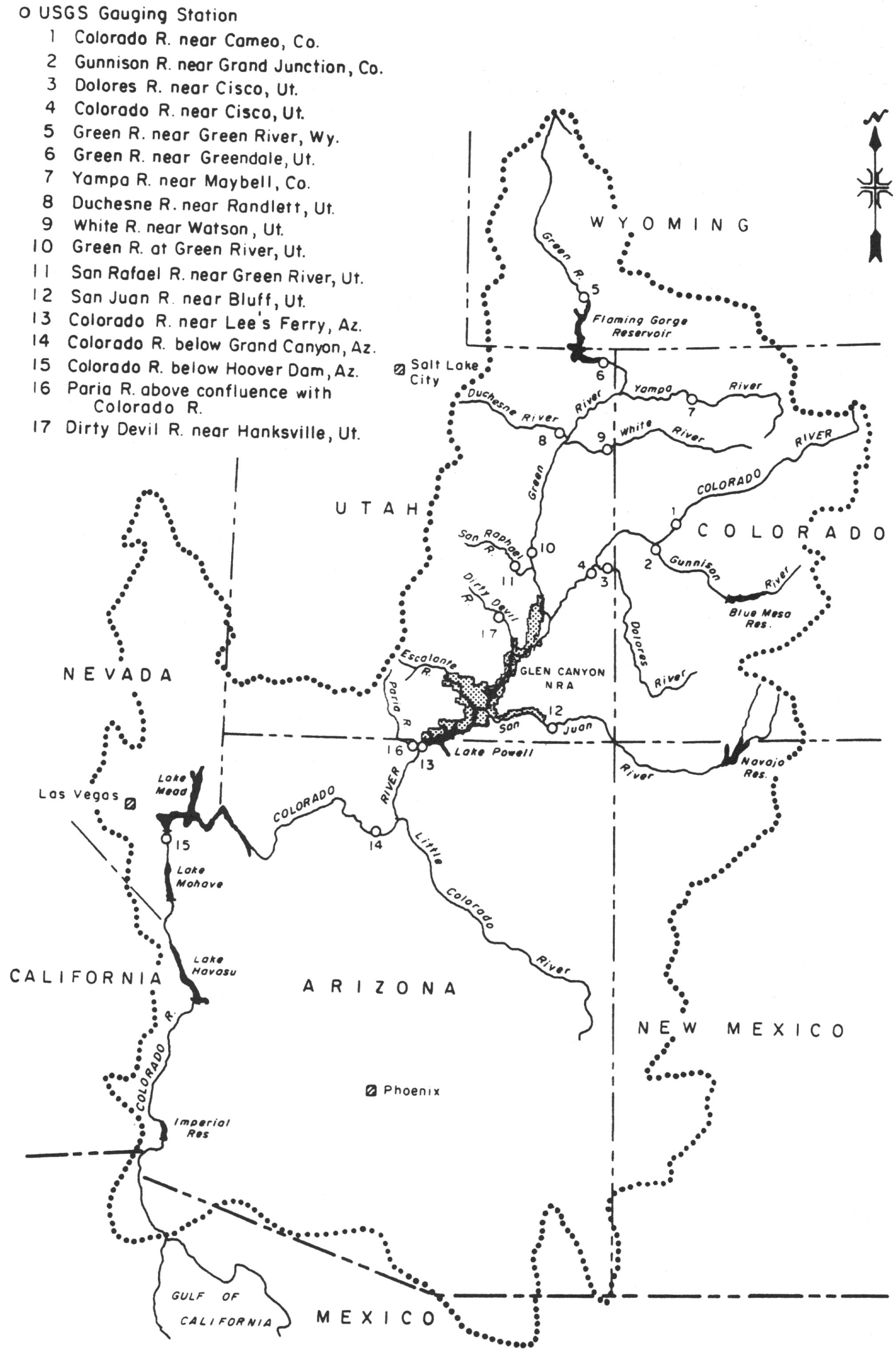

Fig. 2. Colorado River Basin, showing major tributaries, reservoirs, USGS gauging stations, and relative location of Glen Canyon National Recreation Area. (Adapted from Moody and Mueller, 1984.)

.5 MAF/YEAR EVAPORATION LOSS.

about 70 inches per year. The resulting loss from Lake Powell approximates 500,000 acre-feet per year. Maximum ground-water recharge occurs during the winter months, when rainfall usually exceeds evaporation. In all, less than 1 inch of the total annual precipitation is accounted for by surface runoff (USDI 1984).

II.B.3. Geology. Glen Canyon NRA is in a highly dissected plateau landform. The broad upwarped surface is transected by two upfolds, the Waterpocket Fold and the Echo Monocline. The area is characterized by a maze of deep canyons with nearly vertical walls. Flat-topped mesas and rock platforms rise in large tiers from the main drainages to the upland regions of the Colorado Plateau. Elevations in the recreation area range from 3,100 feet at Lees Ferry to 6,200 feet in the Orange Cliffs.

Surface stratigraphy includes outcrops of rock that range in age from Pennsylvanian to Cretaceous. Pennsylvanian and Permian rocks are exposed in the Cataract and San Juan Canyons. Cretaceous rocks are present in the eastern part of the Kaiparowits Plateau, between Rock Creek Canyon and Navajo Point (USGS 1975).

Marine deposition occurred during the Permian, Triassic, Jurassic, and Cretaceous Periods. The Navajo and Wingate Sandstones that are found extensively around Lake Powell originated from wind-blown sands deposited between the second and third occurrences of the inland seas.

II.C. Ground-Water Resources

II.C.1. Aquifers. Ground water typically occurs in the older rocks at or below the canyon floors, although perched bodies of water also occur on and beneath most mesas (Fig. 3). The aquifers are composed of beds of sandstone that lie between nearly impermeable layers of siltstone and mudstone. The main fresh-water aquifers are in the Coconino Sandstone, Wingate Sandstone, Navajo Sandstone, Saltwash member of the Morrison Formation, and alluvium; but all other units yield some water locally to wells and springs (USGS 1975).

Recharge from rainfall or snowmelt near the aquifer outcrops moves vertically to a saturated zone, then downgradient along the regional dip of the geologic strata. Secondary structural features such as faults and fractures affect movement locally by enhancing the permeability of the rocks along their alignments. The annual volume of recharge is a small percentage of both annual precipitation and the total ground water in storage. Hydrogeologic conditions suggest that most recharge occurs on sandy mesa tops and along canyon floors (USDI 1984), and probably occurs as direct infiltration during snowmelt and rainstorms. In the canyons, some of the ephemeral surface flow infiltrates the alluvium and sandstone bedrock of the stream channels. Although little data is available on total recharge in the area, recharge is estimated to be in the range of a few hundred acre-feet per year in excess of what is absorbed

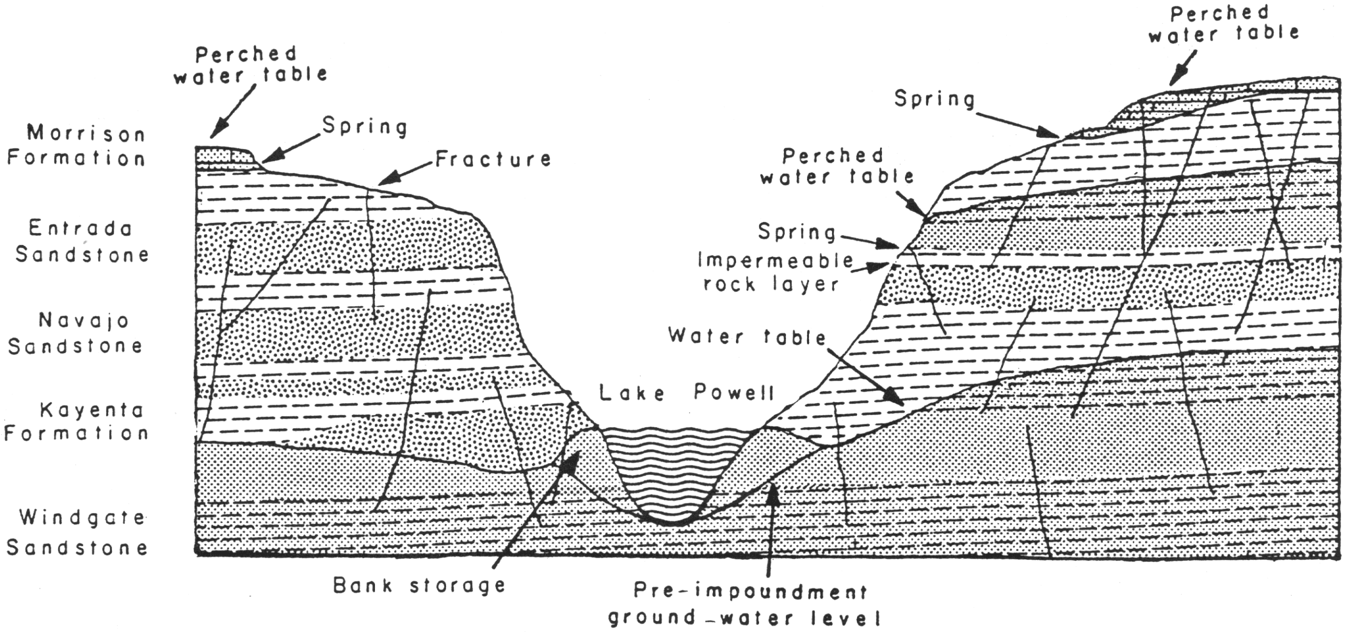

Fig. 3. Generalized geologic cross-section near Glen Canyon Dam. (Not drawn to scale.)

from Lake Powell (USDI 1984). The bank storage from the reservoir (water that percolates into the rock along the lakeshore) is estimated to be 10-13 million acre-feet (unpublished data, U.S. Bureau of Reclamation - Salt Lake City, 1987). A significant amount of water drains from the rocks back into the reservoir with any appreciable drop in lake level (Jacoby et al. 1977).

II.C.2. Springs and seeps. Springs in Glen Canyon NRA are often found in canyons where the surface intersects water-bearing strata or structural features. These springs can emerge from alluvial aquifers, from a zone of contact with an impermeable bedrock layer, or where a fracture zone drains local bedrock aquifers, particularly the Navajo Sandstone aquifer. Springs emerging from the alluvial aquifer fluctuate seasonally and in response to rainfall. Changes in hydrostatic head resulting from the filling of Lake Powell have created several new, large springs that flow from the lower canyon walls between Glen Canyon Dam and Lees Ferry.

Seeps occur where a canyon cuts through an aquifer or a joint connecting to an aquifer. Seeps commonly are found in canyon walls that cut through Navajo Sandstone.

II.C.3. Ground-water quality. Springs that discharge from the Navajo-Kayenta and Wingate Sandstone formations are generally of excellent quality except in places where the overlying Carmel Formation allows for the leaching of sulfate ions. In high concentrations, these sulfate ions act as a laxative, rendering the ground water unpotable. Local outcrops of other sandstones discharge water of good quality because the soluble salts have been leached out. In aquifers where ground water has accumulated soluble salts over longer geologic time, the water quality is poorer (Hand 1979). Williamson (1985) profiled the trace element chemistry of several springs and seeps in the uplake canyons and found them to be relatively low in trace element concentrations.

Saturated alluvium is generally a source of good water, although its original quality can be altered by evapotranspiration and calcium carbonate precipitation. Total dissolved solids (TDS) in alluvial water in the Canyonlands National Park area in Utah are generally less than 400 milligrams per liter (mg/1) (Richter 1980). Alluvial waters in the recreation area have a similar origin and are probably of like quality.

II.D Surface-Water Resources

II.D.1. Rivers, springs, seeps, and waterpockets. The principal sources of surface water in Glen Canyon NRA are five major rivers--the Colorado, San Juan, Dirty Devil, Escalante, and Paria--and Lake Powell. (Lake Powell is described separately in Section II.E.) In addition, most canyons are drained by ephemeral streams that flow in response to rainfall, though short stretches of streams below large springs can be perennial. Some intermittent streams flow throughout the year during wet years, but they do not exhibit other characteristics of perennial streams.

On the mesas and benches of the NRA, the most common sources of surface water are waterpockets found in natural bedrock depressions. They occur where rain fills depressions weathered into exposed sandstone surfaces. Though some of these waterpockets are quite large, all are considered ephemeral.

The U.S. Geological Survey has very few gauging stations on major rivers within the NRA (Fig. 2). Rugged terrain, wilderness protection, and lake inundation have prevented the establishment of a more comprehensive stream-gauging network. As a result, little hydrologic data is available for these rivers near where they enter Lake Powell, although information gathered upstream on the San Juan, Green, and Colorado Rivers may be extrapolated for use at Lake Powell. The Paria River, which enters the Colorado River below Lake Powell, has been gauged since 1923 and monitored for water quality since 1947.

Stream flows on the Escalante and Dirty Devil Rivers are less well known, especially because upstream flows on both rivers are affected by irrigation diversions. Some reaches of the Dirty Devil River are frequently dry during the summer because of irrigation withdrawals and evaporation.

II.D.2. Surface-water quality. Utah Department of Natural Resources data for the Dirty Devil River show ranges in suspended sediment from 10 to 6,140 mg/L during periods of stable flow (Mundorff 1979). Extremely high concentrations occur during high flows, though only for a very short period. Another water quality indicator is TDS, which typically increase as water progresses downstream. At USGS gauging station #09333500 on the Dirty Devil River, TDS ranges from 963 mg/L to 3460 mg/L (Lindscov 1983). The Dirty Devil River is currently being studied by the Bureau of Reclamation for possible water quality improvement under the Colorado River Basin Salinity Control Act (USDI 1983).

Geochemical studies (Reynolds and Johnson 1974) of Lake Powell indicate that its water is moderately saline (500 mg/L TDS), and that its ionic composition is controlled by relative contributions from the Green, San Juan, and Colorado Rivers. The major ionic components present are (in order of decreasing concentration) sulfate, calcium, sodium, alkalinity, magnesium, chloride, and potassium. Surface waters are oversaturated with respect to calcium carbonate; salt change calculations and comparisons of pre- and post-dam bicarbonate concentrations of river water at Lees Ferry suggest substantial precipitation of calcium carbonate in Lake Powell.

II.D.3. Flooding. Flash flooding commonly occurs in drainages of Glen Canyon NRA. Small drainage basins in mountainous areas or in steep desert lands of southeastern Utah are most likely to flood, especially during summer (Whitaker 1969). Peak flows for extremely rare, probable maximum floods have been estimated to be more than 2,000 cubic feet per second (cfs) for a one-square-mile drainage area and about 10,000 cfs for a 15-square-mile drainage area (Cripen and Bue 1977).

II.E. Reservoir Hydrology

II.E.1. Description. Lake Powell was created in 1963 with the completion of the Glen Canyon Dam. During the following 17 years, a 186-mile stretch of the Colorado River was transformed into the United States' second largest reservoir. At a maximum operating level of 3700 feet, Lake Powell has a mean depth of 167 feet and a maximum depth of 561 feet. It covers a surface area of 255 square miles and stores a volume of 26,753,000 acre-feet (Paulson and Baker 1980; USBR 1981).

II.E.2. Operation. The Bureau of Reclamation's long-range operating criteria for Lake Powell are complex and are undergoing revision. These criteria are required by the Colorado River Basin Project Act (Public Law 90-537), which also establishes guidelines for their adoption. The criteria were published in the Federal Register on June 9, 1970, under the title "Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs." They provide guidelines and regulations for coordinated operations of the Colorado River Storage Project reservoirs in the Upper Basin and Lake Mead in the Lower Basin. Operations are administered consistent with applicable federal laws, the United States and Mexico International Boundary and Water Treaty, and interstate compacts and decrees relating to the use of Colorado River water. A formal review of the operating criteria is made by the Secretary of the Interior at least every five years, and annual reports on past and contemplated annual operations are issued by the Bureau of Reclamation.

Whenever Lake Powell's storage is equal to or greater than that of Lake Mead's, releases greater than 8.23 million acre-feet annually are made from Lake Powell (a) to the extent they can be applied to downstream consumptive uses, (b) to maintain equal storage in Lake Powell and Lake Mead, and (c) to avoid using the emergency spillways of Glen Canyon Dam. Except during flood conditions, all releases are through the Glen Canyon Power Plant; and when necessary, adjustments in (a) and (b) above are permissible to avoid a bypass of water around the Glen Canyon Power Plant (USDI 1983).

II.E.3. Reservoir dynamics. With the completion of the initial filling of Lake Powell in June 1980, the water storage capacity of the Colorado River system was increased by two to three years of mean annual discharge. To utilize this resource effectively, the Bureau of Reclamation has applied a two-dimensional reservoir model to evaluate selective withdrawal methods that would meet peaking power needs and maximize water conservation. In addition, the model has been used to determine whether better long-term routing methods can be used to improve projections for salinity in the lower Colorado River.

The physical limnology of Lake Powell is complex but reasonably well studied (Johnson and Merritt 1979; Gloss et al. 1980; USDI 1983). The lake has been described as "warm monomictic" which indicates that convective mixing (lake turnover) occurs only once a year, during the winter cool-down period. However, Johnson and Merritt (1979) report that advective circulation, caused by differences in water density (which is related to changes in TDS and temperature), is significant. They further state that during a typical year the lake will receive two distinctive types of inflow: a lower-density water associated with the spring flood, and a higher-density water during the winter.

The impact of the density-dependent advective circulation is important in the limnology of Lake Powell. The influx of warm, lower-density water (spring overflow current) largely sets the thickness of the summer thermal equilibrium, especially in the upper reaches of the lake. Johnson and Merritt (1979) report that years with a large spring flood are associated with a deeper, more diffused metalimnion than are years with a small spring flood.

As the summer progresses, the TDS content of the inflow water increases, eventually closing off the overflow current. By early winter, the water is sufficiently dense to become an underflow current (the winter underflow current) (Johnson and Merritt 1979). This current contains cold, saline water with a high initial dissolved oxygen concentration and flows into the deeper areas of the lake, replenishing the deep-water dissolved oxygen concentrations. This phenomenon, along with the behavior of other downlake currents, indicates that the lake still possesses much of the character of a river reach in which the water has a long residence time.

Although the bottom of Lake Powell generally contains adequate dissolved oxygen for a good fishery, Johnson and Page (1981) describe an oxygen-depleted layer that develops in late summer below the mixed layer at about 45-60 feet below the surface. This layer is found the full 186-mile length of the lake and is more distinct in the tributary bays. Oxygen depletion is thought to be caused by bacterial respiration and the chemical process of organic decay. These processes result in oxygen depletion below the mixing zone where the organic debris concentrates. The distribution of oxygen may have a substantial impact on the fishery of Lake Powell. In particular, the depleted oxygen layer presents a formidable barrier to the vertical migration of fish during late summer and early fall.

Record high flows along the mainstem of the Colorado River in 1983 caused severe flood damage throughout parts of the Colorado River Basin (Vandivere and Vorster 1984). Large discharges through the Glen Canyon Dam resulted in the release of large amounts of more saline water from the depths of the lake. These releases in turn reduced the TDS concentration in hypolimnetic deep waters of Lake Powell. Overall, the TDS concentration in Lake Powell is at an all-time low due to heavy runoff since water year 1983 (Jerry Miller, Bureau of Reclamation, personal communication, 1986).

II.E.4. Reservoir nutrient dynamics and productivity. Nutrient dynamics within Lake Powell are characterized by the high removal of phosphorus, which results from the deposition in sediment of phosphorus bound to silt and clays close to the tributary inflow points. Because phosphorous bound in sediment is biologically unavailable, it cannot contribute to lake productivity. Paulson and Baker (1984) estimate that Lake Powell traps 98 percent of the total phosphorus and 46 percent of the total nitrogen entering from the tributaries. Thus, with the exception of certain areas near the inflow of the tributaries, nutrient concentrations are low, with mean soluble reactive phosphorus concentrations ranging from 0.002 - 0.003 mg/L and mean total phosphorus concentrations ranging from 0.008 - 0.010 mg/L in 1981 and 1982 (Paulson and Baker 1984). Because of its sediment dynamics and great depth, Lake Powell appears on Arizona's Clean Lakes Priority List as having the lowest trophic index in the state (least eutrophic). Although extensive data is not available, the low nutrient concentrations found in Lake Powell indicate that primary productivity may be limited except in areas close to the source of nutrient inflow, such as the inflow points of the Colorado, San Juan, and Escalante Rivers. Thus, the river arms may be highly productive for fish and phytoplankton even though the lake itself is nutrient-poor.

II.E.5. Reservoir sedimentation and heavy metal deposition. Sedimentation is the deposition of silt and soil on the reservoir bottom when silt-loaded river waters enter the lake. The energy of flowing water, required to keep the silt in suspension, is much reduced in the slowly circulating lake, and sediments quickly settle to the lake bed below the mouths of the rivers. To a lesser degree, windblown soil from the shoreline contributes to sediment accumulation. Sedimentation gradually fills in lakes, although hundreds of years may be required to complete the process.

Heavy metals are sometimes associated with deposited sediments. Graf (1985) states that the weathering of natural source rocks in the lake's watershed is responsible for most of the estimated 2200 kg of mercury deposited annually in Lake Powell. Also, elevated selenium concentrations in fish have been reported for Colorado River stations in Arizona (Bill Kepner, U.S. Fish and Wildlife Service, personal communication, 1985), with some concentrations high enough to cause reproductive problems in the affected fish.

The Bureau of Reclamation periodically measures reservoir-bottom profiles at Lake Powell to allow modeling of the sedimentation process. This information can be used to project reservoir life and to determine the usable life of potential development areas. A complete series of profiles was obtained in 1986, but the results will not be available until mid-1987.

Sediment erosion and deposition on river shorelines below the dam is also a significant resource management issue to neighboring Grand Canyon National Park, since the existence of the dam and fluctuating water releases have greatly changed erosion and deposition patterns of many beach areas in Grand Canyon. A multi-disciplinary, interagency team is currently investigating this problem and the possible effects of different water release schedules from the dam.

II.F. Water Use

All water consumptively used by the National Park Service operations at Wahweap, Bullfrog, Halls Crossing, Dangling Rope, and Lone Rock comes from deep wells. At Lees Ferry water is taken directly from the Colorado River, and at Hite it is taken directly from the lake. In 1979, consumption was estimated to be about 624 acre-feet per year from wells, 6 acre-feet per year from the lake, and 8 acre-feet per year from the Colorado River at Lees Ferry. The 14 acre-feet taken from the lake and from the Colorado River is about 5 percent of the 260 acre-feet reserved for the Glen Canyon Unit by Public Law 93-423 (NPS 1979) (this allotment does not apply to ground-water withdrawals from wells). Abandoned wells at Wahweap, Hite, and Hans Flat are not being used because of water quality problems, although these wells are considered reserve water supply that could be used for certain applications.

II.G. Monitoring Programs

In 1965, the Bureau of Reclamation initiated a major ion chemistry and physical limnology monitoring program in Lake Powell. The purpose of this program was to create a comprehensive data base relating to the salinity and major ion changes brought about in the Colorado River Basin by the closing of the Glen Canyon Dam. Sampling locations, frequencies, and parameters measured have been modified slightly over the years (Table 1). While this data collection program has focused primarily on salinity management questions, the long-term, consistent nature of this program has proved invaluable in providing baseline and trend information used in a number of studies. Due to budget constraints, sampling frequency was reduced in 1984 from monthly to quarterly. However, quarterly sampling should still be adequate to detect any major changes that could occur in response to changes in water management practices within the Colorado River Basin.

Three long-term discharge and water quality stations, maintained cooperatively by the U.S. Geological Survey and the Bureau of Reclamation, monitor water quality of the major tributary inflow into Lake Powell (Stations 4, 10, and 12 in Fig. 2). Data presently collected at these stations and their collection frequencies are given in Table 2.

Table 1. History of the Bureau of Reclamation major ion chemistry and physical limnology monitoring program in Lake Powell.

Period	Program Description
1965-1971	Six stations (Wahweap Bay, Padre Bay, Oak Canyon, Cha Canyon, Hall's Crossing, and Hite) were monitored quarterly at 50' depth intervals (top to bottom) for physical parameters including temperature and dissolved oxygen, and chemical parameters including specific conductance, TDS, pH, and common ions (Jerry Miller, U.S. Bureau of Reclamation, personal communication, 1986).
1971-1984	Seven stations (Wahweap Bay, Padre Bay, Oak Canyon, Cha Canyon, Halls Crossing, Good Hope Mesa, and Hite) were monitored monthly at 50' depth intervals for physical parameters including temperature and dissolved oxygen, and chemical parameters including specific conductance, TDS, pH, and common ions (calcium, sodium, magnesium, potassium, chloride, sulfate, alkalinity, and bicarbonate) (Jerry Miller, U.S. Bureau of Reclamation, personal communication, 1986). In addition, a special two-year study occurred in 1981-82 that focused on nutrients and productivity (Paulson and Baker, 1984).
1984-present	With an extensive data base established from 1965-1984, the Bureau of Reclamation elected to reduce sampling to a quarterly basis. An eighth site (Cataract Canyon) was added to the seven sites previously listed. Parameters sampled remain the same except for the addition of silica to the parameter list. In addition, continuous recording (at 2 hour intervals) at three depths for temperature and specific conductance has been attempted at two sites (Cataract Canyon and Clearwater Canyon). Because of instrumentation problems, only intermittent data are available (Jerry Miller, U.S. Bureau of Reclamation, personal communication, 1986).

Table 2. Water quality information from long-term USGS monitoring stations on the major inflow tributaries of Lake Powell. (Taken from USGS, 1985.)

USGS #	Station Name	Period of Record	1984 Water Quality Parameters
09180500	Colorado River near Cisco, UT	DSX 1895-present WQ 1928-present	D, C, B, T, S
09315000	Green River at Green River, UT	DSX 1894-1899 1904-present WQ 1928-present	D, C, B, T, S
09379500	San Juan River near Bluff, UT	DSX 1914-present WQ 1929-present	D, C, B, T, S

LEGEND:

DSX = Discharge

WQ = Water quality

D = Daily discharge

C = Monthly water chemistry (nutrients and metals quarterly)

- specific conductance
- pH
- turbidity
- dissolved oxygen
- hardness (carbonate and non-carbonate)
- major cations (Ca+, Na+, Mg+, K+)
- major anions (alkalinity, Cl-, SO_4--)
- total dissolved solids
- nutrients (ammonia, nitrate and nitrite, organic nitrogen, total nitrogen, dissolved phosphorus, dissolved orthophosphorus, and total phosphorus)
- heavy metals and trace elements (Al, As, Ba, Be, Cd, Cr, Co, Cu, Fe, Pb, Li, Mn, Mo, Hg, Ni, Se, Ag, Sr, V, Zn, B)

B = Quarterly bacteriological data, including fecal coliform bacteria and fecal streptococcus bacteria

T = Daily water temperature and specific conductance

S = Suspended sediment (daily) and particle size (quarterly)

The Colorado River station near Cisco, Utah, lies approximately 160 miles above the upper reaches of Lake Powell. Located between this station and the lake are the town of Moab, Utah, and some uranium mining and milling operations. The Green River station is located in Green River, Utah, approximately 117 miles upstream from its confluence with the Colorado River. Much of the watershed between the Green River Station and the confluence of the Colorado and Green Rivers is within Canyonlands National Park, and human disturbances are negligible. The San Juan River station, located southwest of Bluff, Utah, is approximately 38 miles from the upper reaches of the San Juan Arm of Lake Powell and may be affected by uranium mill tailings and small oil fields around Mexican Hat, Utah. In addition to these long-term stations of the Geological Survey, the Bureau of Reclamation has recently begun to monitor continuous water temperature and specific conductance at three depths in Cataract Canyon. When an adequate data base has been developed, these data will be correlated with data from the upstream USGS stations. Currently, no routine water quality monitoring occurs on the minor tributaries of Lake Powell.

III. WATER RESOURCES ISSUES, MANAGEMENT ALTERNATIVES, AND THEIR ENVIRONMENTAL IMPACTS

Several work sessions were held at Glen Canyon NRA to identify and consolidate management concerns, problems, and conflicts involving water resources in the recreation area. The 15 water resource issues identified as needing management action are discussed below in a standard format. Specifically, the problem statement introduces the water resource issue and provides background information. The section on management alternatives presents the courses of action that might be followed in response to the problem and the impacts associated with each alternative. The recommended action is noted as the "preferred alternative." All management alternatives would comply with existing laws and regulations.

III.A. Identification of Outstanding National Resource Waters

III.A.1. Statement of the problem. The Clean Water Act provides a nationwide strategy for the management of surface-water quality generally to be administered by each state. The strategy contains three major elements:

1. the uses to be made of waters (recreation, drinking water, fish and wildlife propagation, industry, or agriculture);
2. criteria to protect these uses; and
3. an anti-degradation statement to protect existing high-quality waters from degradation by the addition of pollutants.

The Environmental Protection Agency's (EPA) guidance to the states for water quality management program development requires state water quality standards to include the following key elements:

- protection of existing beneficial instream uses;
- maintenance of high-quality waters unless the state decides to allow limited degradation where economically or socially justified (limited degradation is permitted to the extent that national water quality goals are maintained);
- identification and protection of outstanding national resource waters; and
- limitation of thermal discharge.

In addition, EPA regulations in 40 CFR 131.12 (a)(3) require the states to ensure that "where high quality waters constitute an outstanding National resource, such as waters of national and state parks and wildlife refuges, and waters of exceptional recreational or ecological significance, that water quality shall be maintained and protected."

As a National Park Service unit containing waters of outstanding recreational and ecological significance, Glen Canyon is eligible for consideration under this program. The Service believes that such designation could increase recognition of the importance of these waters and contribute to maintaining their high quality.

In accordance with this national policy, Arizona adopted designation criteria and an implementation policy for protection of high-quality waters (the Arizona Water Quality Control Council Unique Waters Policy) in April, 1981 (A.C.R.R. Title 9, Chapter 21, Section 102, Subsections C-E). In 1984, the National Park Service made initial application, currently being revised at the State's request, to nominate the waters of the Colorado River from Glen Canyon Dam to Lees Ferry as an Arizona "Unique Water of Exceptional Recreational and Ecological Significance."

Utah has a program for designating "anti-degradation segments" that could provide similar protection of water quality and associated resource values for waters of the recreation area within the State of Utah. However, the Utah program is presently oriented toward protecting drinking water supplies. Options for designating the lake or other waters of the recreation area in Utah under this program should therefore be explored with state officials.

III.A.2. Management alternatives and impacts.

Alternative A: No action

Under this alternative, no further action to designate outstanding national resource waters in the recreation area would be undertaken. In all probability, a National Park Service decision not to seek special anti-degradation status for the waters of Lake Powell would not have an adverse effect on the maintenance of water quality, because it is already NPS policy to maintain high water quality in accordance with state and federal regulations. For example, the existing Utah regulations state (Section 2.3.1):

"Water whose existing quality is better than the established standards for the designated uses will be maintained at high quality unless it is determined by the Committee, after appropriate intergovernmental coordination and public participation in concert with the Utah continuing planning process, that a change is justifiable as a result of necessary economic or social development. However, existing instream uses shall be maintained and protected. No water quality degradation is allowable which would interfere with or become injurious to existing instream uses."

However, adoption of Alternative A would forego both the opportunity to increase public recognition of the national significance of NRA waters, and the possibility of preventing exceptions to the existing standards in specified areas based on "National Resource Water" status.

Alternative B: Seek designation of Lake Powell and other recreation area waters as Outstanding National Resource Waters (preferred alternative)

Under this alternative, watersheds and the lake would be evaluated for outstanding recreational and/or ecological significance, in consultation with state officials, and nominated for formal designation under state programs. Applying for the most protective water quality classifications would serve to enhance the public's recognition of the national significance of the waters within Lake Powell and Glen Canyon National Recreation Area and provide a review of specific watershed areas to determine the need for additional protection. In no case would designation require higher quality water than currently exists; the effect of any designation would be to limit exceptions to the existing water quality standards. Proposed developments outside the recreation area may require more stringent review for their potential effect on NRA water resources. Designation would not adversely affect grazing or mineral leasing in the recreation area, since existing regulation and policy already prohibit water contamination from these activities.

The National Park Service would investigate the feasibility of seeking designations for tributary streams within the recreation area as conditions dictate. The portion of the free-flowing San Juan River that is within the recreation area would appear to be an ideal candidate for study because of its intensive use by river runners and its overall recreational significance. The Escalante River, a favorite area of hikers and a portion of which has been designated as an Outstanding Natural Area by the Bureau of Land Management, would appear to be another such candidate because of its unusual ecological and recreational significance.

As part of this alternative, and in conjunction with efforts by NPS to have Lake Powell designated as an anti-degradation segment by the State of Utah, the park would prepare the revisions requested by the State of Arizona in its application for status as "Unique Waters of Exceptional Recreational and Ecological Significance."

III.A.3. Recommended course of action. As a unit of the National Park Service dedicated to water-oriented recreational use and conservation, Glen Canyon is ideal for designation as an area of Outstanding National Resource Waters. The National Park Service would evaluate designation options available under the state water programs and prepare designation proposals in consultation with state officials. Such designations would require the approval of the NPS Rocky Mountain Regional Director and the state agencies responsible for the applicable water resource programs.

Additional research on water quality may be proposed to develop information in support of designations. Increased monitoring may be required in some areas as part of the designation process. This would most likely involve the measurement of additional parameters in samples already being collected for the park water quality monitoring program.

III.B. Water Rights

III.B.1. Statement of the problem. Glen Canyon National Recreation Area is presently involved in the adjudication of water rights in two drainage basins in Utah. It is likely to be involved in the near future in similar proceedings in Arizona. These adjudicative proceedings determine the legal status and priority of claimants' water rights. During the adjudication of a drainage basin that includes parts of Glen Canyon NRA, the United States on behalf of NPS must file its claim for federal water rights within the recreation area.

The McCarran Amendment (Act of July 10, 1952; 66 Stat. 560) gave the consent of the United States to be joined as a defendant in any suit involving the general adjudication of water rights in river systems. When joined in such a proceeding, the United States must assert and defend its right to the use of water on lands administered by agencies such as the National Park Service. This right generally takes the form of either a Federal Reserved Water Right or a State Appropriated Water Right.

The doctrines associated with these two kinds of water rights differ primarily in the way in which priority, the principal determinant of the right to first use, is assigned, and in the kinds of uses to which the water legitimately may be applied. Once adjudicated by the State, the water rights of the United States, reserved or appropriated, fit into the state priority system along with those of all other appropriators. In general, when it is brought into a general adjudication, the United States is given its only opportunity to assert its claim to water rights. Unless legally absent from the proceedings, it is generally understood that failure to assert a claim to water rights in such a proceeding may result in forfeiture of these rights.

The scope of this problem is limited to water-related concerns of management, but it extends geographically and functionally throughout the NRA. Furthermore, the problem potentially can affect future management prerogatives and the expenditure of funds (if acquisition of water rights should become necessary). The potential for resource impacts from the actions of appropriators outside of the NRA must also be considered in the water rights question.

Although the water rights issue is legal or administrative in nature, field data, special studies, and literature searches may be required to support claims of the United States. A failure to address this issue at this time could lead to additional problems in the future of unknown magnitude and complexity.

Until recently the United States has been largely unaffected by water rights proceedings. This situation is changing rapidly throughout the West as states proceed to adjudicate their water rights with the particular intent of quantifying and adjudicating federal reserved and appropriated water rights.

The immediate impact of the situation is found in the workload generated in preparing and supporting the claim of the United States in the ongoing adjudications in Utah. The United States has submitted to the State of Utah its claim to federal reserved water rights with a priority date of October 27, 1972. Included in its claim are quantifiable administrative uses from six water sources in the Colorado River and eight in the San Rafael River adjudications, respectively. The sources and amounts claimed in the Colorado River adjudication are the following:

1. Bullfrog Basin Well #1 (0.334 cubic feet per second [cfs])
2. Bullfrog Basin Well #2 (0.279 cfs)
3. Wahweap Well (0.33 cfs)
4. Lone Rock Well (0.30 cfs)
5. Dangling Rope Well (0.12 cfs)
6. Halls Crossing Test Well (0.13 cfs)

In addition, a general claim has been filed for 13.38 cfs for the support of ongoing authorized livestock grazing activities with an 1864 date of priority.

The sources and amounts claimed in the San Rafael River adjudication are these:

1. Horseshoe Canyon (seep)
2. Horseshoe Canyon (0.75 gallons per minute [gpm])

3. Anderson Bottom (seep)

4. Horse Canyon (0.10 gpm)

5. South Fork (seep)

6. Pictograph (2.0 gpm)

7. Jasper Canyon (seep)

8. Water Canyon (1.8 gpm)

Quantification of the instream and other flows claimed necessary for recreation area purposes may be required in the Colorado River and San Rafael River adjudications in Utah. In addition, the portion of Glen Canyon NRA located in Arizona is yet to be adjudicated. With Arizona currently engaged in the adjudication of water rights throughout the state, it is reasonable to assume that this portion of Glen Canyon NRA will also be adjudicated in the near future. In addition to federal reserved water rights for instream flows and other resource protection purposes, the United States will need to claim federal reserved rights for consumptive administrative uses. The claims of the National Park Service to water rights, especially federal reserved rights, in Glen Canyon NRA have been and will need to be made in light of the purposes of the NRA and its cooperative agreement with the Bureau of Reclamation.

Additional actions related to water rights will include responses to potentially damaging external water development proposals. Such response will entail the determination of the type, magnitude, and location of potential injury and may involve the further quantification of federal reserved water rights.

The immediacy of this problem, in the sense of timely response, was addressed above. The United States must assert and defend its claim to water rights or face the possibility of losing them.

III.B.2. Management alternatives and impacts.

Alternative A: No action

If the National Park Service does not fully participate in the adjudication of water rights located in river basins that encompass parts of Glen Canyon NRA, the legal right to make use of water for certain purposes could be forfeited. Furthermore, use of water by other appropriators may affect the Service's ability to accomplish its mission if the acquisition of non-federal water rights is not feasible.

Alternative B: <u>Respond to actions of the States of Arizona and Utah for the adjudication of water rights, and of water rights holders or potential holders who propose or take actions potentially damaging to the purposes underlying the creation of Glen Canyon National Recreation Area</u> (preferred alternative) (Note: The United States is bound by the McCarran Amendment, cited previously, to participate in certain water-rights-related state proceedings.)

Under this alternative, when joined in a general adjudication of water rights, the United States will assert its claim to water rights under the Federal Reserved Water Rights Doctrine and state appropriation procedures to the extent of its need in support of the purposes of the unit. Claims to water rights by the United States (Glen Canyon National Recreation Area) shall be prepared with full consideration being given to Congressional intent in the establishment of the NRA and construction of the Glen Canyon Dam and reservoir. In those areas of no conflict or mutual advantage, the National Park Service shall move forward in asserting its claim to all applicable water rights.

No other alternative is offered for analysis. The nature of this problem devolves to a straightforward commitment to participation or non-participation in the states' determination and administration of water rights.

II.B.3. <u>Recommended course of action</u>. In accomplishing the recommended alternative the necessary course of management action will be the preparation of materials for presentation to the State which will assert and support the claims of the United States. These materials may include existing water rights decrees, statements of claims, copies of supporting legislation, maps and drawings, photographs, listings of claimed quantities and schedules of flow, supporting research findings, and other ancillary material.

While it is not yet known if additional water rights information will be necessary in Glen Canyon NRA, some data collection might be required to support the claim of the United States for reserved water rights. This would be necessary if either of the following questions should arise as legal issues: (1) a conflict is alleged to exist between claimed water uses in support of recreation area purposes and state-recognized beneficial uses, or (2) the role of water in the accomplishment of primary recreation area purposes is alleged by the State or other parties to be different in nature or quantity from that claimed by the United States.

III.C. Floodplain Identification and Management

III.C.1. Statement of the problem. Flash floods are a major concern in Glen Canyon National Recreation Area, particularly in summer and fall. Brief, intense thunderstorms produce high amounts of rain in a short period. Thin soil, sparse vegetation, and large areas of exposed bedrock do little to retain this rainfall, resulting in high runoff rates, flash floods in narrow drainages and canyons, and waterfalls off of canyon walls.

The principal areas of concern are popular backcountry trails, mouths of canyons, locations for potential developed facilities, or any confined terrain where visitors congregate. For example, a trailhead at the Paria River is a departure point for the adjacent wilderness area, which has trails in high-hazard areas. Houseboaters on the lake frequently hike into the canyons from shoreline camps and may become exposed to flood hazards. Other backcountry users may encounter floods on roads and trails or at campsites within drainages.

Flood hazards are of particular concern in Antelope Canyon, the Warm Creek/Smoky Mountain area, in tributary canyons to the Escalante River, and in Dark Canyon, all locations where visitor use may be relatively high. The NRA has one developed facility, a maintenance shop, in the 100-year floodplain of the Paria River. This facility has been recommended for removal to a location outside of the floodplain.

Legal and policy constraints apply to floodplain and wetland management in NPS areas. Specifically, compliance with Executive Order (EO) 11988 (Floodplain Management) and EO 11990 (Protection of Wetlands) is required, along with the Water Resource Council's guidelines on floodplain and wetlands management. To implement these policies the National Park Service has issued servicewide guidelines for NPS units. These direct the Service to avoid placing facilities for visitors in high-flood-hazard zones and to provide warning measures in undeveloped areas frequented by park visitors that are within high-hazard zones.

One difficulty in implementing the guidelines adequately is that little information exists about flood frequency in the Colorado Plateau region, principally because of short gauging records. Only the Paria River is gauged within the NRA; the other major rivers are gauged some distance upstream of the NRA boundary. There is no gauging record for lesser drainages.

III.C.2. Management alternatives.

Alternative A: No action

Under this alternative, existing management would be continued using the NPS Floodplain Guidelines. For developed areas, floodplain identification has been accomplished on a case-by-case basis during planning. However, a thorough floodplain assessment may take as long as two years to complete and is often needed to select between competing sites, resulting in inadequate information for many planning projects. The information needed to quantify flood hazards in the ungauged backcountry drainages is lacking.

Alternative B: Flood hazard assessment and mitigation (preferred alternative)

Areas of proposed development and heavy visitor use would be assessed for floodplain hazards. Following the assessment, mitigation alternatives would be examined for the visitor use areas, and development sites would be selected only outside of high-hazard zones as required by NPS guidelines. Mitigation options might include identifying flood hazard zones on maps provided to visitors; posting warning signs at trail- and roadheads; restricting use on a seasonal basis; and increasing ranger patrols during periods of heavy flooding. Monitoring of high-hazard zones could be incorporated into the visitor protection program, and cooperative programs may be initiated with surrounding land managers to provide early warning capability. Where hazards are extreme and visitor exposure high, extensive actions such as seasonal area closures, specific flood-proofing of structures such as dikes, raising or relocation of facilities, or radio-controlled remote warning signs or systems could be considered.

Alternative C: Comprehensive floodplain assessment

Under this alternative all drainages in the NRA would be scheduled for floodplain evaluation and necessary floodplain mapping as funding became available. Maximum use of cooperative investigations with other agencies such as the U.S. Geological Survey would be made.

These site-specific evaluations would provide a floodplain delineation of several magnitudes as required by NPS guidelines for consideration under various visitor usage patterns. These evaluations will allow any modification of developed sites as required. Also, the proper development of proposed sites would be based upon these evaluations, which will have been prepared and ready for use. This is an important aspect of the projects in that any one effort may require up to a year for completion.

III.C.3. Recommended course of action. Floodplain management through Alternative B would identify the areas of principal concern. Alternative C would cover the entire recreation area, but the low additional margin of information gained would probably not justify the expense. Alternative A is not acceptable because of the potential for poor planning coordination, time delays, and incomplete assessment of potential hazards.

III.D. Shoreline Water Quality

III.D.1. Statement of the problem. Lake Powell is the most important recreational resource of Glen Canyon National Recreation Area. With 255 square miles of surface and more than 1,800 miles of shoreline, it is the second largest artifical lake in North America, and its clear, high-quality waters offer outstanding recreational opportunities. The management objectives of the recreation area include encouragement of "water-oriented recreation . . . (and) maintenance of high water quality. . . ." Excessive recreational use, however, can threaten water quality and result in high turbidity and unhealthful levels of pathogenic bacteria. Diseases caused by contaminated recreational waters usually fall into the categories of gastroenteritis and ear, nose, and throat ailments.

Since techniques are not available to detect the full range of possible disease-causing organisms in water, the Environmental Protection Agency has established health standards for recreational waters based on the occurrence of easily-monitored fecal coliform bacteria. Presence of these organisms indicates contamination of the water by mammalian feces (usually human) and the possible presence of pathogens. Arizona and Utah state standards for fecal coliforms in recreational waters are as follows:

- Full-body contact: 200 colonies/100 mL water (log mean for 30 days)
- Partial-body contact: 1,000 colonies/100 mL (log mean for 30 days)

At Lake Powell recreational waters should be kept well within the standard for full body contact (swimming).

In 1975 a problem-assessment study of bacterial contamination was published for Lake Powell (Kidd 1975). Following lakewide water sampling over several seasons, Kidd found the waters "generally safe for human body contact," although contamination sometimes exceeded state standards. Continued water quality monitoring was recommended. A similar study in 1976 (Cudney 1977) found water along the shoreline at heavily used sites to have very low bacterial concentrations, and the sanitary quality of the lake was characterized as "excellent," with a few sites in the "good" range. Problem-assessment monitoring was again carried out lakewide in 1985 by Fitzgerald et al. (1985). In this study it was found that lake waters generally were of excellent quality, but that individual samples sometimes exceeded the standards at heavily used shoreline sites. At Lone Rock Beach and one or two other sites, the geometric mean of samples was high enough to cause concern about the long-term water quality trend, although the figures were well within the legal standards (127 coliforms per 100 mL at Lone Rock, the site with the highest value). Based on these studies it is believed that water quality standards for recreational activities are presently maintained in Lake Powell, but growth of recreational use has led to increased bacterial levels at high-use beaches.

Another aspect of this problem requiring clarification is the source(s) of the fecal pollution and its longevity in beach waters and sediments. Possible sources include illegal discharges from vehicles and watercraft on a beach; people's bodies; defecation by humans on shoreline areas subsequently inundated by rising lake waters; pets; or runoff from upslope areas around camps where further human defecation occurs. At some sites the source of fecal pollution may be cattle or wildlife. Fitzgerald et al. (1985) found that 48 percent of the streptococcal samples on which bacterial speciation was performed were dominated by Streptococcus species originating from livestock or wildlife. A better understanding of pollutant origins clearly is needed to develop effective mitigative measures.

III.D.2. Management alternatives.

Alternative A: No action

This alternative would continue the present system of monitoring water quality through special-funding projects every five to ten years. Its disadvantage lies in the possibility that a monitoring project may not be funded at the time it is needed. Also, because investigators frequently use different techniques, results between studies would continue to be difficult to compare. The risk of not detecting unhealthful water quality conditions is relatively great under this alternative and could result in more cases of gastroenteritis among park visitors.

Alternative B: Establish a regular monitoring program (preferred alternative)

This alternative would enable the NRA to closely monitor bacterial levels in beach waters and identify potential health problems before they occur. Compliance with legal standards would be enhanced. A monitoring plan would be designed specifically for the NRA, outlining sites, sampling methods and schedules, and analytical methods. The monitoring could be conducted by NPS staff, state officials, or by contract to a professional laboratory, but would be funded to occur on a regular basis. The monitoring not only would identify problem areas, but also would help identify pollution sources by allowing a direct comparison of the dominant uses of contaminated sites with clean sites.

Alternative C: <u>Fund research on the origin and longevity of bacterial contamination</u>

This alternative would result in detailed field and laboratory studies to determine the sources of pollution and the progress of contamination over the course of a season. An intensive sampling program would be required to achieve the objectives of such a study.

Alternative D: <u>Phase in management actions to control shoreline contamination</u> (preferred alternative)

A wide range of management actions exists that would benefit shoreline water quality. Some examples include the following, ordered from least to most intrusive:

- Place signs on problem beaches warning of potential health hazards.
- Increase enforcement of existing regulations prohibiting the discharge of sewage. This measure would pertain to houseboats and cruisers with sewage holding tanks. Boats could be inspected, either on a routine or an incident basis, to determine whether they are properly fitted to discharge only into designated pumpouts. This action would affect private craft the most because the rental fleet is standardized with approved, closed-sewage systems.
- Institute educational programs emphasizing the need for sanitation and providing information on proper sanitation practices for Lake Powell recreation.
- Designate swimming-only zones at certain of the heavily used beaches experiencing water quality problems. The water quality standards are use-specific; this alternative would provide areas where only swimming would be permitted, making it easier to meet water quality standards for swimming. The zones could be established using buoys and signs (or blockages) to prevent boats and motor vehicles from entering, thereby reducing the possible sources of contamination. This action would be taken at locations where boat and/or on-shore vehicle use of the beach is high. Their restriction would substantially reduce the population of beach users.
- Promulgate a regulation requiring all watercraft to have either closed-system sewage holding tanks or portable toilets aboard while on Lake Powell. The inspection for these items would become a part of regular procedures that include inspecting for personal flotation devices and fire extinguishers.

III.E.2. Management alternatives.

Alternative A: No action

Presently, no monitoring or study programs are aimed specifically at gray water. This alternative would continue that condition.

Alternative B: Begin problem-assessment investigations (preferred alternative)

Under this alternative, marina anchorages and sites of concentrated shoreline use by houseboats would be monitored for the presence of fecal coliform bacteria to determine whether sewage is associated with boat discharges. (Monitoring would be carried out as part of the shoreline water quality monitoring described in Section III.H.) Anchorages would also be monitored for concentration of phosporus, nitrogen, and chlorophyll a to check the nutrient status of waters where gray-water discharges are occurring. Concurrently, communications with state water pollution control agencies would be maintained to coordinate regulatory issues. The results of the monitoring programs would provide field data to evaluate the need for any additional regulatory efforts.

A corollary activity would be to incorporate inspection of boat water-handling facilities into regular boat safety and health inspections conducted by NPS rangers. Inspection results would be recorded concerning gray-water handling so that discharge estimates for gray water could be improved. Regulations prohibiting sewage discharges would continue to be enforced during such inspections.

Alternative C: Prohibit gray-water discharges

Gray-water discharge would be prohibited under this alternative by special regulations of the National Park Service. The regulations would necessarily require new construction and licensing standards for houseboats and cabin cruisers, requiring containment of all wastewaters and discharge only into approved treatment facilities.

This alternative would have substantial economic effects, since additional holding tanks would be required on boats of the rental fleet and on private craft with facilities for water use. Design changes and possibly larger boats could become necessary. Additional sewage treatment capacity would be needed at the marinas to handle the added wastewater loads. Some vessels might be prohibited from launching on Lake Powell if they could not be structurally modified to contain all wastewater. Implementation of this alternative could affect regulation of gray-water discharge in federal recreation areas nationwide.

An improvement of an unknown (but probably low) magnitude would occur in water quality resulting from the reduction in gray-water discharges. This alternative would not affect the regulation of sewage discharges, which are already illegal, but could make enforcement easier. Possible actions to increase the monitoring and enforcement of prohibitions on sewage discharges are discussed in the section on shoreline water quality (III.D).

III.E.3. Recommended course of action. Although Alternative B is recommended, Alternative C may become necessary based on monitoring results (and state regulatory decisions). However, the potential economic effects are significant. Any prohibition of gray-water discharge should be based on field data indicating both a need for regulation (evidence that a negative effect exists) and the possibility of substantive water quality improvement if gray-water discharges are stopped. Alternative B would provide sufficient data to determine whether a gray-water problem exists.

III.F. Water Quality of Rivers for Recreational Use

III.F.1. Statement of the problem. The five rivers in Glen Canyon NRA used for recreational purposes are the Colorado, San Juan, Escalante, Dirty Devil, and Paria Rivers. River running is the predominant activity on the Colorado and San Juan, but all the rivers are used extensively for wilderness recreation and the associated activities of wading, swimming, bathing, cooking, drinking, and fishing. The Colorado River between Glen Canyon Dam and Lees Ferry is heavily used by fishermen and commercial one-day raft tours. This is the most heavily used river segment in the NRA, receiving up to 120,000 river users a year (these figures include fishermen, rafters destined for the Grand Canyon, and one-day tourists in Glen Canyon). The San Juan, the next most-visited river in the NRA, is used by 2,000 river runners annually. The Paria River is least visited; it is used primarily (and increasingly) as a hiking route for people entering the Paria Wilderness Area.

River recreation presents a two-fold water quality problem: (1) when use levels are high, the potential exists for contamination of the water by recreationists; and (2) with contamination comes the related problem of determining when the water is safe for recreation with minimum health risks.

Tunnicliff and Brickler (1981) reported to the National Park Service that fecal contamination of river waters above Lees Ferry was reaching unacceptable levels, mainly as a result of contamination by humans fishing and camping on the shoreline. Since then, vault toilets have been installed along the river corridor to control the problem, but follow-up monitoring has not been carried out to assess their effectiveness. Past monitoring in the Grand Canyon and on other rivers has thoroughly documented contamination of rivers during high levels of recreational use, when the deposition of human waste is uncontrolled.

Commercial rafting parties on the Colorado and San Juan Rivers are required to contain and carry out all human waste to minimize this impact.

Even when contamination by recreationists is controlled, river waters are not safe for drinking without pretreatment. When watercourses are laden with sediments they often carry enteric bacteria originating from upstream settlements, livestock and wildlife in the watersheds, or other sources. Many organisms found in natural waters can cause illness. The list of waterborne diseases is lengthy, but the most common by far is gastroenteritis, which can be caused by several different organisms when untreated water is ingested. The parasite Giardia, which is transmitted by humans and wildlife (and possibly cattle), is an increasingly common source of enteric disease in natural waters of the West. The incidence of this organism in the NRA is not known, however.

River recreation usually results in partial or total immersion of the user at some time. Although natural waters are usually safe for non-consumptive uses, the presence of a source of pollution (such as human or animal waste) may render the water unsafe for bodily immersion. In addition, it recently has been documented that normal storm events and spring runoff can cause unusually high bacterial levels in river waters, even in wilderness watersheds (Tunnicliff and Brickler 1981). This is because bacteria accumulated in sediments and on organic debris in the watershed is suddenly flushed into the rivers. The organisms are protected by sediments in suspension, which lengthen their viability; thus, they may be found in high numbers whenever sediment levels are high. Common illnesses resulting from immersion in unsanitary water include ear infections, nose and throat inflammations, and skin rashes. If contaminated water is accidentally ingested, gastroenteritis may result. Water quality standards have been established by the states (usually following EPA criteria) for partial-body and whole-body contact to permit monitoring for the healthfulness of recreational waters.

A monitoring study of the San Juan River during a period of normal flow in July of 1985 revealed virtually no contamination by fecal coliforms. The water was almost of drinking water quality in many locations (Doyle et al. 1985), indicating that river recreationists are not contaminating the water at present. However, the authors note that the San Juan carries high sediment loads during spring runoff and should be monitored for bacterial content then. Other rivers in the NRA have not been monitored in recent years.

III.F.2. Management alternatives.

Alternative A: No action

No further baseline information would be gathered, and water quality monitoring would not be conducted. A public health hazard could occur without warning.

Alternative B: Monitor river water quality (preferred alternative)

River waters in the NRA would be monitored periodically to document their continued conformity with health standards or to detect episodes of contamination. Monitoring would be conducted during high runoff and normal flow periods in all of the rivers, with each river segment being monitored once every few years. A problem-assessment survey of backcountry stream waters would be included for the detection of Giardia on at least the Escalante River drainage. Park rangers would continue to monitor compliance with regulations applying to commercial raft trips that require the carry-out of human waste.

Alternative C: Increase educational programs on the hazards of drinking untreated water (preferred alternative)

Current efforts to warn visitors of the health hazards associated with drinking untreated water would be supplemented by informational material developed specifically for the NRA and distributed through visitor contact stations. Included would be information on the most effective disinfection techniques and best-camping practices to avoid disease. (When health problems do occur on river trips, epidemics are common.) If Giardia is found to be prevalent in particular areas, special signs may be required at trailheads.

III.F.3. Recommended course of action. The expenditures for Alternatives B and C would be low enough to be easily implemented, and public safety and health would be better protected. Under these alternatives, rivers and streams would be monitored for bacterial contamination and the presence of Giardia. Also, educational programs on water quality, disinfection techniques, and backcountry hygiene would be expanded through the distribution of pamphlets, campfire talks, or other means. Signs may be erected at trailheads where a special warning is needed.

III.G. Springs, Seeps, and Waterpockets

III.G.1. Statement of the problem. The natural waters of Glen Canyon NRA include springs, seeps, and waterpockets located in canyons and uplands. These waters are recognized for their significance as habitat and as unique ecosystems of the desert, but they have received little study and are poorly understood.

Seeps are common in alcoves along the walls of canyons and at the heads of canyons. The seeps, in fact, help form the alcoves. These water sources support a specialized vegetation known as "hanging gardens." Seeps usually appear where a canyon has been cut through an aquifer or has intercepted a water-bearing joint connected with an aquifer. Most commonly, the aquifer is the Navajo Sandstone.

Springs in the recreation area are more often found in intermittent drainages where subsurface flow finds an outlet. Occasionally, they are found in upland alcoves or beneath perched aquifers. Springs are not common in the NRA; they sometimes discharge only seasonally or diurnally. Springs usually support a water-dependent plant community and associated fauna. A special case of spring flow occurs between Glen Canyon Dam and Lees Ferry, where several spontaneous, copious flows from the lower canyon walls have begun in the past few years. These springs are believed to originate from Lake Powell bank storage in the Navajo Sandstone.

(Waterpockets, or natural bedrock depressions,) are the most numerous source of surface water in the uplands of Glen Canyon NRA. They occur where rain fills depressions weathered into exposed sandstone surfaces. Most waterpockets are ephemeral, although some are large enough to be virtually permanent. Waterpockets often support a diverse assemblage of invertebrate fauna such as water fleas, amphipods, fairy shrimp, and insects, and in some cases amphibians such as the canyon tree frog. These animals are important food sources for native terrestrial fauna and a source of interest for recreationists.

Threats to these three water sources are varied. Seeps can be depleted by mineral development on adjacent land or by use of the aquifer recharge water for development. Springs are subject to these same threats, and additionally they can be fouled by cattle. Waterpockets are not threatened by development affecting the subsurface, but because they are used by cattle they are vulnerable to surface pollution. Waterpockets are in serious need of formal study to document their biology and their role in the desert ecosystem.

The chemical quality of water from springs and seeps in the recreation area is usually quite high. Williamson (1985) performed chemical profiles on 13 surface seeps and springs in the NRA and found anions, cations, and trace elements to be well within the "normal" range for waters in this region.

III.G.2. Management alternatives.

Alternative A: No action

Under this alternative no additional information would be obtained on seeps, springs, or waterpockets. Future proposals potentially affecting water resources, such as mineral leasing, could be inadequately evaluated due to poor baseline information. Sensitive ecosystems or unusual biota may remain unidentified.

Alternative B: Collect baseline information on springs, seeps, and waterpockets (preferred alternative)

The baseline chemistry and hydrology of springs and seeps would be further documented through research and monitoring by NPS or other organizations and scientists. Study objectives would include chemical profiles to document aquifer origins and the current condition of spring water, and flow measurement to generate a basis for comparison against possible future disturbances.

Spring flow along the Colorado River below Glen Canyon Dam would be measured periodically to detect any potentially significant changes in flow rate. This objective could be achieved cooperatively with the Bureau of Reclamation.

The biology of springs, seeps, and waterpockets would be systematically studied to identify significant communities and the water resource features necessary to support them. Such studies would also improve impact evaluation efforts and the interpretation of park resources for the visitor.

III.G.3. Recommended course of action. Alternative B would result in additional information about significant park resources subject to diminution by developments involving minerals or range cattle. Without the background data base, improper assessment of adverse impacts to these backcountry water resources could occur.

III.H. Water Resources of Riparian Ecosystems

III.H.1. Statement of the problem. Riparian ecosystems are water-dependent biotic communities that develop along the banks of rivers, streams, and lakes. They are of major significance as wildlife habitat, recreational sites, and sources of productivity.

Riparian ecosystems in Glen Canyon National Recreation Area consist of 1) riverbank biotic communities in the numerous canyon tributaries to the lake and along the major rivers entering the area, 2) lakeshore plant communities, and 3) vegetation around springs and seeps. They support a diversity of fish, wildlife, and plants and provide cool, scenic recreational sites for the recreation area visitor.

The riparian communities along the Colorado River below Glen Canyon Dam are the best known, having been studied extensively for nearly 20 years. These studies document the progress of ecosystem changes resulting from curtailed flooding. Changes include an expansion of tamarisk (Tamarix ramosissima, an exotic species) and an accompanying increase in bird and insect abundance (Carothers and Aitchison 1976). An intensive interagency study of this river reach is in progress to evaluate the potential effects of alternate water release schedules from the dam.

The Escalante River supports the most extensive native riparian community in the recreation area. This 50-mile river reach is not controlled by a dam, which allows periodic floods to control the potential invasion of tamarisk. The riparian vegetation along this river is therefore in a "near-natural" state: willow and cottonwood dominate, and tamarisk build-up occurs mainly along slackwater reaches below Coyote Gulch where the lake enters Escalante Canyon. The San Juan and Dirty Devil Rivers also support significant riparian communities in the recreation area. The major influences on flow of these three rivers originate outside the recreation area and include consumptive withdrawals for agricultural and municipal purposes. Potential water impoundment and mineral development sites surround the recreation area. Information pertaining to the effects of such outside influences on riparian ecosystems in the NRA is deficient.

Canyon tributaries of the lake contain the greatest number of riparian zones in the park, and they are probably the most manageable from the standpoint of NPS programs. Many of these canyons are wholly within the park boundary; others have portions of their watershed outside the park. Surface flow in the canyons is intermittent, although subsurface flow may still occur during dry periods. Larger watercourses such as Halls Creek support perennial flow most years and can support small populations of native fish in the perch, minnow, and sucker families. Water must be available to plants during most of the year for riparian vegetation to develop, making water a basic resource issue in managing these specialized communities.

Flow originates from seasonal surface runoff and from ground-water discharge into the canyons through springs and seeps. The water that sustains riparian biotic communities can therefore be affected by activities such as mineral development, road construction, or grazing. Mineral development may deplete aquifers or cause contamination. Road construction contributes to channel siltation and is a source of pollution from accidental fuel spills.

The impact of domestic and feral livestock is presently the most serious adverse influence on canyon and spring riparian zones. Animals confined in the narrow canyons are drawn to the water and nearby forage, resulting in extensive trailing on slopes and fouling of the water. The effects of trailing are especially long-lasting because soil is destabilized and erosion cycles are often started that are very difficult to control. The effect on water resources is exerted through channel silting, increased runoff rates, and lowered water retention times. These effects reduce flow over the long term and are detrimental to riparian ecosystems. If placed in a riparian area to enhance flow, water developments for livestock could affect the water source by altering the flow regime. Additional information on sedimentation rates as related to disturbance by livestock would be necessary to document and mitigate these effects.

The invasion of tamarisk along rivers is well advanced in the NRA. The high transpiration rate of this plant has been shown to reduce surface flows in streams where it dominates the bank vegetation. In addition, litter from tamarisk is known to hinder competition from other plant species by causing an accumulation of salts at the soil surface. These impacts could be significant if the plant invades the smaller canyon riparian zones. The effect of tamarisk is also a subject needing further study at Glen Canyon.

Tamarisk along the lakeshore is still becoming established; it has not yet formed stable ecosystems. These communities will probably attain some importance as insect and wildlife (particularly bird) habitat in the future, and already offer habitat for fish during high water. Tamarisk transpires great quantities of water into the atmosphere; significant water losses from the lake could occur as the vegetation matures, and these would be reflected in either lower releases from the dam or lower storage. At some lakes in the Southwest tamarisk has been actively controlled by herbicides or anti-transpirants as a means of "water salvage" on an experimental basis. This has not yet been suggested at Glen Canyon, but it could become an issue in future years.

III.H.2. Management alternatives.

Alternative A: No action

At present, no management programs are aimed specifically at riparian communities in the NRA. Impacts to these sensitive ecosystems are considered in environmental compliance programs under the wetlands protection requirement and other guidelines, and riparian zone protection is incorporated into park management programs for minerals and grazing. However, the key resource to protect in preserving riparian communities is water. Information is needed on the hydrodynamics of riparian zones in the park to diagnose threats. Under Alternative A this lack of information would continue.

Alternative B: Articulate a management policy to protect riparian resources (preferred alternative)

Under this alternative park management would adopt a policy giving high priority to inventorying, quantifying, and protecting riparian water sources. This policy would pertain to natural communities and natural waters of the NRA and not to the relationship between the reservoir and tamarisk, an exotic plant. Such action would provide guidance for protecting riparian waters from depletion by competing uses such as grazing and mineral leasing. The policy would further require the quantification and maintenance of minimum instream flows before such competing uses are approved, and would require the prevention of water quality degradation in riparian areas. This policy would be consistent with the conservation of existing water rights for NRA purposes and with existing regulations controlling water quality degradation.

Alternative C: Investigate and monitor water sources for rivers and streams (preferred alternative)

A program of research and monitoring would be established to study the hydrodynamics of recharge and flow in intermittent streams. This program would be consistent with, and very likely part of, baseline research on springs and seeps. The objective of this program would be to establish specific water sources and minimum flows required to maintain the riparian ecosystems. In a similar vein, seasonal discharge patterns in the lower Escalante River would be monitored to supplement data from existing gauging stations on the Paria, Dirty Devil, San Juan, and upper Escalante Rivers. An objective of this monitoring would be to establish instream flow rates consistent with maintaining natural riparian vegetation. The effect of tamarisk along streams would be investigated to assess water depletion rates caused by the plant and subsequently to develop a monitoring plan.

III.H.3. Recommended course of action. Under Alternatives B and C, a policy for protecting riparian waters would be established requiring the maintenance of minimum flows for riparian ecosystems when evaluating competing uses of watersheds. Included in the policy would be the specific goal of maintaining water quality in riparian zones and curtailing its degradation by livestock or other users of riparian waters. Stream flows and the discharge of springs and seeps would be monitored periodically. Recharge zones would be defined, and the effect of tamarisk on water depletion at springs and seeps investigated.

III.I. Water Resources as Habitat for Fish

III.I.1. Statement of the problem.

III.I.1.a. Lake Powell--Glen Canyon Dam changed the aquatic ecosystem above and below the dam so dramatically that many native fish species could not adapt. A few of the native fish species that once inhabited the Colorado River are believed to be still present in the lake, but they are probably associated with the influent tributaries. Most notable among these species are the Colorado River squawfish and the razorback sucker, which appear to be present in the upper lake near rivers. These are long-lived fish and it is not known whether they are reproducing within the recreation area. Lake Powell is not suitable spawning habitat for these fish, but it is possible that the lower reaches of influent rivers may still contain breeding habitat.

Lake Powell now supports an outstanding sport fishery based on a variety of fish species adapted to the lake environment. The Lake Powell fishery is unique among Utah's waters. It is not only the state's largest and most important sport fishery, it is one of the few warm-water fisheries found in the state. Game fish in the lake include largemouth and smallmouth bass, walleye, northern pike, catfish, crappie, bluegill, and--most important from the standpoint of poundage harvested--striped bass. All of these species are non-native fish. Walleye, northern pike, and catfish were present in the river drainage before the reservoir filled and have thrived in their new environment. The other gamefish are introduced species. Striped bass were introduced into Lake Powell during 1974 following the establishment of shad as the foodbase, and have since developed into an excellent fishery.

Striped bass normally require large river systems in which to spawn. The river currents suspend the eggs until hatching, keeping them in well-oxygenated water. In reservoirs the eggs would normally sink to anoxic substrates on the bottom and fail. Riverine spawning does occur at Lake Powell in the Colorado River, but an unusual limnological characteristic of the lake also allows inlake spawning of striped bass to be successful in the lower reservoir. Because of the low productivity of phytoplankton in the lake, high oxygen values are usually found near the bottom of Lake Powell. In addition, dissolved oxygen concentrations in the bottom waters are replenished by the winter underflow current, discussed earlier in this plan. This phenomenon allows striped bass eggs to survive in what would normally be a lethal reservoir environment. The large reproductive potential thus afforded striped bass has allowed their numbers to increase dramatically, and thereby has placed a great strain on Lake Powell's limited forage fish population (threadfin shad).

The populations of shad and striped bass appear to increase and decline in response to poorly understood productivity cycles; consequently, the possibility of introducing a second prey-base fish to supplement the shad and help keep striped bass populations high has been discussed. However, data is lacking on the lake's primary productivity, plankton populations, and associated water quality requirements. Such information is critical to gamefish management and is also needed as a baseline to evaluate future nutrient loading and aging of the reservoir.

Fluctuating reservoir levels affect fish habitat through the shoreline vegetation. Vegetation growing on shore during low-water periods provides excellent fish habitat when later inundated by high water. Tamarisk, an exotic species, is presently the dominant shoreline shrub (or tree) at Lake Powell and is on the increase.

Sport fisheries on Lake Powell are managed by the Utah Division of Wildlife Resources under a cooperative agreement with the National Park Service and the Arizona Department of Game and Fish.

III.1.1.b. Sensitive areas with high fishery values--The majority of Lake Powell is nutrient-poor and would be classified as oligotrophic. Some areas, however, are quite productive and approach a eutrophic state. Such areas include mixing zones where the major rivers flow into Lake Powell carrying nutrients and sediments. These areas have an extremely high fishery value and should be considered highly vulnerable to activities potentially affecting water quality or other habitat value.

The most important areas of Lake Powell for fisheries management are the following:

1. Inflow areas and mixing zones where the major waterways flow into the lake (the Colorado River inflow at Hite, the San Juan River inflow at Paiute Farms, and the Escalante River Arm).

2. Numerous canyons throughout the lake that contain free-flowing and intermittent streams.

3. Special Utah Division of Wildlife Resources Study Areas:

   a. sites of initial smallmouth bass introductions (Crosby Canyon, the Rincon, Neskahi Canyon, Stanton Creek, and upper Good Hope Bay);

   b. sites of annual trend surveys for gamefish populations (Warm Creek, Padre Bay, Paiute Canyon, Neskahi Canyon, the Rincon, Stanton Creek, and upper Good Hope Bay);

   c. sites of annual trend surveys for ichthyoplankton (Warm Creek, Wahweap Creek, Navajo Canyon, Bullfrog Creek, Halls Creek, and Paiute Farms).

III.I.1.c. Rivers and streams--The Colorado River below Glen Canyon Dam supports a trout population classified by Arizona as a "blue ribbon" trout fishery. Trout thrive in this river reach because of the clear, cold waters released from Lake Powell. The trout (rainbow, cutthroat, and brook) are introduced species regularly stocked by the Arizona Department of Game and Fish.

Little is known about the fish species, native or exotic, that exist in streams such as the Escalante River, Ticaboo Creek, Wilson Creek, and Desha Creek, to name a few among the numerous tributaries to Lake Powell that can support aquatic life. Native species are known to reside in these streams, and exotic species such as the red shiner are competing with the native fish. A survey is needed of the biological and water quality features of secondary inflowing waters of Lake Powell. This would provide baseline information on a little-understood park resource.

While the fish resources of Glen Canyon National Recreation Area are obviously diverse, they have in common a dependence on maintaining high-quality aquatic habitat--which is largely a water resource management issue. An objective of the National Park Service is to maintain the high habitat value of water in the recreation area.

III.1.2. Management alternatives.

Alternative A: No action

Under this alternative Glen Canyon NRA would continue to have less information than needed on the food base and essential habitat features for game fish in Lake Powell, and for the native aquatic life in tributaries. As a result, water resource requirements of the many different species could be inadequately protected.

Alternative B: Incorporate aquatic habitat analysis into resource management programs (preferred alternative)

Under this alternative NPS would develop a better information base on aquatic habitat in the recreation area through cooperative programs with the Utah Division of Wildlife Resources, Arizona Department of Game and Fish, and the U.S. Fish and Wildlife Service. New research on phytoplankton productivity in the lake and native aquatic habitats in tributaries would be assimilated into Glen Canyon's resource management objectives. This program would necessarily include a survey of aquatic species in tributaries and evaluation of their water habitat requirements. In addition, nutrient cycling in Lake Powell would be investigated to determine its long-term effect on lake waters as habitat. Productive fisheries habitat and sensitive areas would be identified, mapped, and considered in park planning and environmental analyses. Finally, the process of tamarisk invasion of the shoreline and its utilization as fish habitat would be monitored to better understand the relationship between reservoir fluctuations and fish production.

Alternative C: Monitor water resources for habitat value

Monitoring regimes would be conducted in lake and stream waters, in cooperation with other agencies, to ensure that water quality and quantities needed for aquatic life are maintained.

III.1.3. Recommended course of action. Under Alternative A, NPS could not ensure that aquatic resources would be protected and remain productive. Alternative C will eventually become necessary; however, the basic information proposed for acquisition under Alternative B is needed first, and this will take most of the current ten-year planning period (ending in 1997) to complete.

Under Alternative B, lake productivity would be studied, including nutrient relationships; the aquatic flora and fauna of tributary streams would be investigated; and baseline water quality and flows of these habitats would be determined. The use of shoreline vegetation as fish habitat would be investigated, and this use correlated with water levels. Finally, cooperative programs to share information and coordinate aquatic habitat management would be established (or expanded) with other agencies.

III.J. Heavy Metals in Fish Flesh

III.J.1. Statement of the problem. Because of its position on the Colorado River, Lake Powell is trapping sediments from upstream watersheds. Certain heavy metal ions attached to these sediments are also moving into the lake (Graf 1985). With the exception of a small amount remaining in suspension, the metals are being deposited with the sediments in the upper reaches of the lake near the inflow of the Colorado and San Juan Rivers. Among the trace metals found in the lake environment, mercury and selenium are of the greatest concern because of their persistence and toxicity in small amounts. Mercury is presumed to be from natural sources because of the geochemistry of certain rock formations found upstream in Utah and Colorado. Graf (1985) believes that Lake Powell is a regional sink for heavy metals, especially mercury, and that almost all of the mercury is derived from weathering and erosion of rock formations of the Colorado Plateau.

While data are limited, studies by Potter et al. (1975) indicate that mercury concentrations are being bioamplified in fish. (Bioamplification is the process in which trace element concentrations in animal tissue increase with successively higher levels of the food chain. In reservoirs, larger individuals of predatory fish are more likely to have the highest trace element content.) In certain species, concentrations approaching Food and Drug Administration maximum standards for human consumption are sometimes reached. A significant problem in the management of the Lake Powell fishery would occur if mercury content above 500 parts per billion (ppb) is confirmed as common in the muscle tissues of large game fish.

Potter et al. (1975) analyzed samples from Lake Powell and reported yields of mean mercury levels of 0.01 parts per billion (ppb) in water, 30 ppb in bottom sediments, 10 ppb in shoreline substrates, 34 ppb in plant leaves, 145 ppb in plant debris, 28 ppb in algae, 10 ppb in crayfish, and 232 ppb in fish muscle. Mercury concentrations increased with increased body weight and higher levels in the food chain. Muscle tissue of some large fish (over 2 kg whole body weight) exceeded 500 ppb.

According to analyses of whole fish conducted by the U.S. Fish and Wildlife Service from 1970 to 1984, mercury levels in largemouth bass and rainbow trout taken from Lake Powell range from 50 to 490 ppb. It should be noted that in 1975 the reservoir was filling, and the above data reflect "new water" conditions.

The U.S. Fish and Wildlife Service (USFWS 1985) has summarized information on selenium in fish for Arizona. Residue data are from samples of nine species of fish collected between 1972 and 1980 at 12 stations across the state, including one at Lake Powell. In the Arizona data base, elevated concentrations (>2,000 ppb) of selenium in fish appear only in the Colorado River stations. Selenium in concentrations above 2000 ppb whole body weight can cause reproductive problems in fish; at levels of 5000 ppb or more, reproductive problems are a certainty (USFWS 1985). Recommended limits for selenium have not been established for fresh-water fish consumed by humans. In comparison, the recommended concentration limit for selenium in ocean commercial fisheries is 2 mg/kg of wet weight (Ron Eisler, U.S. Fish and Wildlife Service, personal communication, 1986).

Other trace metals in Lake Powell fish were investigated in a report by Bussey et al. (1976). Ten tissue samples from each of four species of fish (largemouth bass, black crappie, walleye and rainbow trout) were analyzed for the presence of these ten heavy metals: iron, calcium, magnesium, copper, chromium, cadmium, zinc, arsenic, selenium, and lead. The study indicates that, with the possible exception of selenium, none of the other metals analyzed appear in concentrations high enough to pose a known health hazard. Reflecting the high levels known to exist in the plankton and sediments of the lake, high selenium concentrations were observed in all fish tissues sampled. Selenium levels in fish flesh ranged from 6.4 mg/kg to 16.8 mg/kg, and in bass these levels appeared to be dependent upon size. Relatively high levels of lead were observed (compared with other stations), which possibly can be attributed to recreational activities such as the use of outboard motors.

The Utah Department of Natural Resources, Division of Wildlife Resources (UDWR), annually publishes reports of numerous studies on measurements of fish harvest, food base, and population trends. The UDWR manages fishing in Lake Powell through licenses and limits on fish catch (UDNR 1983). The U.S. Environmental Protection Agency (EPA) has recently been funding nationwide monitoring for the Priority Pollutant List, which includes 129 metals and pesticides in water, sediments, and fish of major drainages. At Lake Powell, water, sediment, and fish samples were collected and analyzed by the U.S. Fish and Wildlife Service in May, 1985. Preliminary results of this study, available from the EPA's STORET data base, indicate that high concentrations of selenium are being found in fish tissue.

Table 3 presents the results of two years of sampling of heavy metals in fish flesh by the USFWS National Contaminant Biomonitoring Program.

Table 3. Metal content analyses of fish flesh samples taken at USFWS Station 93, Colorado River at Lake Powell, Arizona. (Taken from T.P. Lowe et al., 1985.)

Year	Species	Mean TL[1] (cm)	Mean TW[2] (Kg)	Lipid (%)	Moisture (%)	Elemental residues (ug/g [ppm] wet weight)						
						Pb	Cd	Hg	As	Se	Cu	Zn
78	Common carp	14.4	1.3	2.4		0.43	0.37	0.09	0.21	2.99	1.8	101.7
78	Common carp	14.2	1.2	3.2	70.6	0.43	0.32	0.14	0.14	2.77	1.4	92.2
78	Largemouth bass	13.2	1.0	4.7	70.3	0.25	0.02	0.08	0.19	2.94	0.6	22.9
80	Common carp	13.9	1.2	3.9	74.5	0.19	0.18	0.12	0.16	1.12	1.2	67.3
80	Common carp	14.3	1.3	4.4	76.5	0.15	0.20	0.10	0.13	0.93	1.0	60.2
80	Largemouth bass	14.5	1.7	8.4	71.8	0.10	0.01	0.11	0.72	0.67	0.4	13.5

[1] average total length

[2] average total weight

III.J.2. Management alternatives.

Alternative A: No action

Existing programs (such as the National Contaminant Biomonitoring Program) from other agencies would continue to monitor the levels of heavy metals found in game fish of Lake Powell.

Alternative B: Basic monitoring (preferred alternative)

Intermittent monitoring of heavy metals in targeted game fish would be conducted. Fish species and location of sampling would be coordinated with ongoing monitoring programs. While existing monitoring programs completed by other agencies provide valuable information, they do not address the issue of heavy metals in edible portions of major game fish. Cooperation would be sought with other agencies on future monitoring objectives, heavy metal monitoring, and fishery management. If monitoring results indicate a potential health hazard from steady consumption of Lake Powell fish, public education programs would be developed.

Alternative C: Intensive study and monitoring

A lake-wide study in cooperation with other agencies would be conducted to compare heavy metals in various fish species to earlier post-impoundment studies. New studies would be initiated to locate trace metal concentrations and the extent of their distribution. Studies on fishery management would be considered if contaminated populations could be identified and isolated. Heavy metals in game fish muscle would be frequently monitored, plotted, and interpreted. Periodic reports displaying the location and content of contaminated fish and the risks of ingestion would be released to cooperating agencies and to the public.

III.J.3. Recommended course of action. Alternative B is recommended, in which Glen Canyon NRA would continue to support the USFWS National Contaminant Biomonitoring Program of biannual sampling of bottom and game fish. Such long-term monitoring is useful in indicating trends of heavy metal concentrations in whole fish. In addition, NPS would support periodic surveys of mercury and selenium contamination (and possibly that of other heavy metals) of the edible portions of striped bass and other game fish. Imposing consumption limits on large game fish or managing the fishery for a lower mercury or selenium contamination might become advisable if the results of the study show a continued increase of these metals in Lake Powell.

III.K. Range Management Practices

III.K.1. Statement of the problem. Grazing is legislatively authorized throughout Glen Canyon National Recreation Area. Forty grazing allotments on the NRA are used by 75 permittees, and virtually all of the allotments pre-date the establishment of Glen Canyon NRA by many years. Allotments include about 80 percent (980,000 acres) of the land surface of the NRA, with an authorized use of 26,500 licensed animal unit months (AUM). (An AUM is a measure of the amount of grazing, in this case one cow and calf, on a range for one month.) Cattle are the predominant livestock species grazing on the NRA, although sheep formerly grazed in the area, feral horses are present in some canyons, and burros frequent portions of the NRA on the Navajo Reservation shore. Managed cattle allotments are typically used seasonally in fall, winter, and spring; also, most Glen Canyon grazing allotments extend beyond the park boundaries. In a few isolated areas, small numbers of unmanaged cattle that have escaped control of present or former permittees remain year-round. These animals are classified as feral cattle.

Grazing leases are administered by the Bureau of Land Management (BLM), using the same range management policies and procedures exercised on BLM-managed lands. In 1986, BLM and NPS agreed by Interagency Agreement to consult and cooperate to ensure that grazing management activities do not conflict with the management purposes of the NRA described in the unit's enabling legislation and General Management Plan (NPS 1979). This requires that the National Park Service determine the potential effects of any proposed range management action on the values and purposes of the NRA. Range management practices potentially affecting water resources fall into four categories, as follows:

- Land treatments--Trees and shrubs are sometimes reduced on public ranges to increase forage production for cattle. Burning, chaining (mechanical removal by drag chains), and herbicides are the most common land treatment methods. The effect on water resources results principally from lowered water retention and increased runoff. Sediment loads downstream may increase, especially during storms, and higher sediment loads may be deleterious where stream flow is sufficient to support benthic macroinvertebrates. If the treatment area is large, enough additional runoff may be generated to raise the magnitude of floods in downstream drainages, causing further ecosystem effects.

  The effect of herbicides on downstream waters is poorly documented. It is known, however, that herbicide residues are often present in water draining agricultural areas; such residues could therefore be expected in runoff from range areas where herbicides have been applied. Although the effects of a few discreet herbicide applications on rangeland may be transitory, caution is clearly needed, especially since some aquatic species are sensitive to low concentrations of some of the chemicals used (Kosinski 1984; Nimmo 1985).

- Livestock water developments--Spring developments, catchments, and reservoirs are frequently used on public ranges to increase production, redistribute stock, or change forage utilization patterns by adjusting the water supply for livestock. Common practices are the creation of catchment basins through excavation or blockage of a small drainage, diversion of flow to a trough, storage in tanks, and flow enhancement (often using a pipe driven into the source of a slow seep). Twenty-three developments of springs and reservoirs were proposed in the NRA during 1980-1985, of which 15 were constructed.

  Most water developments for range cattle proposed in the recreation area use either springs or seeps with low flow, or catchments. Catchments trap and store water that otherwise would run off downstream, so that one effect is a minor lessening of recharge to the affected drainage. Also, improper location and maintenance of the water-holding structures can cause alteration of natural stream channels. If a low-flow water source is used, water diverted from such a source to a tank or trough may cause a break in flow over part of the streambed, drying up a portion of the stream channel. Similarly, flow enhancement can deplete seasonal recharge more quickly and lengthen the dry period. Such changes can be critical to wildlife or local areas of riparian habitat.

- Improvements for grazing operations--Roads, trails, and fences may be constructed in new areas (or closed and removed) to assist in a change of grazing operations. The effects on water resources are usually indirect, except that fencing is sometimes used to exclude cattle from watered areas.

- Grazing systems--These are implemented through schedule of placing stock on the range, division of ranges into pastures, and determination of optimum stocking rates. Any change in grazing system is likely to generate ecosystem changes, which in turn can influence the hydrologic balance of the allotment and thus the water resources of the NRA.

Of all range management practices, those involving water use by cattle probably have the most far-reaching effects on water quality. Where cattle have direct access to a natural source, it will be fouled by feces. Several bacterial, protozoan, and viral diseases can be transmitted from cattle to humans via this route (Buckhouse and Gifford 1976; Charles Gerba, University of Arizona, personal communication, 1986), in addition to the adverse aesthetic effects. (According to Gerba, the protozoan Cryptosporidia has been implicated in human disease, with cattle as a vector.) These effects set up potential competition for the water resource between range cattle and backcountry recreationists. Studies by Kunkle (1970) and Buckhouse and Gifford (1976) indicate that bacterial contaminants from cattle feces may not be transported very far from the source; thus, water quality effects easily could be mitigated by excluding cattle from immediate source areas where high water quality is desired.

Grazing operations entail several other categories of potential impact on water resources. Foremost among these is the effect of livestock on soil stability and consequent increased erosion and sedimentation rates in grazed drainages. A considerable body of literature on this subject clearly establishes that poorly managed livestock grazing can result in severe damage to water resources and aquatic habitats, including channel widening, bank erosion, and lowered stream velocity (Platts 1981). Changes in channel configuration and bottom texture are typical where sediment deposition increases, and these are accompanied by alterations in the aquatic communities. Such impacts are probably most profound when an area is grazed for the first time.

III.K.2. Management alternatives.

Alternative A: No Action

This alternative would continue the present practice of addressing water developments for livestock on a case-by-case basis with no uniform evaluation criteria established parkwide. Inconsistencies in the approval of rangeland water developments have occurred and could continue. Also, the impact of range management practices on water resources is inadequately documented insofar as operations in the recreation area are concerned. While years of grazing on the recreation area have already caused many of the impacts discussed above, any proposed change in grazing operations has the potential to improve or diminish NRA water resources with respect to their present condition. Under Alternative A, neither the current condition of park waters nor the effect of a change would be adequately documented.

Alternative B: Establish water resource management guidelines for grazing (preferred alternative)

Under this alternative, guidelines for rangeland water developments on the recreation area would be established, providing instruction for NPS and BLM managers and the range allottees on the types of projects consistent with NPS management objectives for the recreation area. The guidelines would also be incorporated into a forthcoming Grazing Management Plan for the recreation area. The following criteria are proposed:

1. Livestock grazing in the recreation area will be managed with an objective to conserve and protect the quantity and quality of water resources.

2. Proposed water developments for livestock will be evaluated to verify the feasibility of the development and its appropriate configuration in light of the purpose of the project. The purpose of this guideline is to avoid unnecessary water storage or construction of ineffective design.

3. Livestock will not be permitted to foul natural water sources. Project proposals should include measures to prevent such pollution.

4. Minimum flows to support riparian and aquatic biota must be maintained in the natural channel. In no case will total diversion be permitted.

5. Land treatments are not appropriate in the NRA and will not be permitted. Water resource effects in the NRA from land treatments on adjacent lands should be minimized during allotment planning.

6. Wildlife and recreationist access to water sources must not be impaired, and should be enhanced where feasible.

7. All projects involving changes in grazing operations will be evaluated for potential beneficial or adverse effects on NRA water resources.

8. Grazing on NRA lands will conform to approved allotment management plans. Such plans will only approve grazing systems and stocking rates that will protect NRA water resources from damage. Where feasible, practices will be prescribed to rehabilitate damaged water resources, including riparian zones.

9. The water supply of riparian-dependent resources (plants and animals) must be maintained.

10. All water rights will be retained by the federal government when a water source is developed for cattle on federal lands in the recreation area. No water right, expressed or implied, will pass to the permittee.

These guidelines would be communicated to BLM District Managers and through them to the allottees.

Under this alternative, programs to monitor park waters affected by grazing would be initiated. All range management actions would be evaluated for their effect on water resources and conformance with the above guidelines. Existing developments not meeting the guidelines would be scheduled for upgrading on a phase-in basis if they are still considered necessary under current allotment planning. Water resource concerns would be incorporated into allotment management plans, providing long-range guidance for allottees and land managers.

* Need to include a statement on cumulative impact of multiple grazing allotments

Consequences of this alternative could include the elimination of range improvements that are unnecessary or of marginal benefit, and mitigation of potentially severe water resource impacts from future projects.

III.K.3. Recommended course of action. Alternative B, which would establish water resource management guidelines for grazing accompanied by monitoring programs, is recommended. Rangeland water developments would receive consistent evaluation under published standards. Adherence to standards would ensure consistency with recreation area and National Park Service management objectives for backcountry waters, and improve the management of an important natural resource.

III.L. Mineral Extraction

III.L.1. Statement of the problem. Prior to the establishment of Glen Canyon National Recreation Area (October 27, 1972), its lands were open to mineral entry under the U.S. mining laws, and federally owned oil and gas rights were available for leasing under the Mineral Leasing Act of 1920 as amended. The enabling legislation withdrew the recreation area from mineral entry but authorized mineral leasing. In 1981, the National Park Service promulgated leasing regulations for the five NPS units in which federal mineral leasing is authorized. National Park Service consent is required for issuing mineral leases and approving site-specific operations.

In 1979, a General Management Plan (NPS 1979) was approved for the recreation area that subdivided the area into four management zones: Natural (668,670 acres), Recreation and Resource Utilization (RRU) (557,890 acres), Development (19,270 acres), and Cultural (25 acres). In 1980, a Mineral Management Plan (MMP) was approved for Glen Canyon. This plan limited the leasing of mineral resources to the RRU zone with the exception of the lake surface and adjacent lands that can easily be seen from Lake Powell. These excepted areas constitute the immediate scenic setting for visitors using Lake Powell. Under the MMP, approximately 373,000 acres are available for leasing within the recreation area. When applications are received for these lands, they are evaluated for conflict with other purposes of the recreation area, including their effect on water resources. If the conflicts are not found to be significant, the lease may be issued.

There are no patented mining claims in the NRA; two unpatented claims have been recorded. Federal minerals normally subject to claim under the mining law of 1872 are leasable in the NRA. Twelve hundred acres of private oil and gas rights at the mouth of Halls Creek are partially inundated by lake waters. There are 82 state section inholdings encompassing 51,000 acres (including surface and subsurface interests) in the NRA. The state has issued 39 mineral leases for 28,500 acres, some of which are in areas closed to minerals disposition in the MMP. No plans of operation (other than for tar sands), prospecting permits, or special use permits for mineral operations are pending.

Forty-seven over-the-counter lease offers for approximately 130,000 acres are being evaluated on a case-by-case basis by the BLM. Currently there are 34 suspended federal oil and gas leases encompassing 38,000 acres in the Tar Sands Triangle and Purple Hills areas. Thirty-one of the 34 leases are being evaluated for conversion to "combined hydrocarbon" leases.

Surface disturbances associated with oil and gas development may result in increased runoff and erosion. If an area can support production, surface disturbance could affect recharge areas for springs and seeps. Produced hydrocarbons, process fluids, and liquid wastes could enter local drainages due to spills and ultimately enter Lake Powell. Another potential water resource impact from oil field development stems from road construction, which often increases sedimentation rates in affected watersheds.

Should the operation require settling and surge/storage ponds, overflows and leaks could occur that would affect surface water resources. In addition, local degradation of shallow ground water could result from impacts occurring in the surface recharge areas. Any impact on available water, whether through diminished flows or degraded quality, is considered serious.

Drilling can produce brine waters from each of several formations within the recreation area. Brine can contaminate aquifers if not properly sealed downhole. Concrete plugs must be placed both above and below the aquifer to protect the water-bearing zone. When downhole pressure occurs, contaminated water blow-out could follow. This could result in severe surface and subsurface impacts, especially if brine is emitted.

During the oil and gas production phases, leakage or spills can occur as a result of transportation and handling in trucks and pipelines. On-site product upgrading also produces water that must be reinjected or transported to a designated disposal site.

The final stages of petroleum recovery may pose additional water resource impacts. Secondary recovery utilizes techniques involving horizontal subsurface fracturing and enhanced recovery programs driven by steam, water, or other agents. These procedures could establish communication with aquifers and recharge areas for springs and seeps. Resulting impacts may include contamination of aquifers and spring areas but also includes elimination of surface water sources.

To evaluate the potential for such effects when considering mineral lease applications, accurate information on water resources in the area of concern is needed. Currently this information is inadequate.

III.L.2. Management alternatives.

Alternative A: No action

A regulatory structure is in place governing the evaluation of oil and gas lease applications that includes assessing environmental impacts to water resources. However, there is no set of standards to include in leases and operating permits that would ensure compliance with water resource protection requirements. Continued lack of such standards under this alternative would result in development of lease standards on a case-by-case basis, and, consequently, in uncertain protection of water resources from oil and gas development impacts. Lack of an adequate information base on water resources would continue to hamper the evaluation of mineral-lease applications and could result in over- or underestimating potential impacts.

Alternative B: Develop lease and operation standards for water resource protection (preferred alternative)

Standard language to govern leasehold operations would be developed to ensure water resource protection. The stipulations would be included in each lease or operating permit and become part of the legal requirements for development. The standards would ensure maintenance of natural flows and the quality of potentially affected waters, whether ground water or surface water. Mitigation of all impacts would be required. Existing standards of state and federal agencies would be reviewed and supplemented as needed by lease standards specific to the recreation area. Standards for leasing, exploration, development, production, and abandonment would be covered in the review. Three standard lease stipulations specifically proposed under this alternative are the following:

1. no drilling will be permitted within one-quarter mile of any spring or seep;

2. abandoned wells or drill holes must be cemented from the bottom to the surface; and

3. natural flows of water must be maintained in all operating areas.

Alternative C: Develop baseline information on water resources in prospective leasing areas (preferred alternative)

Under this alternative, data on hydrology and water quality in prospective lease areas would be obtained as research funding becomes available. Identification of aquifers and recharge areas, the origin of surface flows, and baseline water quality are among the subjects requiring investigation.

III.L.3. Recommended course of action. Alternatives B and C are recommended because Alternative A would prolong the lack of park-specific standards and background data. This in turn could result in inadequate protection of park resources from the effects of oil and gas operations.

III.M. Tar Sand Operations

III.M.1. Statement of the problem. Energy firms with extensive oil and gas lease holdings in Glen Canyon National Recreation Area have filed a Plan of Operations with the Bureau of Land Management for converting their leases to combined hydrocarbon leases, which would allow development of tar sands to produce ~~crude~~ oil. The leases are within the Tar Sand Triangle, the largest of eleven "Special Tar Sand Areas" in Utah where the federal minerals are available for competitive lease. About half of the 66,000-acre development proposal would be within the NRA in the Orange Cliffs region bordering Canyonlands National Park. Steam injection is proposed to soften the tar and allow its extraction through conventional pumps. An estimated 1,680 acre-feet of water per year from the Dirty Devil River would be consumed.

Other Tar Sand Triangle operations for lands bordering the NRA have also been proposed, affecting 50,000 acres of public lands between the Dirty Devil River and Orange Cliffs. Steam injection and in-situ combustion methods are proposed in this area.

Another proposal for development could affect the Circle Cliffs Special Tar Sand Area adjacent to Glen Canyon NRA and Capitol Reef National Park. This operation would use in-situ combustion techniques to extract oil from an area encompassing 57,000 acres of BLM-managed public land located in the angle between the two parks. All of the area is within the drainage of the Escalante River, which empties into Lake Powell and is a major water resource of the NRA.

White Canyon Special Tar Sand Area, east of the Colorado River, is within five miles of the NRA boundary at Short Canyon. This deposit is smaller than the others and has received no development proposals. It is available for future competitive lease; if development were to occur, Dark Canyon and White Canyon could be affected.

Draft Environmental Impact Statements, prepared by bureaus of the Department of the Interior for the larger Tar Sand Triangle proposal and the Circle Cliffs operation, document the extensive water resource impacts associated with such developments. Steam injection techniques use large quantities of water, produce water contaminated with hydrocarbon products requiring disposal as a byproduct of extraction and upgrading, and leave contaminated remainder water in the tar horizon where it could leak into aquifers through fractures. Surface activities disturb the watershed, posing a significant threat of sediment contamination of surface waters that drain into Lake Powell. Brine-containing aquifers pierced or fractured by tar sand operations could potentially leak into fresh-water horizons or onto the surface, a potential impact magnified by the large number of wells required for tar sand operations. Finally, there is the threat of oil spills or spills of byproducts and wastes. The 66,000-acre Orange Cliffs operation would, for example, produce ten tons per day of liquid sulfur wastes to be transported for disposal. Spillage would acidify surface waters coming into contact with the material and kill fish and other aquatic life in the affected drainage.

In-situ combustion techniques use less fresh water but result in larger amounts of contaminated water requiring disposal. Water is usually produced in significant quantities with the petroleum. Acidic waters contaminated with hydrocarbons are also left in the formation where they can affect adjoining aquifers or leak to the surface through inadequately sealed wells. Most of the impacts noted for steam techniques could also occur, depending on the exact nature of the operation.

Tar sands can be surface-mined in some localities. Should this method be used in the deposits neighboring Glen Canyon, entire surface watersheds could be affected by runoff contamination and discharges from the mines.

The National Park Service will not approve operations having significant adverse effects on NRA resources. Therefore, basic information on the quantity and quality of water resources in potentially affected areas is needed prior to Plan of Operations approval to assess potential impacts. This problem is addressed in an NPS report by Flug (1985), which outlines a recommended baseline monitoring program.

III.M.2. Management alternatives.

Alternative A: No action

Under this alternative existing gauging stations would provide background water data for some of the potentially affected areas. However, the existing stations are upstream of potential operations in some cases, and in others the data gathered is inadequate to document baseline water quality. Under this alternative NPS would not have sufficient information to completely evaluate the potential effects of tar sand projects on park waters. The agency's ability to prevent or mitigate impacts through stipulations on operations would be less. Any monitoring efforts begun at the time of operation approval would be less meaningful due to lack of comparative data from previous years.

Alternative B: Implement baseline monitoring (preferred alternative)

Under this alternative the monitoring plan recommended by Flug (1985) would be required in all leases issued for tar sands. As many as eleven sites would be monitored for physicochemical parameters defining water quality and quantity. The monitoring program would be initiated prior to final approval of any tar sand Plan of Operation. If monitoring data indicates that a particular Plan of Operation would cause significant water resource impacts that could not be mitigated, the operation would not be approved.

III.M.3. Recommended course of action. Implementing the monitoring program in Alternative B would be expensive and require a level of expertise beyond the immediate capability of the recreation area to provide; yet the data resulting would be the minimum needed to fully understand tar sand project effects and the types of mitigation necessary. Therefore, it is recommended that the monitoring program be made a precondition of development, with full costs to be borne by the developers, particularly since the need for the monitoring is caused by the existence of development proposals. A minimum of one to two years of data would be required before surface-disturbing development activities could commence. This recommendation is feasible because large-scale mineral projects normally require several years to complete the permitting and design phases prior to actual development.

III.N. Energy-Related Wastes

III.N.1. Statement of the problem. The Salt River Project Agricultural and Improvement District (SRP) operates the Navajo Generating Station east of Page, Arizona, and south of Glen Canyon National Recreation Area. The Navajo Power Plant is rated at 2250 megawatts (mw) and burns coal from Black Mesa, Arizona, that has an ash content of approximately 16 percent. Ash emissions from the plant are controlled by means of electrostatic precipitators. Fly ash is collected in hoppers and trucked to a disposal area approximately 3.5 miles east of the power plant site. The disposal area is at the head of a small ephemeral tributary to Lake Powell. Fly ash and bottom ash are placed in terraces behind a dam constructed across the canyon of the tributary. The ash disposal area, which has approximately 35 years remaining in its planned operating life, is "active" due to the on-going disposal operations, so revegetation of the area has not occurred.

Surface runoff from lands adjoining the disposal site is routed around the site, and all runoff from the ash itself is contained within the disposal area. Shallow ground-water wells have been installed by SRP at depths ranging from 30 to 50 feet at distances of 30 to 500 feet from the ash disposal site. According to SRP, no changes in ground-water quality have yet been detected in the wells. However, since the ash disposal site is in a drainage tributary to Lake Powell, the potential effects of fly-ash constituents, particularly metals, on water resources are of concern.

North of Bullfrog, uranium mine waste and mill tailings have been placed adjacent to Shootering Creek, a tributary of Hansen Creek that drains south into Lake Powell. The mine waste and tailings are located approximately 10 miles north of the NRA near Ticaboo, Utah, and occur on lands administered by the Bureau of Land Management (BLM) and the State of Utah. These waste materials were generated by the Tony-M uranium mine and an associated milling operation. Both are owned and operated by Plateau Resources. The operation is closed down due to the currently depressed economic state of the uranium industry; however, Plateau Resources continues to keep the mine dewatered. Water is pumped to a nearby total containment pond. When the mine was operating, large amounts of unprocessed ore were placed immediately adjacent to Shootering Creek. Only a small amount of commercial production occurred. Tailings from the mill were disposed of in a bentonite-lined pond located near Shootering Creek.

Plateau Resources submits monitoring reports to the State of Utah and the Nuclear Regulatory Commission on its current pumping activities and on surface- and ground-water resources in the immediate vicinity of the mine and mill. Utah's Bureau of Water Pollution Control conducts no surface- or ground-water monitoring in the area of Plateau Resources' operation or downstream on either Shootering or Hansen Creeks. The Bureau of Land Management has conducted some very limited hydrologic monitoring downstream on Hansen Creek and at several springs on Ticaboo Mesa, two miles to the east.

III.N.2. Management alternatives and impacts.

Alternative A: No action

Under this alternative, no additional information would be obtained by NPS with respect to SRP's ash disposal activities near Page or the mine wastes and mill tailings disposed of adjacent to Shootering Creek by Plateau Resources. Specific information on local hydrologic effects associated with these waste disposal activities would remain sparse, and potential downstream impacts on the water resources of the recreation area would remain unknown.

Alternative B: Development of cooperative programs (preferred alternative)

This alternative would entail the development of a cooperative program with SRP to review and share ground-water data collected near the ash disposal site and to receive information regarding reclamation and stabilization activities (and the results of revegetation trials) in the ash disposal area. In addition, it would involve cooperation with Utah's Bureau of Water Pollution Control and the Nuclear Regulatory Commission in order for NPS to receive hydrologic monitoring data submitted by Plateau Resources on its uranium mining and milling operations in Shootering Creek. Based on assessments of the initial data, the need for additional monitoring locations could then be evaluated. With these two cooperative programs in place, the potential for downstream effects on the water resources of the NRA can be evaluated using the site-specific information provided by the cooperating entities.

Alternative C: Site-specific monitoring

For this alternative, the comprehensive hydrologic monitoring program for the recreation area would specifically address hydrologic concerns associated with the ash disposal site and Plateau Resources' uranium mining and milling operation.

III.N.3. Recommended course of action. Alternative B, the development of cooperative programs with the private entities and/or agencies responsible for regulating energy-related activities, is recommended. This would provide NPS with a cost-effective means of assessing potential impacts on the water resources of the NRA from waste disposal activities on adjacent lands.

III.O. Management of Hazardous Materials Spills

III.O.1. Statement of the problem. An Oil and Hazardous Substance Spill Contingency Plan has been drafted for Glen Canyon NRA as required by the Clean Water Act. The plan describes a policy for containment and cleanup of spills on water and establishes response procedures for use at Glen Canyon NRA.

Hazardous materials spills at Glen Canyon are considered infrequent since careful planning and safe operating practices are emphasized to minimize accidents. When spills occur, however, they usually originate from fueling facilities associated with the marinas on the lake. A fuel tanker operates on the lake between the Wahweap and Dangling Rope marinas, keeping the latter facility supplied with boat gas and diesel fuel. Wahweap, Dangling Rope, Halls Crossing, Bullfrog, and

Hite marinas all have fuel storage tanks which have been sources of leaks or accidental spills. The process of fueling boats at these marinas regularly results in small spills from hoses and tank overflows, since the care taken by individuals doing the fueling is highly variable. Most spills of this type are only a few ounces in quantity and are not covered in the contingency plan.

Another potential source of spills is mineral operations. Oil pipelines cross drainages that enter the recreation area in San Juan County. The only known significant oil spill in the park occurred when oil from a pipeline leak outside the NRA entered the San Juan River. Continued operation of a producing field at Mexican Hat will make this an ongoing hazard. Mineral activities authorized in the future within the recreation area could result in accidental spills, although best operating practices to minimize this possibility will be required.

The highways passing through the recreation area offer a potential source of spills resulting from truck accidents. A wide variety of hazardous materials could potentially be released this way, but the probability of such a spill reaching NRA waters is relatively remote. No other sources of potential hazardous spills on recreation area waters are known.

When spills do occur, National Park Service policy dictates that containment and cleanup are immediately put into effect. Cleanup of spills in federal waters is the legal responsibility of the party making the spill; however, NPS will clean up such spills if the responsible party refuses or is incapable of adequately completing the cleanup job. Effective cleanup procedures necessitate an adequately organized system, including sufficient material and equipment for a local response on small spills. For large spills beyond local capability, regional response teams can be called in under procedures outlined in the contingency plan.

III.O.2. <u>Management alternatives</u>.

Alternative A: <u>No action</u>

This alternative includes completion of the Oil and Hazardous Substance Spill Contingency Plan, but no new actions for implementation.

Alternative B: <u>Implement the Oil and Hazardous Substance Spill Contingency Plan</u> (preferred alternative)

Actions to implement the final contingency plan would be taken, including coordinating contacts with other agencies, inspecting spill-prevention features required at developed facilities, and stockpiling containment and cleanup materials for use by NPS and its concessioners and contractors. The plan most specifically covers developed facilities on the lake, but the procedures, coordination, and materials would all be of benefit in the event of roadway spills. This alternative would require new expenditures, but it would enhance the protection of NRA water resources and help avoid the costs associated with uncontrolled spills of fuel, oil, or other hazardous substances.

Alternative C: Assess the water quality effect of spills not covered by the contingency plan

Under this alternative a study plan would be developed to quantify the level of small-quantity spills from fueling activities that may be occurring and to evaluate their cumulative effect. The study would attempt to document the persistence and accumulation of spilled materials in the water environment.

III.O.3. Recommended course of action. Alternative B is recommended. Alternative A is not acceptable because inadequate response to a serious spill could result. At present, the small-quantity fuel spills addressed under Alternative C do not appear sufficiently prevalent to warrant a new study. Under Alternative B, supplies and equipment would be obtained and stored locally by NPS and its concessioners to allow containment and cleanup of spills. Inspection of facilities would be performed to ensure compliance with spill-prevention requirements set forth in plans and state or federal regulations. The spill-response components of the contingency plan would be synthesized into a field manual for use by rangers, maintenance personnel, and concessioner employees--the likely first responders to spills in the NRA.

III.P. Problem Statements Considered but Not Developed in Detail

Three potential water resource management problems identified during scoping were researched and initially considered for inclusion in the Water Resources Management Plan, but these were later rejected as insignificant over the term of the present planning cycle.

The first of these problems concerns development of a pumped-back storage reservoir. Such a project would involve construction of another reservoir adjacent to Lake Powell at a higher elevation. Water from Lake Powell would be pumped into the upper reservoir during periods when hydroelectric demand is low and released back into Lake Powell through power-generating turbines when electric demand is high. The purpose of this project would be to generate additional power during peak demand periods when revenues are higher. In 1985 a company was issued a permit by the Federal Energy Regulatory Commission to study the feasibility of such a project at Lake Powell (Warm Creek), but the Department of the Interior opposed the project and would not issue on-site study permits. Since it is current Interior policy to oppose pumped-back storage reservoir development on Lake Powell (because of potentially significant impacts and limited public benefits), this issue is not considered a current problem requiring planning.

"Acid rain," or acid deposition, is another issue that initially was considered. However, acid deposition is not at present considered a problem in the arid Southwest deserts because of predominantly calcareous soils and basic waters with a high buffering capacity. Regional programs already in place to monitor acid deposition will provide adequate early warning of any change in conditions that could lead to an adverse effect in the Glen Canyon area. Therefore, advance planning relating to acid deposition is not deemed necessary at this time.

The third of these potential problems relates to lakeshore development. Glen Canyon National Recreation Area is a developing park for which plans have been proposed for two new marinas and expansion plans approved for several existing marinas and water-related facilities. More specifically, these planned developments include the following:

- Halls Crossing Amended Development Concept Plan (DCP) (September, 1985): Provides for increased recreational use at Halls Crossing through expansion and/or addition of water-related facilities, including public boat launch ramp, boat pump-out facilities, marina expansion, water supply well, and sewage lagoon and aeration system.

- Lone Rock DCP (August, 1981): Provides for beach camping and day-use areas, boat launching area, potable water supply, and sewage treatment.

- Bullfrog Basin Amended DCP (September, 1985): Provides for the modification and/or addition of various water-oriented facilities, including public boat launch ramp, marina, and floating sanitary dump station.

- Wahweap DCP (July, 1983): Provides for potable water well modification; construction of additional water tank; and additional sewage lagoons, boat launch ramps, and marina facilities.

- Hite Developed Area DCP (August, 1983): Provides for expansion of the potable water supply and treatment systems and modification of the sewage disposal system.

- Lees Ferry DCP (August, 1985): Provides for improved river launching facilities and relocation of water treatment facilities, as well as reopening an irrigated ranch as a living-history interpretive exhibit.

- Paiute Farms/San Juan Marina DCP (September, 1985): Draft plan calls for development of an interim facility at Paiute Farms on the Navajo Indian Reservation to include a marina with fueling capability, boat launching ramps, and sewage disposal system.

- Antelope Point DCP (September, 1985): Draft plan calls for water-related development activities by the Navajo Nation and NPS at Antelope Point. Planned activities include a marina with fueling and boat pump-out capabilities; a boat launch ramp; a day-use beach area; potable water wells and water treatment and distribution system; and central sewage collection and treatment system.

These planned expansion activities raise several concerns associated with the water resources of Lake Powell. Water intake structures (no fixed structures on Lake Powell are designed with discharge capability) must be evaluated for possible effects on water quality. The design and location of facilities and their operation practices must also be evaluated from the standpoint of impact on surface runoff. Most of the current planning noted above includes additional boat sewage pumpout and water treatment capacity to handle wastewater from new developments. It will be important to monitor the accuracy of design projections to ensure that capacity does not outstrip water treatment. While development plans normally treat impacts on water resources in a general way, most of the major issues are resolved during the planning stage, such as locating facilities outside of floodplains. Specific problems and details are resolved at the design and permitting stages of development.

Facility expansion will result in higher visitor use, which in turn could lead to additional adverse water quality effects from human waste in beach areas or discharges from boats (impacts are described more fully in the problem statement on shoreline water quality). Also, sedimentation rates (including the presence of river debris), possible shoaling (due to reservoir water level fluctuations), and flood hazards need sufficient evaluation in the siting of facilities (particularly marinas). Although these factors generally have been considered in prior planning activities, they must receive more intensive analysis in lakeshore development planning.

The planning process for lakeshore development activities must assure (1) that impacts to the hydrologic balance of Lake Powell resulting from such activities are properly understood, and (2) that possible water-related effects on such facilities (e.g., flooding potential and water level fluctuations) are carefully evaluated. With this information, informed decisions regarding water resources can be made early in the development planning process (as opposed to later in the permitting or implementation phases). These issues currently are addressed during planning and subjected to public review then. Continuing such analyses is the only reasonable alternative, so a separate problem statement concerning lakeshore development has not been included in this document.

IV. RECOMMENDED MANAGEMENT PROGRAM

IV.A. Monitoring

IV.A.1. Shoreline water quality and gray water. A routine bacterial monitoring program at the primary swimming beach and marina areas will be established (Table 4). Multiple samples will be taken every two weeks during periods of heavy use. The objective of this program is to monitor compliance with recommended water quality standards for contact recreation, although the resulting data could also be compared with beach usage trends or used to detect the source of violations. Another major objective of the monitoring is to assess gray-water effects in marinas and popular houseboat anchorages on the lake.

Similar programs are in place at Indiana Dunes National Lakeshore, Fire Island National Seashore, and Golden Gate National Recreation Area. Urban influences in each of these areas create short-duration bacterial contamination episodes that are much more severe than those encountered at Lake Powell. In these cases, monitoring data are frequently used by park management to identify areas where a temporary health hazard may exist so that warning signs can be posted.

Equipment presently available in Glen Canyon NRA will be used, including a Hydrolab 4000 instrument for measuring water temperature, specific conductance, pH, and dissolved oxygen in sampling zones.

A fully-equipped laboratory within the park will be used to analyze the samples. The lab contains Millipore microbiological apparatus for determining total and fecal coliform bacterial contamination. The NRA intends to apply for state certification of the laboratory in Utah in the near future. Water sampling, sample handling, and analysis procedures will follow Environmental Protection Agency recommendations (USEPA 1979).

IV.A.2. Water quality of rivers for recreational use. The National Park Service will monitor the quality of river waters in the NRA and their important tributaries through a survey of each river segment for chemical/bacterial data. Hydrolab parameters, major ions, total coliform bacteria, fecal coliform bacteria, and fecal streptococci bacteria will be measured. Three of the trips will include sampling for Giardia at appropriate sites (particularly smaller tributary areas). Two sampling trips will be conducted in spring during high flow, two during summer, and one in fall or winter.

One major river segment will be monitored each year, except when special situations arise demanding extra problem-assessment monitoring. The proposed order of survey is as follows: Escalante River; Colorado

Table 4. Proposed shoreline and marina bacterial monitoring for Glen Canyon National Recreation Area.

Objective	Frequency	Sites (No. of samples)	Parameters
Routine monitoring of popular beach areas for compliance with water quality standards, and monitoring of boat effluents.	Every other week	Wahweap Swim Beach (3) Wahweap Marina (2) Wahweap pumpout (1) Lone Rock Beach (3) Antelope Point (2) Bullfrog Marina (2) Bullfrog Swim Beach (3)	Fecal coliform bacteria, temperature, pH, turbidity, specific conductance, dissolved oxygen
	Every other month	Farley Canyon (3) Moqui Canyon (3) Oak Canyon (2) Davis Gulch (2)	
Spot-checks at other sites on occasion.			

River above Lees Ferry, including the lower Paria River; Dirty Devil River; San Juan River; and the Colorado River above Hite. Sampling of the latter segment will occur at sites at the inflow, at rafter camps in Imperial or Gypsum Canyons, and in one or two flowing tributaries such as Dark Canyon and Clearwater Canyon.

Giardia will be sampled only in the two Colorado River segments and the Escalante drainage. The purpose of this work is to determine whether the organism is present, and if it is, the extent of its distribution in these areas.

The surveys will be logistically organized to deliver bacterial samples to the laboratory at the NRA within six hours of collection. This will require sampling by helicopter in the Escalante and San Juan drainages. *Giardia* samples will be delivered within 36 hours to a laboratory equipped to handle the analysis and will be analyzed under contract. A high-volume pump to sample for *Giardia* will be leased or obtained on loan.

IV.A.3. Water resources as habitat for fish. A monitoring study is proposed for the Escalante River drainage using suitability parameters for fish habitat. Instream flows would be measured seasonally on the river and several prominent tributaries; a fisheries biologist would be consulted to design a study of habitat factors such as food base and populations of aquatic species.

IV.A.4. Heavy metals in fish flesh. The National Park Service will propose a minor expansion of the National Contaminant Biomonitoring Program (NCBP) to include striped bass from Lake Powell as a species analyzed for lead, cadmium, mercury, arsenic, selenium, copper, and zinc. Muscle tissue as well as whole fish concentrations would be evaluated. This monitoring would be implemented through coordination with the NCBP. If necessary, funding for the additional tests would be provided at an analytical cost of approximately $1,000-$2,000 every other year.

IV.A.5. Range management practices. A one-year monitoring effort will be undertaken to compare the bacterial contamination in springs, seeps, and catchments on cattle range with control springs on ungrazed range. (This project will, if possible, be undertaken preparatory to writing the Grazing Management Plan.) When the opportunity arises, samples will be taken before and after development of a new water source for cattle in a situation where the predevelopment water was not used by cattle. This will document any change in bacterial status of the water. Fecal coliforms, fecal streptococci, total coliforms, water temperature, pH, turbidity, and specific conductance will be measured using instruments and laboratory facilities in the park. The need for follow-up monitoring will be evaluated based on first-year results.

IV.A.6. Mineral extraction. A baseline monitoring requirement for mineral developers is proposed as outlined by Flug (1985) to enable NPS personnel to assess the effects of mineral extraction on water resources. The Service will request the Bureau of Land Management to include the monitoring as a lease requirement for tar sand leases that could affect waters of the NRA. Up to eleven stations could be monitored for the three tar sand areas surrounding the NRA. However, at any one time only the stations measuring waters affected by specific operations would be required; thus, the monitoring would be implemented on a case-by-case basis.

Table 5 lists the monitoring stations required to obtain an adequate data base for each tar sand area. Other land managers may require additional stations. Tables 6 and 7 list the parameters to be measured at each station. Ground-water monitoring would occur at wells developed near the designated stations after consultation with the NPS Water Resources Division on siting. Wells would be located away from the zone of lake bank-storage influence.

For tar sand operations, up to two years of data under this program would be required from developers prior to approval of operations. Monitoring would have to continue during development activities and production and throughout post-operational reclamation for a period to be determined by the NRA, based on the nature of the disturbance. Developers would bear the cost of the monitoring. This requirement would become a stipulation on leases granted for tar sand development within the areas of concern.

Table 5. Recommended monitoring sites for establishing baseline water resources data related to potential tar sands development in Glen Canyon National Recreation Area. (Taken from Flug, 1985.)

TAR SAND AREA

Site No.	Description	Location	County (Utah)
Orange Cliffs			
1	Above tar sand area inflows	On Dirty Devil River near Hanksville	Wayne
2	Midway along tar sand area inflows	Dirty Devil River near Poison Springs Canyon	Garfield
3	Below tar sand area inflows	Dirty Devil River above Lake Powell	Garfield
4	Above tar sand area inflows	On Green River near Glen Canyon NRA northern boundary, below Deadhorse Canyon	Grand
5	Green River below tar sand area	Green River above confluence with Colorado River	San Juan
6	Colorado River above tar sand area	On Colorado River above confluence with Green River	San Juan
7	Below tar sand area inflows	On Colorado River above confluence with Dirty Devil River	San Juan
Circle Cliffs			
8	Above tar sand area inflows	On upper Escalante River near Glen Canyon NRA western boundary, northwest of Silver Falls Creek	Garfield
9	Below tar sand area inflows	On Escalante River above Lake Powell	Kane
White Canyon			
10	Below tar sand area inflows	On White Canyon above arm of Lake Powell	San Juan
11	Below tar sand area inflows and above Lake Powell	On San Juan River near Clay Hills Crossing	San Juan

Table 6. Suggested surface-water-quality monitoring program for streams, springs, and seeps located in the vicinity of tar sands development. (Adapted from Flug, 1985, and State of Colorado, 1982.)

Field measurements

discharge	pH
specific conductance	water temperature
dissolved oxygen[1]	

Chemical constituents[2]

total suspended solids	chloride
total dissolved solids	magnesium
oil and grease	total nitrogen
dissolved organic carbon (DOC)	nitrogen composition[4]
DOC analysis by fraction[3]	total phosphorus
alkalinity	sulfate
sodium	boron
calcium	fluoride

Suggested metals package[2,5]

aluminum	manganese
arsenic[6]	molybdenum
cadmium	mercury[6]
copper	selenium
iron	zinc
lead[6]	

Frequency

1. Perennial streams[7]
   a. Measure field water quality parameters monthly.
   b. Sample water for complete chemical analysis quarterly, especially during high and low flow periods. Record flow at time of sampling.
   c. Install a continuous recording device to monitor flow. Report monthly minimum, maximum, and mean flows.

2. Intermittent streams
   a. Sample frequency will be figured on an individual basis. The Water Resource Division will be consulted before initiating baseline studies. Record flow at time of sampling.
   b. Determine duration of flow season and seasonal peak flow.

3. Springs and seeps
   a. Measure field water-quality parameters monthly (pH, specific conductance, and temperature). Record flow at time of sampling.
   b. Sample water for complete chemical analysis quarterly. Record flow at time of sampling.

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[1]Not needed for springs and seeps.

[2]Dissolved species preferred (when applicable).

[3]Infrequent fraction analysis to determine carbon make-up.

[4]Initial separation of nitrogen compounds to determine make-up, i.e., ammonia (NH_3) and other organics versus NO_2 and NO_3.

[5]ICP package generally most economical if detection methods are deemed adequate.

[6]Separate sampling required to achieve necessary detection limits.

[7]Monitoring locations will be dealt with on an individual basis.

Table 7. Suggested ground-water-quality monitoring program for aquifer sites located in the vicinity of tar sands development. (Adapted from State of Colorado, 1982, and Flug, 1985.)

Parameters[1]

water temperature	ammonia
specific conductance	nitrate-nitrite
pH	phosphate
total dissolved solids	arsenic
calcium	cadmium
sodium	iron
magnesium	manganese
alkalinity	mercury
chloride	selenium
dissolved organic carbon (DOC)	sulfate
DOC analysis by fraction[2]	zinc

Frequency

Measure field water quality parameters (water temperature, pH, and specific conductance) monthly. Record elevation of water level in the well at the time of sampling. Sample water for complete chemical analysis two times per year.

[1]Dissolved species preferred (when applicable).

[2]Infrequent fraction analysis to determine carbon make-up.

Following completion of the recommended lease stipulation analysis for the protection of water resources, similar monitoring requirements may be proposed as stipulations in oil and gas leases affecting the recreation area.

IV.B. Research

IV.B.1. Floodplain identification and management. An inventory of flood hazard zones would be funded to cover all significant undeveloped public use points in the NRA. A flood frequency analysis would be required together with an analysis of regional gauging records to estimate magnitude. A more detailed level of investigation would follow, using field analysis of the flood history of specific drainages by examining remnant alluvial deposits.

Table 8. Proposed bacteria monitoring schedule for heavily-used beaches in Glen Canyon National Recreation Area.

Objective	Frequency	Sites (No. of samples)	Parameters
Intensive transect sample to define bacterial distribution pattern.	Six transect periods; two during low use, four during heavy use.	Lone Rock (15) Moqui Canyon (15) Bullfrog Creek (15) Farley Canyon (15)	Fecal coliform, fecal streptococcus*, total coliform*, temperature, pH, turbidity, specific conductance

*test in every third sample

IV.B.2. Shoreline water quality. A two-season investigation of bacterial distribution patterns at heavily used beaches is proposed (Table 8). This study would be accomplished using the established laboratory in the recreation area. It employs a stronger study design to allow a more thorough statistical analysis of bacterial distribution, and would help determine the causes of contamination.

IV.B.3. Springs, seeps, and waterpockets. A two-phase research project is proposed to supply baseline data on springs and seeps in the recreation area. In the first phase, chemical analysis of spring waters begun by Williamson (1985) would continue through identification of additional springs and seeps, chemical analysis for cations, anions, and trace elements, and measurement of discharge. The chemical baseline phase would be completed when chemical profiles are completed for each selected spring during seasonal low flows and seasonal high flow. Several of the springs studied by Hand (1979) would be revisited to check for long-term changes in chemical makeup under normal conditions. Investigative priority for different areas would be assigned based upon the existence of mineral lease proposals or other development potential. This project could be carried out as a multi-park study in conjunction with other NPS units investigating waterpockets, such as Capitol Reef National Park.

The second phase of the proposed research is the biological inventory of springs, seeps, and waterpockets. A particular focus of this study would be an inventory of the vertebrate and invertebrate aquatic life of these water resources. This phase of the research would have a very high interpretive value and may result in the detection of rare or unusual life forms in the NRA.

IV.B.4. Water resources as habitat for fish. A study of Lake Powell's primary productivity, nutrient status, and zooplankton populations is proposed. The research probably could best be accomplished as a cooperative effort between the National Park Service, the Bureau of Reclamation, and the Utah Division of Wildlife Resources. This work should be repeated every six to eight years. Once funded, the research would be initiated via competitive contract to a qualified investigator; the specific study design would be determined by the selected investigator. However, a suggested study accounting for the parameters and lake stations requiring investigation might be as shown in Table 9.

IV.C. Management

IV.C.1. Outstanding National Resource Waters. The Unique Waters nomination for the Lees Ferry segment of the Colorado River will be completed and forwarded to the State of Arizona. Consultation with state officials in Utah will be initiated to determine if criteria exist for similar designations in Utah.

IV.C.2. Water rights. The recreation area will continue to assert federal water rights through filings for consumptive uses and participation in water rights adjudications in Utah and Arizona. To maintain adequate background information for this activity, water requirements for specific uses will be quantified, including the instream flows needed for recreation and natural resources. This action will be implemented through coordination with the NPS Rocky Mountain Regional Office, the NPS Water Resources Division, and state agencies, all of which can assist in the development of background information and filing procedures. Water resources will be mapped, historical use documented, and statements of claim prepared as needed. Special projects may be proposed for funding to develop quantification of water needs for specific purposes.

IV.C.3. Floodplain identification and management. Backcountry flood hazards would be mapped and flood hazard information provided to visitors via brochures and/or at information stations. Hazard zones with relatively high use rates will be posted seasonally. Should funding become available to increase backcountry ranger patrols, these patrols will be directed at identified hazard zones when floods are anticipated or active. For the Paria River and other large drainages extending beyond the NRA, communication procedures will be established (or continued) with land managers upstream to provide early warning of flash floods descending on the recreation area. When high hazards are anticipated affecting known camping groups, the camps may be evacuated. Other measures may be proposed following completion of the recommended inventory of flood hazard zones.

IV.C.4. Shoreline water quality. The National Park Service proposes to phase in a program of management actions designed to eliminate an observed decline in water quality. Initial actions to be implemented could include the following:

Table 9. Study design for proposed primary and secondary productivity studies for Lake Powell.

Sampling frequency: Study to last 15 months and consist of nine sampling trips including:

Year 1	Year 2
June	January
July	March
August	June
November	July
	August

Stations:

Warm Creek Bay	Halls Crossing
Padre Bay	Hite
Escalante River Arm	Zahn Bay (San Juan Arm)

Physical parameters: Profile of water temperature, pH, specific conductance, dissolved oxygen, and photosynthetically available radiation.

Nutrients: Two samples will be taken at each site. One will be an integrated sample from 0-2.5 m, the second an integrated sample from 1-5 m. Nutrient determination will include:

dissolved species	total (unfiltered)
NH_4-N	total nitrogen
NO_2 and NO_3-N	total phosphorus
Si	
soluble reactive phosphate	

Phytoplankton: Chlorophyll *a* biomass and ^{14}C primary productivity determined at surface, 1 m, 3 m, 5 m, 7 m, 10 m, 15 m, 20 m, and 25 m at shallow stations; and at surface, 1 m, 3 m, 7 m, 10 m, 25 m, and 70 m at deep stations.

Zooplankton: Zooplankton identification and enumeration from integrated plankton tows at depths determined appropriate by the Utah Division of Wildlife Resources.

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1. Promulgate a regulation for Glen Canyon National Recreation Area (in Part 36, Code of Federal Regulations [36 CFR]) requiring the full containment of sewage (human waste) on all watercraft classified as "boats." Portable toilets would be required on board small boats; larger craft with holding tanks will be required to maintain a closed system for sewage. The existing prohibition of discharges under state law would remain as the basic regulation pertaining to boats with holding tanks, while the regulation in 36 CFR would specify penalties for violations. The regulation would require disposal of collected waste only at approved locations, and would describe recommended procedures for disposal. Enforcement of the regulation would be carried out through boat inspections by the National Park Service or other authorities in much the same way as it is for fire extinguisher and personal flotation device requirements.

2. Where monitoring reveals a potential public health problem as determined by water quality standards applicable to shoreline uses, NPS proposes to place signs or formal information stations explaining the health hazard and the sanitation requirements to reduce it. Temporary signs would be used in many instances because they can be removed once monitoring shows water quality to be within the standards again. Three sites most likely to require this action based on present monitoring are Lone Rock Beach, Farley Canyon, and Moqui Canyon.

3. Educational materials or discussions would be developed for presentation to the public at visitor contact points that would explain the effect of poor sanitation practices in natural areas on public health and provide instruction on desirable sanitation/camping practices. This action is needed because many people assume that land and water in a natural area such as Glen Canyon will be uncontaminated and healthful, and they are unfamiliar with proper outdoor camping and sanitation practices.

Based on the results of continued monitoring, the need for additional actions will be evaluated. Temporary beach closures at contaminated sites, developed sanitation facilities, and activity zoning of particular beaches are among the management actions that could be taken. These actions would be implemented where necessary to protect public health and the high-quality outdoor recreation experience presently available in the recreation area.

IV.C.5. Water quality of rivers for recreational use. Educational programs about water quality, disinfection techniques, and backcountry hygiene will be expanded through the distribution of pamphlets, interpretive talks, and other means. Signs may be erected at trailheads where a special warning is needed, particulary if *Giardia* is found to be present.

IV.C.6. Water resources of riparian ecosystems. The recreation area will develop a management policy emphasizing the inventory and protection of riparian communities along tributary streams. Consideration of instream flows and water quality needed to maintain riparian ecosystems would be required prior to the approval of actions that might diminish either resource. The policy will be published in appropriate public documents such as the Statement for Management (NPS 1985g) or individual project reviews.

IV.C.7. Water resources as habitat for fish. Better lines of communication with the Utah Division of Wildlife Resources, the Arizona Department of Game and Fish, and the U.S. Fish and Wildlife Service will be established to share data from existing programs and to develop new cooperative studies. Glen Canyon NRA will maintain a complete information base on aquatic resources based on all applicable data sources.

IV.C.8. Range management practices. The National Park Service will establish water resource management objectives for rangelands in Glen Canyon NRA to define "values and purposes" of the area with regard to water. These objectives will be communicated to the Bureau of Land Management in accordance with the interagency agreement and to range allottees of the NRA through BLM officials. The specific standards, listed in the problem statement section, emphasize maintaining flows, protecting natural waters from fouling by cattle, minimizing impact of cattle in riparian zones, and requiring the use of minimum-disturbance construction and management techniques on the land.

IV.C.9. Mineral extraction. The National Park Service will review lease stipulations commonly used in the intermountain West and other requirements protecting water resources from the effects of mineral development. Stipulations specific to Glen Canyon NRA leases would be developed for inclusion in all leases issued for NRA lands. All phases of oil and gas exploration, production, and well abandonment would be covered by the requirements, as would all phases of development for other minerals. Three specific standard stipulations would be adopted by this plan:

1. No drilling will be permitted within one-quarter mile of any spring or seep.

2. All abandoned wells or drill holes must be cemented from the bottom to the surface.

3. Natural water flows must be maintained in all operating areas.

IV.C.10. Energy-related wastes. The National Park Service proposes to augment information exchange and coordination efforts with the Salt River Project, Plateau Resources, and state water quality officials for the purpose of reviewing monitoring data pertinent to NRA waters.

IV.C.11. Management of hazardous materials spills. The National Park Service will finalize the hazardous spill contingency plan for Glen Canyon NRA and implement the recommended actions to prevent spills and have an adequate response capability should one occur. Facilities in the NRA will be inspected for spill-prevention features, and spill containment and cleanup materials will be obtained for NPS and concession facilities.

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IV. CONSULTATION AND COORDINATION

This Water Resources Management Plan was prepared jointly by specialists in Glen Canyon National Recreation Area and in the Water Resources Division of the National Park Service. The following individuals and organizations contributed information, assistance, and/or review:

AGENCIES

U.S. Department of the Interior
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The many drafts of this report were typed by Patti Stromer of Glen Canyon National Recreation Area and Joan Manson of the National Park Service, Denver Service Center. Dick Morishige, also of the Denver Service Center, coordinated the publication of this document. Editing and preparation of the final draft were provided by Juliette Wilson, Colorado State University/National Park Service, Water Resources Division.

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Copies of this Draft Water Resources Management Plan are available through the Superintendent, Glen Canyon National Recreation Area, P.O. Box 1507, Page, AZ 86040. (602) 645-2471

Water Resources Management Plan – GCNRA

Intro
A. 1. 1st for GCNRA
2. Intended to serve for 10 years
3. Mgmt. Actions Proposed on an Env. Assessment is incorporated into this plan.

B. Purpose of Plan.
1. GCNRA – established via PL 92-593 10/27/72
2. 163,000 acre Lake Powell. + 5 TRIBS.
3. Includes water mgmt. of Rainbow Bridge National Monument.

What about selenium?

What about plankton (BG)?

Reservoir Dynamics? → salinity