Water Resources Management Plan

BIGHORN CANYON *National Recreation Area*

1996

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I. INTRODUCTION

Bighorn Canyon National Recreation Area (hereafter referred to as the "Park") is a diverse area in southeastern Montana and north-central Wyoming (Figure 1). The Park was established as a part of the National Park System by Public Law 89-664 on October 15, 1966 in order to "...provide for public outdoor recreation use in the states of Wyoming and Montana by the people of the United States and for preservation

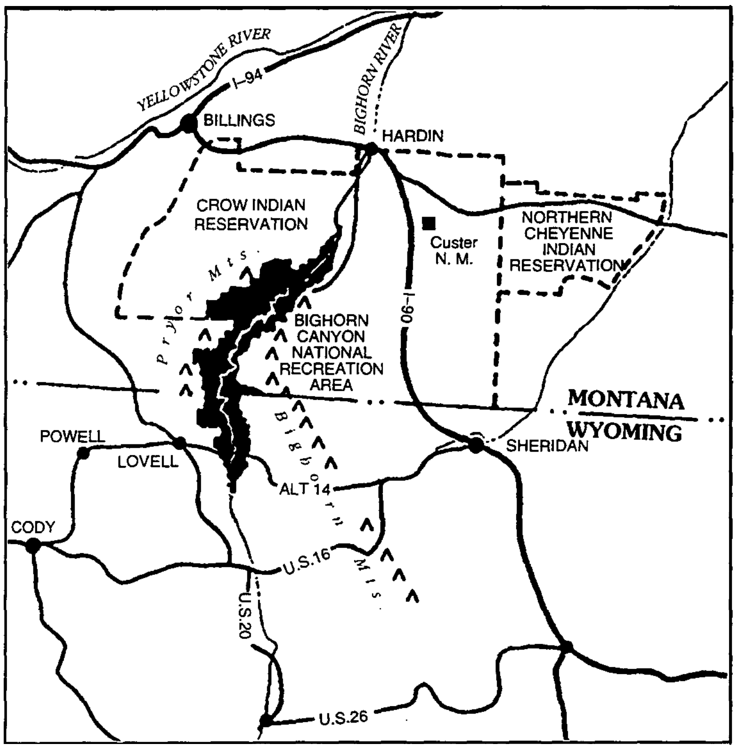

Figure 1. Location of Bighorn Canyon National Recreation Area

of the scenic, scientific, and historic features contributing to public enjoyment of such lands and waters..." The law also provides for utilizing renewable natural resources and for entering into cooperative agreements with other Federal and state agencies for the joint administration and use of the various land and water areas within and adjoining the Park.

Diverse landscape features and land uses are present in and around the Park. The Park's boundaries currently encompass 48,703 ha (120,296 ac) of forests, upland prairies, deep canyons, broad valleys, portions of streams, Bighorn Lake, Yellowtail Dam, Yellowtail Afterbay Dam, and Yellowtail Afterbay Reservoir. Bighorn Lake is a 115-km-long (71-milong) reservoir created by Yellowtail Dam as part of the U.S. Department of Interior (USDI), Bureau of Reclamation's Upper Missouri River Basin Project. The Yellowtail Afterbay Dam and Reservoir are situated immediately below Yellowtail Dam and are operated to diminish fluctuations in water levels of the Big-horn River downstream of Yellowtail Dam. About half of the lands (22,642 ha or 55,947 ac) within the Park's boundaries are Crow Tribal lands, locally referred to as "added lands". These lands are not owned by the National Park Service (NPS) and are outside the jurisdiction of the NPS. They are excluded from specific management considerations in this plan (Figure 2). Bighorn Lake is by far the most prominent feature within the 27,715 ha (68,484 ac) of Federal land within Park boundaries.

Diverse interests and land uses of several Federal agencies, the Crow Tribe, two state agencies, local community organizations, and an array of private groups influence the management of the Park. Some of the local and regional interests in the vicinity of the Park include crop production, energy production, fish and wildlife management, residential development, management of wild horses, water-based recreation, grazing of domestic livestock, and protection of scenic and cultural resources. In this complex setting, the NPS has the responsibility of managing the Park to: (1) provide recreational access and services, (2) protect and interpret the Park's natural and scenic resources, and (3) preserve, restore, and interpret the Park's cultural re-sources (NPS 1992, Table 1).

Water is a valuable commodity in the Park and in the surrounding region. The Park is located in a semi-arid portion of the United States where precipitation averages less than 50 cm

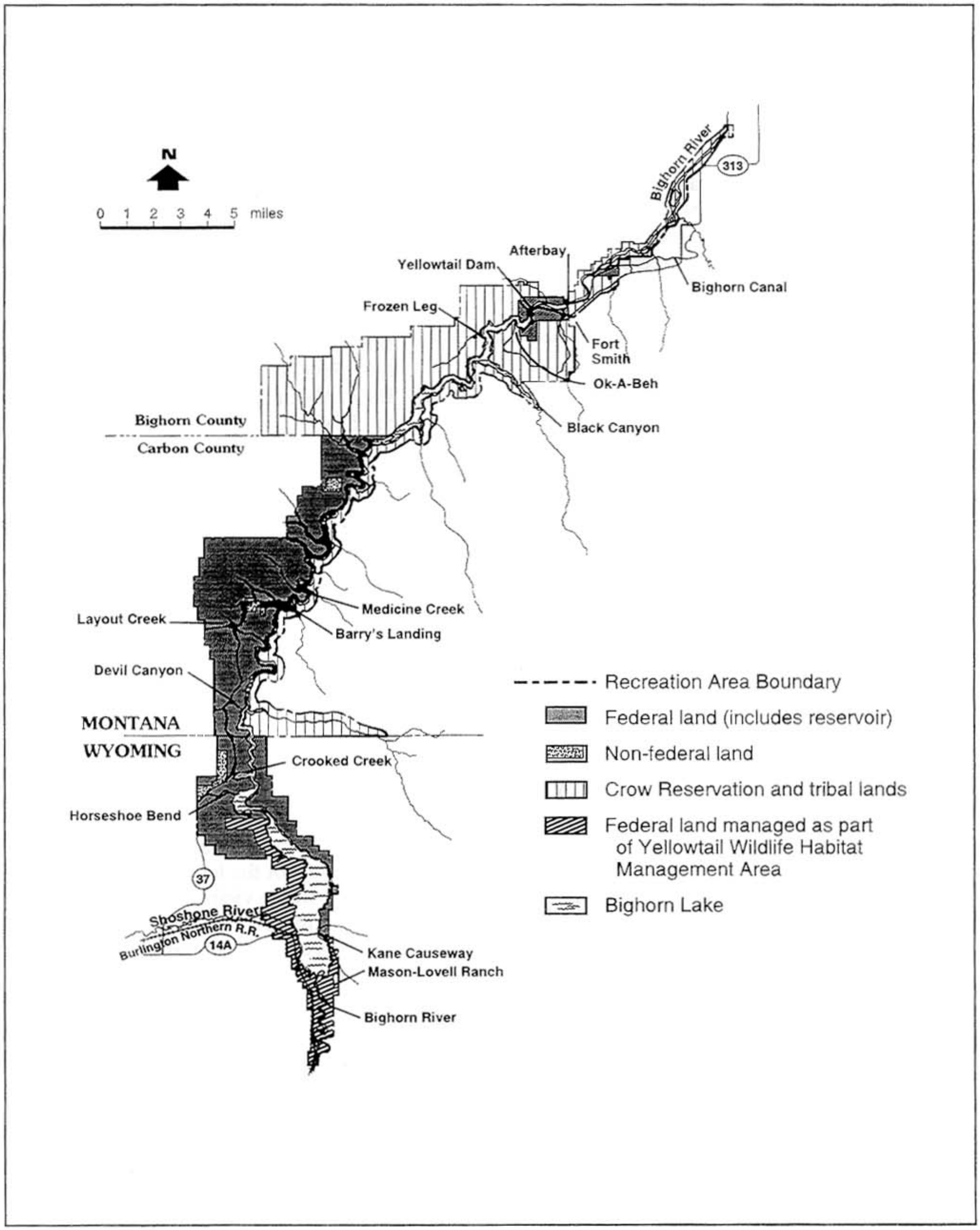

Figure 2. Landownership within the boundaries of Bighorn Canyon National Recreation Area.

(20 in) per year in wet areas of the Park and as little as 18 cm (7 in) per year in dry areas. Water resources are available in a variety of forms, and both natural and cultural systems depend on this water. The area is part of the Missouri River Drainage, with Yellowtail Dam creating one of the largest reservoirs on this riverine system. The Bighorn River is the major river flowing into Bighorn Lake, and the Shoshone River, a major tributary of the Bighorn River, enters the lake at the southern end of the Park. Several small streams drain into the lake from the east and west. In most instances, the Park encompasses only the extreme lower reaches of these streams, although short segments of some tributaries are part of the recreation area, primarily in the southwest portion of the Park. Springs, seeps, constructed ponds, canals, and groundwater are other water bodies present in the Park. These resources are described in detail in Section II of this plan.

PURPOSE OF THE WATER RESOURCES MANAGEMENT PLAN

This Water Resources Management Plan, the first for the Park, is designed to serve as a tool to guide the management of water resources by the Park over the next 10 to 15 years. This plan is intended to be complementary to and consistent with other existing Park management documents, including the General Management Plan (NPS 1981), Natural and Cultural Resources Management Plan (NPS 1994b), Statement for Management (NPS 1992), and the 1994 Management Assessment Workshop (NPS 1994a).

In order to achieve management goals and objectives, NPS policies require that each unit develop and implement a General Management Plan. The Bighorn Canyon National Recreation Area General Management Plan (NPS 1981) provides the overall basis for managing the area's resources, uses, and facilities. The Park's current General Management Plan is the original document adopted following designation of the area in 1966 and is in need of revision (NPS 1994a). Although the General Management Plan does not contain a list of specific management objectives, it specifies that most initial development of the area will be in support of camping, water-based recreation, and interpretation. Interpretation of land-based resources is to increase commensurately with advances in research, cooperative planning with other agencies and interests, and availability of NPS funds and staffing for interpretive programs.

The Park's Statement for Management (NPS 1992), a more frequently revised document than the General Management Plan, includes specific objectives for the area ranging in subject matter from coordination to resource protection (Table 1). The top ten management priorities identified during a workshop held in Lovell, Wyoming by

Table 1. Management objectives identified in the Bighorn Canyon National Recreation Area Statement for Management (NPS 1992).

Objectives are to:

- Include the general public in planning processes and keep public informed about major Park issues and developments.
- Maintain working relationships with other Federal and state land management agencies, state and county governments, local communities, and the Crow Tribe for the purpose of addressing common issues, providing or receiving assistance, and maintaining communications.
- Protect and manage natural and cultural resources in such manner and by such means whereby they can be passed on to future generations.
- Provide programs and facilities that provide visitors and school children opportunities to learn about Park resources and the unique environment of Bighorn Canyon and the surrounding area.
- Develop and maintain Park facilities for the purpose of providing for visitor needs. Incorporate life, health, and safety standards into maintenance and operations.
- Provide for emergency responses, fire protection, and for enforcement of laws and regulations for the purpose of protecting visitors and park resources.

the NPS in the summer of 1994 centered around meeting these objectives (Table 2). The purpose of this workshop, which was conducted with extensive public participation, was to reaffirm the Park's role and purpose and its relation to the National Park System (NPS 1994a).

Water resources planning for a unit of the National Park System typically involves several steps (Figure 3). Planning starts with consideration of the reasons for a park's establishment and identification of the exceptional water-related resource values of a park. The Water Resources Management Plan provides resource-specific information to support the NPS decision-making process related to the protection and management of a park's water resources and water-dependent environments. It includes a review of available information about a park's water resources and water-dependent environments, descriptions of significant water-resources management issues, and information about constraints on water management brought about by the park's enabling legislation. Additionally, the plan provides a recommended management program for water resources, including recommended actions for inventory and monitoring, resource management, and research. Part of the recommended management is a set of project statements prepared following guidelines of the NPS and designed to be incorporated into a park's Resource Management Plan.

WATER RESOURCES MANAGEMENT GOALS AND OBJECTIVES

Water resources are broadly defined for the purposes of this plan. They include the physical and chemical attributes of surface and ground waters, the biological components of the aquatic system, habitat characteristics (e.g., number and size of pools, amount of woody debris, canopy cover, and streambed materials), and the transition zone between the aquatic and terrestrial systems, which occurs in the form of wetlands and riparian areas. The water resources are themselves components of a larger system consisting of natural and cultural components. Components of this larger system that are interrelated and interdependent with the water resources of the Park include climate, geology, watersheds, caves, terrestrial communities of plants and animals, and cultural features such as visitor facilities, local communities, and historic land uses. Water resources

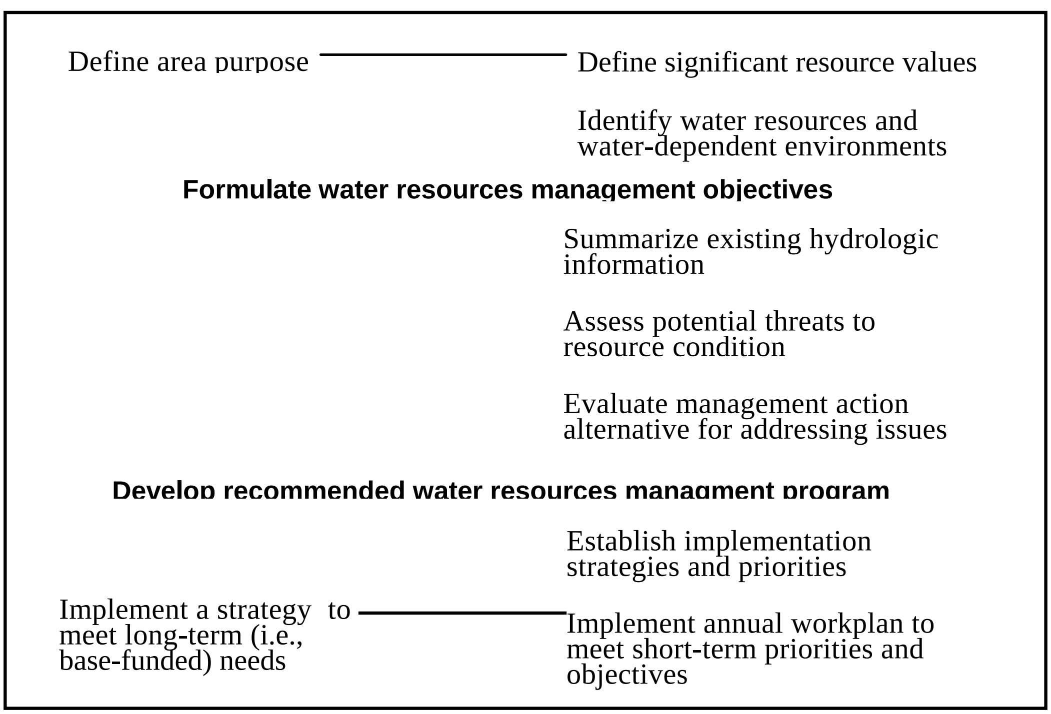

Figure 3. The water resources management planning process.

Table 2. The top ten issues identified during a Bighorn Canyon National Recreation Area Management Assessment Workshop in June, 1994 in Lovell, Wyoming (NPS 1994a).

Top ten **issues are:**

- Agreement with Crow Tribe, including boundary and jurisdictional issues.
- Update General Management Plan.
- Park headquarters—location to best meet needs of people and resources.
- Priorities of Park: Where should time and dollars go?
- Management of water levels for fisheries and recreation activities.
- Human impact on resources.
- Management of Yellowtail Wildlife Habitat Management Area.
- Commercial-use license for fishing outfitters and guides.
- Partnerships to enhance interpretation and education activities.
- Commercial services planning.

'Action statements and assignments were developed for each of these issues. Twelve other issues were identified, but action statements were not developed for them.

Table 3. Significant water and water-related resources of Bighorn Canyon National Recreation Area.

Resources include: Bighorn Lake

Portions of streams flowing through Bighorn Canyon National Recreation Area into Bighorn Lake

Ponds developed as part of the Yellowtail Wildlife Habitat Management Area

Ground water and associated seeps and springs that maintain riparian, wetland, and aquatic habitats and provide water supplies

Cottonwood-dominated woodlands in Bighorn River Floodplain

Other riparian and wetland communities associated with aquatic habitats

Biological communities associated with aquatic habitats

are particularly important and sensitive ecosystem components in a semi-arid system such as the Park. The physical availability and quality of water are critical determinants not only of aquatic resources, but of the characteristics of an area's natural and cultural resources. These water resources also provide important linkages within ecosystems, connecting resources within the Park with resources outside Park boundaries. From this perspective, significant water resources of the Park are numerous and diverse (Table 3).

Because of the important role of water in maintaining resources, it is the policy of the NPS to seek to maintain, rehabilitate, and perpetuate the inherent natural integrity of water resources and water-dependent environments within units of the National Park System (NPS 1991). This is comparable to preserving options and avoiding large-scale, irreversible change due to human land-use practices that influence the water resources and the larger natural systems within which these resources reside. At the Park, the ability of managers to achieve this goal is limited by the construction of major water impoundments, which have substantially changed the Park's natural features and the land uses within the surrounding region. Recognizing this limitation, management objectives have been developed to guide actions related to water resources issues within the Park (Table 4). These guide the evaluation of water-related issues and the development of approaches to deal with them. Specific management actions for water resources that are consistent with these objectives are described in the project statements of this plan.

LAND AND WATER STATUS AND USE

The Park consists of a mixed land base in terms of categories of land ownership (Figure 2). The Park's lands in Wyoming are a mix of Congressionally authorized lands and acquired lands. Ownership and management jurisdiction issues are particularly complex in Montana where four primary categories of land exist within the Park's boundaries. Using the terminology adopted by the USDI Office of the Solicitor, these four categories are: Congressional-take areas, administrative-take areas, Crow Tribal lands, and acquired areas of the NPS (USDI, Office of the Solicitor Memorandum, Aug 7, 1973). Congressional-take areas are lands for which the Crow Tribe received compensation

Table 4. Management objectives for water resources of Bighorn Canyon National Recreation Area.

Management objectives are to:

- Acquire appropriate baseline information to adequately understand and manage water-related resources.
- Use state appropriative and federal reserved water rights to acquire and maintain adequate flows to protect water-related resources.
- Coordinate with the Bureau of Reclamation to manage reservoir levels and releases to provide optimal recreational use and protection of natural, cultural, scenic, and scientific resources.
- Maintain high water quality for water-oriented recreation and for the protection of natural and scenic resources.
- Maintain a recreational sport fishery with emphasis on management of viable populations of native species.
- Provide for a reasonable degree of visitor safety associated with water-related hazards, including lakeshore slumping, driftwood, and use of floodplains.
- Mitigate, when possible, the effects of erosion and sedimentation on park facilities and resources.
- Recognize the significance of wetlands and riparian areas and manage these resources in a manner to preserve their natural functions and integrity. Where these resources are influenced by the presence of the dam, strive to maintain and restore natural values and functions.
- Promote water conservation through direct action of the National Park Service, education, and cooperation with local communities and with regional, state, and federal agencies.
- Provide adequate and appropriate water supplies, sewage treatment, and sewage disposal at all National Park Service facilities.
- Protect park resources from spills of hazardous materials by maintaining and implementing a current spill contingency plan.
- Establish and maintain cooperative relationships with local, state, and federal governments and private entities to further the above objectives.

for the transfer of most rights, titles, and interests. These lands are not subject to laws relating solely to Indian lands and reservations. Administrative-take areas are Indian reservation lands acquired from allottees or from non-Indian owners of reservation lands without a special act of Congress. These lands have a status similar to that of fee patent lands within a reservation. Tribal lands are those reservation lands included in the Congressional boundaries pursuant to a memorandum of understanding first signed on December 1, 1967 between the Crow Tribe and the NPS (see below). Acquired areas are non-reservation lands acquired by the NPS under the Bighorn Canyon National Recreation Area Act (P.L. 89-664). Although Crow Tribal lands constitute nearly half of the 48,703 ha (120,296 ac) of land within boundaries of the Park, these lands are addressed in this plan only to the extent that activities on these lands affect Park resources. This approach is consistent with current wishes of the Crow Tribe and the treatment of comparable lands in other Park plans.

The history of events leading to the current administrative arrangement is complex. A memorandum of agreement was signed in 1967 between the Crow Tribe of Montana and the NPS to facilitate establishment, development, administration, and public use of lands within the boundaries of the Park. The agreement, identified as No. CA-Secy-67-01, added 22,651 ha (55,947 ac) of reservation lands to the Park. A decade later, the Crow Tribal Council passed Resolution No. 76-32 on April 10, 1976 and rescinded the 1967 memorandum of agreement. Although formal and informal negotiations have taken place since then, agreement on the contents of a revised memorandum has not been reached. A moratorium has been placed on further developments of lands of the Crow Tribe within the recreation area until the issue of differences in the memorandum of agreement is resolved. The Crow Tribe is currently requesting removal of these lands from the boundary of the Park and complete relinquishment of any management interests on the part of the NPS (D. Cook, Superintendent, Bighorn Canyon Natl. Rec. Area, pers. comm., Mar. 1995).

Land uses within the boundaries of the Park on lands actually administered by the NPS are varied. Water-based recreation is a primary activity, with support facilities available in the form of campgrounds, boat ramps, parking lots, and two small marinas. Small portions of the Park are set aside to preserve and maintain historic structures and protect cultural sites, but resources to carry out these programs are limited. The Park has four historic ranch sites and several hundred prehistoric sites; seven sites are on the National Register of Historic Places. Cattle grazing occurs on the Dryhead Allotment in the west-central portion of the Park, which consists of 4,654 ha (11,505 ac) of pasture with lifetime tenure for ranchers who used the area prior to acquisition by the Federal Government. Herding of cattle also occurs through designated portions of the Park as herds pass between private lands or from private to public grazing lands outside the Park. Under a memorandum of agreement with the Wyoming Game and Fish Commission, 4,696 ha (11,600 ac) of the Park near the town of Lovell, Wyoming are part of the Yellowtail Wildlife Habitat Area. These lands are commonly referred to as "Area B Lands", and a small portion of these Park lands is farmed for purposes of wildlife management (see page 16). Open rangeland (3,683 ha, 9,100 ac) along the west-central edge of the Park is part of the much larger Pryor Mountain Wild Horse Range managed by the Bureau of Land Management (BLM). The Park's portion of the range is known as the Dryhead Herd Area and is closed to cattle grazing.

Numerous private mineral rights for oil and gas, sand, and gravel are present in the Park and will remain as private property unless they are purchased or otherwise acquired by the NPS. No systematic review or mapping of private mineral ownership has been conducted within the Park. Most of the sand and gravel areas are located within or near riparian areas where any surface-disturbing activity or roads to extract minerals would be detrimental under the management objectives of the Park. In addition to private mineral rights, several claims exist in the Park, staked under the 1872 Mining Act. Validity determinations were conducted for bentonite and uranium claims, and only five unpatented claims remain. The other claims are assumed to be valid until a formal determination can be conducted.

Administrative and visitor centers are present at north and south ends of the Park, and some staff housing is present within the Park. The housing consists of a mix of house trailers, transportable modular homes, custom-built homes, and one residence at the historic Ewing-Snell Ranch.

Land ownership and use patterns outside the Park are even more diverse than those within Park boundaries. The nearest towns are Lovell, Wyoming with a population of slightly over 2,000 residents at the southern end of the Park, and Fort Smith, Montana, with a population of about 100 residents at the northern end of the Park. The Crow Reservation extends north and east of the Park, with a mix of Indian and non-Indian ownership of this reservation land. Grazing, irrigated agriculture, non-irrigated agriculture, and timber production are prevalent on these reservation lands. The BLM administers much of the land adjacent to the southern end of the Park, with grazing the predominant land use. There are also a number of inactive uranium mines adjacent to the Park, mostly on BLM lands. A semi-precious gem called Dryhead agate is quarried intermittently near Deadman Creek on lands adjacent to the Park. The U.S. Forest Service has land holdings immediately west and east of the recreation area in Custer National Forest and Bighorn National Forest. These lands are managed for multiple uses, including grazing, timber harvest, recreation, and wilderness. Lands that are entirely outside the jurisdiction of the NPS but part of the Wyoming Game and Fish Department's Yellowtail Wildlife Habitat Management Area include State of Wyoming, BLM, and Bureau of Reclamation lands, the latter covering 1,133 ha (2,800 ac) and commonly referred to as "Area A lands". Private land holdings are extensive within the vicinity of the Park, are primarily concentrated in the floodplains of the major rivers, and are principally used for agriculture, grazing of domestic livestock, mining, and residences.

The region in which the Park occurs has a long history of human use. As summarized in the Park's General Management Plan and supported by descriptions in Bearss (1970), the earliest evidence of human occupation and use of the Bighorn Canyon and Pryor Mountain area is from the end of the Pleistocene when Paleo-Indians wandered widely throughout the area. Crow Indians and other Native American tribes utilized the Bighorn Canyon area until they were joined by Euro-Americans starting with the arrival of fur traders, miners, cattle ranchers, farmers, and the U.S. Army in the 1800s. The Crow were renowned hunters and horsemen at the time that Euro-Americans began arriving in large numbers to conduct ranching and farming. The Indians made a remarkable transition from hunter-gatherers to a farming and ranching lifestyle in less than a generation in order to accommodate changes accompanying Euro-American settlement. Notably, from 1893 to 1904, the Crow Indians built an irrigation system known as the Bighorn Canal at the northern end of the canyon, which opened 14,140 ha (35,000 ac) of arid land to irrigated farming. The first Crow Indian Reservation was established by treaty with the United States in 1868, and the major settlement on this reservation was moved in 1884 to its present location at Crow Agency on the Little Bighorn River in Montana.

The free-flowing nature of the Bighorn River above the Park has been greatly altered by several large irrigation, power, and flood-control projects. Akashi (1988), in her thesis on riparian vegetation dynamics, provides an excellent summary of these alterations, with references to USDI (1953, 1974, 1980, 1983) and Wyoming (undated). Current information on operation of dams and reservoirs in the Upper Missouri River Basin is provided annually by the Bureau of Reclamation (e.g., But of Reclamation 1994).

The first organized large-scale irrigation system along the Bighorn River was initiated near Worland, Wyoming in 1885 and marked the beginning of commercial crop production in Wyoming. Under the Carey Act of 1894 and the Reclamation Act of 1902, state and Federal developments of irrigation systems began along the Bighorn River and its tributaries. Several dams also were built by private citizens. A concrete dam was constructed across the Wind River Canyon during 1907-1908 by a Danish immigrant to provide power for gold and copper mining. The Sunshine Dam was built on the Greybull River in 1939 for irrigation by a group of private individuals. The Buffalo Bill Dam and Reservoir system on the Shoshone River about 100 km (60 mi) upstream of the Park was constructed in 1910 for irrigation, power generation, and some incidental flood control. This is the only major dam on the tributaries of the Bighorn River upstream of the Park, and storage capacity of the reservoir is 5.2 x $10^{\$}$ m^3 (423,974 ac-ft) (Bur. of Reclamation 1994).

Major modification to natural flow on the Bighorn River itself began with the construction of Boysen Dam about 150 km (95 mi) upstream of what is now the Park. Construction of this dam across the Wind River Canyon began in 1947 and was completed in 1952 under the Pick-Sloan Missouri Basin Program. Justification for the project was flood control, power generation, irrigation, recreation, and fish and wildlife. Storage capacity of Boysen Reservoir is 11.7 x 10^8 m^3 (952,432 ac-ft).

Yellowtail Dam was completed in 1965 across the northern end of Bighorn Canyon to provide for power generation, irrigation, flood control, fish and wildlife, and recreation. The Afterbay Dam and its small reservoir were completed in 1966 about 3.5 km (2.2 mi) downstream from Yellowtail Dam to store and re-regulate peaking power releases from Yellowtail Power Plant, providing a more stable flow in the Bighorn River than possible without the Afterbay Dam. Additional information about these dams and their reservoirs is provided starting on page 37.

As previously stated, the Park was established to provide for public use of the reservoir and the surrounding park lands, and for the preservation of scenic, scientific, and historic features contributing to public enjoyment of the lands and waters within the Park. Nonetheless, the Park does not have authority to regulate reservoir levels to achieve these goals, rather, this authority resides with the Bureau of Reclamation. This situation exists because the Park was created in conjunction with the reservoir. The reservoir was created with designated water storage and release purposes. When decisions regarding lake levels and flow releases are made, the Bureau of Reclamation considers the Park's water-level concerns and needs along with those of other groups using the water.

LEGISLATIVE AND PLANNING RELATIONSHIPS

The following state and Federal statutes, regulations, and executive orders have regulatory significance regarding water resources management at the Park. A description of the applicable tenets of each statute is provided.

Federal Legislation and Authorities

NATIONAL PARK SERVICE ORGANIC ACT (1916)

The Organic Act specifies that the NPS is responsible for the preservation and conservation of natural resources in all parklands under its jurisdiction. This act was reinforced by Congress in 1970 with legislation stating that all parklands are united by a common purpose of preservation, regardless of title or designation. Hence, all water resources in the National Park System are protected equally by Federal law, and it is the fundamental duty of the NPS to protect those resources unless otherwise indicated specifically by Congress.

PUBLIC LAW 89-664

The legislation that established Bighorn Canyon National Recreation Area includes a number of provisions relating to the water resources of the park.

- Notwithstanding any other provisions of Public Law 89-664 or any other law, the Crow Indian Tribe shall be permitted to develop and operate water-based recreational facilities, including landing ramps, boathouses, and fishing facilities along the shoreline of Bighorn Lake that is adjacent to lands comprising the Crow Indian Reservation. Any such part so developed shall be administered in accordance with the laws and rules applicable to the recreation areas, subject to any limitations specified by the tribal council and approved by the Secretary of the Interior. Any revenues resulting from the operation of such facilities may be retained by the Crow Indian Tribe.
- The Secretary of the Interior shall permit hunting and fishing on lands and waters under his jurisdiction within the recreation area in accordance with the appropriate laws of the United States and of the states of Montana or Wyoming to the extent applicable. The Secretary may designate zones where, and establish periods when, no hunting or fishing is permitted for reasons of public safety, administration, fish or wildlife management, or public use and enjoyment. The Crow Tribe and its members retain the right to hunt and fish on lands of the Crow Tribe that are included in the recreation area, and the rights of the members of the Crow Tribe to hunt and fish under section 2(d) of the Act of July 15, 1958 are retained. Except in emergencies, any regulations of the Secretary pursuant to this section shall be put into effect only after consultation with the Montana Fish and Game Department or the Wyoming Game and Fish Commission.
- No part of the Tribal mountain lands or any other lands of the Crow Tribe of Montana are included within the recreation area unless requested by the Council of the Tribe. The Indian areas so included may be developed and administered in accordance with the laws and rules applicable to the recreation area, subject to any limitation specified by the tribal council and approved by the Secretary.

FEDERAL WATER POLLUTION CONTROL ACT

The Federal Water Pollution Control Act, commonly known as the Clean Water Act, was first promulgated in 1972 and amended in *1977,* 1987, and 1990. This law was designed to restore and maintain the integrity of the nation's water. Goals set by the act were swimmable and fishable waters by 1983 and no further discharge of pollutants into the nation's waterways by 1985. The two strategies for achieving these goals were a major grant program to assist in the construction of municipal sewage treatment facilities and a program of "effluent limitations" designed to limit the amount of pollutants that could be discharged.

As part of the act, Congress recognized the primary role of the states in managing and regulating the nation's water quality within the general framework developed by Congress. All Federal agencies must comply with the requirements of state law for water-quality management, regardless of other jurisdictional status or land ownership. States implement the protection of water quality under the authority granted by the Clean Water Act through best management practices and through water-quality standards. Best management practices are defined by the U.S. Environmental Protection Agency (EPA) as methods, measures, or practices selected by an agency to meet its nonpoint control needs. These practices include but are not limited to structural and non-structural controls, operational procedures, and maintenance procedures. They can be applied before, during, and after pollution-producing activities to reduce or eliminate the introduction of pollutants into receiving waters (Code of Federal Regulations 1990). Water-quality standards are composed of the designated use or uses made of a water body or segment, water-quality criteria necessary to protect those uses, and an anti-degradation provision to protect the existing water quality. Federal legislation and regulations generally are implemented by the states, with the EPA serving in an oversight role. A triennial review of a state's water-quality regulatory program is conducted by each state's water-quality agency to determine if its standards are adequate to meet Federal requirements. These standards are then forwarded to the EPA for approval.

Section 404 of the Clean Water Act requires that a permit be issued for discharge of dredged or fill materials in waters of the United States, including wetlands. The Army Corps of Engineers administers the Section 404 permit program with oversight and veto powers held by the EPA.

FEDERAL RESERVED WATER RIGHTS

When the Federal Government reserves land for a particular purpose it also reserves, commonly by implication, enough water unappropriated at the time of the reservation as is necessary to accomplish the primary purposes for which Congress or the President authorized the land to be reserved. The right to the water vests as of the date of the reservation, whether or not the water is actually put to use, and is superior to the rights of those who appropriate the water after the reservation date. Depending upon the purposes of the reservation, Federal reserved rights may include water for consumptive uses, such as domestic and irrigation, as well as non-consumptive uses such as instream flow.

General adjudications are the means by which the Federal Government claims its reserved water rights and waives its immunity from suit pursuant to the Act of June 10, 1952 (66 Stat. 560, 43 U.S.C. 666) (McCarran Amendment). Commonly in a general adjudication, all water users on a stream and its tributaries must claim their water rights, and after considering evidence and testimony, the court issues the decree(s) setting forth the rights within the adjudicated area, including the Federal re-served water rights. Adjudications are generally in state courts, but Federal courts have concur-rent jurisdiction.

FLOODPLAIN MANAGEMENT (EXECUTIVE ORDER 11988, 1977)

The objective of this executive order is to require agencies to avoid to the extent possible the long-term and short-term adverse impacts associated with occupancy and modification of floodplains, and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative. The NPS has developed guidelines for management of floodplains in parks (45 FR 35916), most recently revised in 1994.

PROTECTION OF WETLANDS (EXECUTIVE ORDER 11990, 1977)

This order furthers the purposes of the National Environmental Policy Act of 1969 by directing Federal agencies to avoid to the extent possible the long- and short-term adverse impacts associated with the destruction or modification of wetlands and to avoid direct or indirect support of new construction in wetlands when practicable alternatives exist. The NPS Flood-plain Management and Wetland Protection Guidelines (45 FR 35916, with minor revisions for wetland guidelines incorporated in 47 FR 36718 on August 23, 1982) outline NPS requirements for complying with Executive Order 11990. NPS Wetland Guidelines are scheduled for revision starting in 1996.

OTHER APPLICABLE FEDERAL LAWS

National Environmental Policy Act (1969). This law requires a systematic analysis of major Federal actions including a consideration of reasonable alternatives and an analysis of short- and long-term irretrievable, irreversible, and unavoidable impacts. The projects proposed in this plan will be evaluated individually according to NEPA requirements once it is reasonably certain a project will be carried out (e.g., when funding becomes available).

Endangered Species Act (1973). This act provides for the conservation, protection, restoration, and propagation of selected species of native fish, wildlife, and plants that are threatened with extinction. All entities using Federal funding must consult with the Secretary of the Interior, through the U.S. Fish and Wildlife Service, on activities that potentially affect endangered flora and fauna.

Water-Quality Improvement Act (1970). This act requires Federally regulated activities to have state certification that they will not violate standards for water quality .

Safe Drinking Water Act (1974) and Amendments (1986). This act sets national minimum water-quality standards and requires regular testing of drinking water for developed public drinking water supplies.

Mining in the Parks Act (1976). This act closed any remaining NPS units to the location of mining claims and directed the Secretary of the Interior to regulate all activities within NPS units in connection with the exercise of mineral rights on claims.

Federal Cave Resources Protection Act (1988). This act is intended to secure, protect, and preserve significant caves on Federal lands for use, enjoyment, and benefit of people and to foster cooperation in use of caves on Federal lands for scientific, educational, or recreational purposes.

Taylor Grazing Act (1934). This act emphasizes the livestock industry and the use of Federal land for grazing purposes. Stock owners obtained privileges to the lands being grazed.

American Indian Religious Freedom Act (1978). This act declares policy to protect and pre-serve the inherent and constitutional right of Native Americans to believe and express their traditional religions.

Archaeological Resources Protection Act (1979). This act secures the protection of archaeological resources on public or Indian lands and fosters increased cooperation and exchange of information between groups in order to facilitate the enjoyment and education of present and future generations.

National Historic Preservation Act (1966). This act primarily declares a national policy of historic preservation, authorizes the Secretary of the Interior to expand and maintain a National Register of Historic Places, and provides funding for acquiring and developing historic properties.

Resolutions of the Crow Tribal Council

RESOLUTION 67-59

Following passage of the Park's enabling legislation and negotiations between the Crow Tribe and the NPS, the Crow Tribal Council passed Resolution 67-59 on May 20, 1967 and approved a draft memorandum of agreement for the inclusion of 22,651 ha (55,947 ac) of reservation lands within the boundaries of the recreation area. A modified version of this agreement was signed by a representative of the Crow Tribe and a representative of the Department of Interior on December 1, 1967. The Secretary of Interior adjusted the boundaries of the Park to include these reservation lands by publication of a boundary description in the *Federal Register* on October 2, 1968.

RESOLUTION 73-06

The Crow Tribal Council passed Resolution 73-06 in October, 1973. This resolution called for the renegotiation of Resolution 67-59 and approval of the agreement by the entire Crow Tribal Council. Planning activities by the NPS for a proposed trans-park road were pivotal points of discussion in passage of this tribal resolution.

RESOLUTION 76-32

Controversy over the development of the trans-park road continued in 1974, including objections by the Montana Wildlife Federation and Montana Wilderness Association. A tribal resolution concerning the road and withdrawal of lands from the Park was tabled at the October 12, 1974 meeting of the Crow Indian Tribe. A lawsuit filed by the two Montana environmental groups resulted in a temporary injunction on road construction, but by November 1977, the road leading between two lake access points, Horseshoe Bend and Barry's Landing, at the south end of the Park was constructed. The Crow Tribal Council passed Resolution 76-32 on April 10, 1976, which called for withdrawal of all tribal lands formerly included in the Park, denial and rejection for the construction of roads across tribal lands, and invalidation of the 1967 memorandum of agreement. The Secretary of the Interior then instructed the NPS to place a moratorium on any further development of Crow Tribal Lands with the Park until the 1967 memorandum was renegotiated. The Crow Tribe continues to request deletion of added lands (letter from R.S. Pelcyzer, representing Crow Tribe, to Secretary of Interior dated March 10, 1995), and the NPS currently supports this request (D. Cook, Superintendent, Bighorn Canyon Natl. Rec. Area, pers. comm., Mar. 1995).

State Statutes

Some legal authority for maintaining the quality of surface- and ground-water resources, fish and wildlife populations, and other water resources of the park are provided under state laws and regulations. Compliance with the various laws is complicated because boundaries of the park encompass land and water in Wyoming and Montana. State laws and regulations often are similar but not always consistent between states.

WYOMING STATUTES 35-11-101 THROUGH 1304 (WYOMING ENVIRONMENTAL QUALITY ACT).

The State of Wyoming adopted water-quality rules and regulations pursuant to Wyoming Statutes 35-11-101 through 1304. This set of rules limits activities that can alter characteristics of water based on the classification of the various bodies of water within the state. Four classes of surface water are recognized in Wyoming for purposes of water-quality management, with Class 1 carrying the highest standards for water quality. Class 1 waters in Wyoming are the equivalent of Outstanding National Resource Waters (J. Wagner, WY Dept. Env. Qual., Cheyenne, pers. comm., Apr. 1995). Although the Wyoming water-quality rules and regulations specify that all surface waters located within the boundaries of national parks and congressionally designated wilderness areas are Class 1 waters, the state does not apply this stipulation to the Park because of its designation as a "recreation area" rather than a "national park" (J. Wagner, WY Dept. Env. Qual., Cheyenne, pers. comm., Jul. 1994). All waters of the park are listed as Class 2 waters, although the Park has the option of petitioning for Class 1 designation. Such a petition is not currently under consideration.

Class 2 waters are those surface waters that are determined to: 1) be presently supporting game fish, or 2) have the hydrologic and natural water-quality potential to support game fish, or 3) include nursery areas or food sources for game fish. The primary difference between Class 1 and Class 2 waters is that no new point-source discharges are allowed into Class I waters, whereas new point-source discharges are allowed into Class 2 waters as long as water-quality standards are not exceeded (see Appendix I for some of the numerical standards). Water uses in existence on June 27, 1979 generally provide the baseline from which new point-source discharges are evaluated.

Some protection of Park wetlands is provided under the Wyoming water-quality rules and regulations (Section 12). Specifically, point or nonpoint sources of pollution are not allowed to destroy, damage, or impair naturally occur-ring wetlands except when mitigated through an authorized wetlands mitigation process. Wetlands created by point or nonpoint sources are not protected, nor does Wyoming require them to be maintained through continuation of discharges.

Dead animals, such as livestock carcasses, have been found occasionally in Bighorn Lake. Fish, wildlife, and livestock carcasses have the potential to pollute tributaries to the lake and the lake itself. Section 14 of the Wyoming water-quality rules and regulations clearly states that dead animals of any description cannot be placed or allowed to remain in Wyoming surface waters or be placed or al-lowed to remain in any location that would result in contamination or threatened contamination of Wyoming surface waters. This section also addresses solid waste and specifies that, except as authorized through a "404 permit", solid waste shall not be placed or allowed to remain in surface waters of the state, nor shall solid waste be placed or allowed to remain in any location that would cause or threaten contamination of Wyoming surface waters.

WYOMING FISH AND WILDLIFE MANAGEMENT

Wyoming Statutes 23-1-1 through 23-1-12 and 23-1-10 to 23-6-207 apply to fish and wildlife management and establish the authority of the state to manage the fish and wildlife in the Park. The purpose of these statutes is to provide an adequate and flexible system for control, propagation, management, protection, and regulation of all Wyoming wildlife. The term wildlife covers all wild mammals, birds, fish, amphibians, reptiles, crustaceans, and mollusks. These statutes establish the authority of the Wyoming Game and Fish Commission and the Wyoming Game and Fish Department. The commission has the authority to protect, enhance, and preserve the wild resources, including their habitats, of the State of Wyoming and to adopt rules to implement this mandate. Staff of the Wyoming Game and Fish Department are employed to carry out specific activities under these authorities, and they interact extensively with Park resources management staff in carrying out these responsibilities.

The Wyoming Game and Fish Department has implemented a five-tier trout stream classification rating system for streams as part of its wildlife management efforts (Fish Division Procedures Manual of the Wyoming Game and Fish Department, Cheyenne, Wyoming). The classification of any individual system is determined by an evaluation of productivity for trout, aesthetics, and public access, with a classification of 1 indicating a high rank for these attributes and a classification of 5 indicating the lowest rank. The classification is used to guide trout management activities, such as fish stocking and stream restoration. Starting about 140 km (85 mi) upstream of the Park, the Bighorn River is class-1 "premium trout stream" for about 30 km (20 mi) from the mouth of Wind River Canyon past Thermopolis to its confluence with Kirby Creek. For about 30 km (20 mi) from Kirby Creek downstream to just below Gooseberry Creek, the Bighorn River is designated as class-3 "important trout stream". From about Gooseberry Creek for about 80 km (50 mi) to Bighorn Lake, the classification is "low-production trout waters" (class 4). Although not classified under the Wyoming system, the waters of the Bighorn River below the Yellowtail Afterbay Reservoir in Montana are considered extremely high-quality trout habitat (Montana Department of Fish, Wildlife & Parks 1987). Tributaries of the Bighorn River in the vicinity of the Park and within Wyoming have various classifications (Table 5) but generally are considered low priority for intensive management for trout.

MONTANA WATER QUALITY ACT

Water quality in the portion of the Park in Montana is protected under the Montana Water Quality Act. Surface water-quality classification and standards are defined under the Administrative Rules of Montana, Title 16, Chapter 20, Sub-Chapter 6 (see Appendix 2 for standards for an array of characteristics). Waters of the Park within Montana are classified as B-1 and are considered suitable for drinking, culinary purposes, and food processing purposes after conventional treatment. They are also suitable for bathing, swimming, recreation, growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers, and agricultural and industrial water supply. The highest class of waters in the state are Class A and differ from Class B waters primarily in that the former are dedicated for public water supplies. Class A designation for Park surface waters would not be appropriate because these waters do not constitute a public supply. Some waters in national parks and wilderness areas in Montana have also been designated as Outstanding National Resource Waters, but, as

Table 5. Summary of classification of tributaries in Wyoming of Bighorn Lake as part of the Trout Stream Classification System of the Wyoming Game and Fish Department, fish species present in tributaries, and fish species recently stocked in tributaries (Wyoming Game and Fish Department files, Cheyenne, Wyoming). Tributaries not listed are either not suitable for planting or are managed as wild fisheries.

Water Name	Class	Species Present	Species Stocked
Crooked Creek	3	rainbow, brown, brook, and cutthroat trout; white sucker, flathead chub, fathead minnow	rainbow trout
Cottonwood Creek	4	brook trout	
Shoshone River	4	brown trout, common carp, river carpsucker, longnose sucker, white sucker, mountain sucker, shorthead redhorse, channel catfish, stonecat, burbot	rainbow trout channel catfish
Willow Creek	4	brook trout	none
Five Springs Creek	3	brook trout	none
Crystal Creek	3	brook and rainbow trout	none
Big Horn River	4	see Table 12	channel catfish
Porcupine Creek	3	rainbow and brown trout	none

Scientific names of species listed: brook trout *(Salvelinus fontinalis)*, brown trout *(Salmo trutta)*, burbot *(Lota Iota)*, common carp *(Cyprinus carpio)*, channel catfish *(Ictalurus punctatus)*, cutthroat trout *(Oncorhynchus clarkii)*, fathead minnow *(Pimephales promelas)*, flathead chub *(Hybopsis gracilis)*, longnose sucker *(Catostomus catostomus)*, mountain sucker ***(Catostomus platyrhynchus)***, rainbow trout ***(Oncorhynchus** mykiss)*, river carpsucker ***(Carpiodes** carpio)*, shorthead redhorse *(Moxostoma **macrolepidotum)***, stonecat ***(Noturus** flavus)*, white sucker *(Catostomus commersoni)*.

in Wyoming, the Park's waters are not automatically classified as such because of the designation of the Park as a recreation area. The Park could petition either Montana or Wyoming for such a classification under the states' water quality acts.

Montana's nondegradation policy for water, a standard policy applied to all waters in the state, is stringent. Dischargers into water are regulated through permits issued under Administrative Rules of Montana Title 16, chapter 20, subchapter 9. These permits must conform with nondegradation rules specified in Administrative Rules of Montana 16.20, Sub-Chapter 7 and 16.20.631(4). In general, existing uses of state water and the level of water quality necessary to protect those uses must be maintained and protected. The Department of Health and Environmental Sciences may not authorize degradation of water quality unless it has been affirmatively demonstrated by a preponderance of evidence to the department that the benefits outweigh the detriments of degradation or that no alternatives to the proposed project exist that would result in no degradation. This policy applies to surface and groundwater.

Montana has developed a classification system for its ground water, incorporating four classes distinguished primarily by values for specific conductance (Administrative Rules of Montana 16.20, Sub-Chapter 10). The process of actually classifying all bodies of ground water in the state has not been conducted because of insufficient information about characteristics of various bodies of groundwater (John Arrigo, MT Dept. Health & Env. Sci., Helena, pers. comm. Oct. 1994). Any groundwater whose existing quality is higher than the established groundwater quality standards for its classification must be maintained at that high quality, unless it has been affirmatively demonstrated that a change is justifiable as a result of necessary economic or social development and will not preclude present or anticipated use of such waters.

MONTANA AGRICULTURAL CHEMICAL GROUNDWATER PROTECTION ACT (JULY, 1991).

Public concerns about possible effects of agricultural practices on water supplies in Montana has resulted in state legislation to protect groundwater from agricultural chemicals. Because of the prevalence of agricultural land uses in the region of the Park, this legislation also is important to the Park. The Montana Department of Health and Environmental Sciences is responsible under the Montana Agricultural Chemical Groundwater Protection Act for the establishment and enforcement of agricultural chemical groundwater standards and interim numerical standards for groundwater monitoring. The Montana Department of Agriculture is responsible for the preparation, implementation, and enforcement of agricultural chemical groundwater management plans. The Agriculture Department is to develop criteria for ensuring that the content of the management plans meets the objectives of preventing groundwater impairment, minimizing the presence of agricultural chemicals in groundwater, and protecting present and future beneficial uses of groundwater.

MONTANA FISH AND WILDLIFE MANAGEMENT (ARM TITLE 87)

The fish and wildlife resources in the Park within the boundaries of the State of Montana are managed by the Montana Department of Fish, Wildlife and Parks. Title 87 of the Administrative Rules of Montana establishes the authority of this department and the authority of the Commission of Fish, Wildlife and Parks, which oversees the department. The department and commission have the authority to protect, enhance, and preserve the wild re-sources, including their habitats, within Montana and to adopt rules to implement this mandate. Included with this authority is the option to adopt management plans by the department with approval of the commission. Such a plan was adopted for purposes of fisheries management on a portion of the Bighorn River, commonly referred to in Montana as the "Upper Bighorn River" just below Yellowtail Dam and the Afterbay Reservoir. The five chapters of Title 87 and rules that were adopted address the following: *Chapter 1,* organization; Chapter 2, licenses; Chapter 3, restrictions and regulations such as movement, disease control, and gear restrictions; Chapter 4, commercial activities; and Chapter 5, wildlife and stream protection, wildlife importation and introductions, and classification of game and nongame species.

Water Rights

Adjudication-related developments, in both Wyoming and Montana, may soon essentially resolve Park issues related to Federal reserved water rights. A 1983 Wyoming District Count ruling (Civil No. 4993) denied "reserved water rights" for the portion of the Park in Wyoming. Subsequent to this, negotiations between the United States and Montana during the period of 1993-1994 resulted in an agreement, finalized May 30, 1995, that provides significant water-right protection for the Montana portion of the Park.

Whereas the agreement, known as the "NPS-Montana Reserved Water Rights Compact", does not describe the rights as "reserved water rights", the agreed upon water rights satisfy the Park's fundamental purposes. These rights support existing and anticipated consumptive water use in the Montana portion of the Park. They also provide a level of instream flow protection for creeks and springs that occur on Park reserved lands within Montana. Specifically, instream flow protection was negotiated for all or portions of Layout Creek, the North and South Forks of Trail Creek, Davis Creek, Deadman Creek, Dry Head Creek, Pete's Canyon Creek, Sorenson Spring, Lockhart #1 Spring, Lockhart #2 Spring, Hillsboro Spring, and the tributary of Davis Creek that receives flow from Anerrer Spring.

Adjudications have also addressed state-appropriated water rights at the Park. In most cases, these rights came to the United States as part of a land acquisition, and the historic water use may or may not have been continued by the

Park. In a few cases, the United States is the original owner of the right.

In Wyoming, the status of the Park's state-appropriated rights is uncertain. The previously referenced 1983 court ruling included the statement that:

> All state appropriative rights held by the United States having a point of diversion or place of use in the Bighorn Canyon National Recreation Area shall be merged into the Bureau of Reclamation's state-awarded permits for Yellowtail Reservoir. The Wyoming State Board of Control shall take appropriate action to cancel those state-awarded rights.

It is unclear what the court meant in using the terms "merged" and "cancel". One interpretation is that the rights are still in use and are not abandoned; that the paper certificate was cancelled because the rights are now validated through the United States' rights for the reservoir. Additional research is required to clarify this issue.

All but two state-appropriated rights in the Montana portion of the Park were consolidated into water rights recognized in the NPS-Montana Water Rights Compact. As a consequence, these recognized uses will continue to be supported by water rights, but the nature of the rights will change in two respects: 1) the priority dates will shift to the date of the Park reservation and 2) the purpose and location of these uses within Montana can be changed by the Park, as long as the uses stay within the state and the total amount of water use in this area does not exceed an agreed upon value. The Montana state-appropriated rights unchanged by the compact are at Bighorn Canal and at Pete's Spring.

Agreements and Judgments Governing Specific Activities

The Park's Statement for Management (NPS 1992) contains an excellent summary of many of the agreements governing multiple-party activities in the Park. Several of those agreements are briefly described in this section if they specifically relate to water issues. A court ruling clarifying the status of water rights in the vicinity of the Mason-Lovell Ranch is also included.

YELLOWTAIL WILDLIFE HABITAT MANAGEMENT AREA

The Yellowtail Wildlife Habitat Management Area encompasses major portions of the south-ern end of the Park. Presently the Yellowtail Area is managed by the Wyoming Game and Fish Department primarily as habitat for water-fowl and upland game birds, although a wide variety of plants and animals inhabit the area. The NPS and the Wyoming Game and Fish Commission consummated the cooperative agreement (CA-Secy-67-02) in 1971 for management of the 4,696 ha (11,600 ac) of Park lands in the Yellowtail Area. This agreement was supplemental to the general plan for Bighorn Lake signed January 18, 1967. The present boundaries of the Yellowtail Area include 7,864 ha (19,424 ac) of land and water, of which 60% are Park lands. The Wyoming Game and Fish Department manages the area under the cooperative agreement with the NPS and under other agreements with the Bureau of Reclamation and BLM. A number of important aquatic and wetland features exist on Park lands in the Yellowtail Area. These include Railroad Pond, Kane Ponds, Cemetery Pond, and Ponds 612, 7, 9, and 10. In the case of Railroad Pond, the United States has received a water right permit for the purpose of maintaining a "fishing preserve." The Park is interested in using this same approach to protect some or all of the other sites.

A management plan for the Yellowtail Area was written in 1989, with subsequent revisions and additions. A wide variety of projects have been proposed for the area addressing management of ungulates, upland game birds, waterfowl, a variety of other birds and small mammals, and several species of fish (Wyoming Game and Fish Department 1989). Management to provide a huntable surplus of some species of fish and wildlife, wildlife viewing opportunities, environmental education, wildlife protection, and wildlife habitat protection are conducted on the area. Of the total lands in the Yellowtail Area, about 340 ha (850 ac) are farmed under cooperative agreements designed to maximize benefits to wildlife. Farmers are allowed to plant and harvest certain crops in exchange for habitat and farmland improvements of equivalent dollar value to the bid value for agricultural production. The 142 ha (352 ac) of farmed Park lands currently are used to raise legumes and grain crops.

WATER AND SEWER SERVICES, BIGHORN CANYON VISITOR CENTER

A memorandum of agreement between the NPS and the Town of Lovell, Wyoming was signed in 1976. The memo provides water and sewer service and construction of sewer and water facilities to serve the Bighorn Canyon Visitor Center.

GRAZING MANAGEMENT PLAN FOR DRYHEAD ALLOTMENT

Cattle grazing occurs on the Dryhead Allotment pastures with lifetime tenure for ranchers who had used the area prior to acquisition of the land by the United States. Lands of the Dryhead Allotment in Townships 7 and 8, ranges 28 and 29 E, PMM are entirely within the boundaries of the Park and have been managed for grazing since February of 1985 under the Grazing Management Plan of Bighorn Canyon National Recreation Area. Prior to this plan, grazing was administered by the BLM under direction of the NPS. The allotment consists of four pastures totalling 4,654 ha (11,505 ac). The general management strategy is grazing the pastures on a rotation basis in the spring or early summer, followed by rest for one complete growing season. Animal-unit-month adjustments are based on use calculations using the BLM Ecological Site Method developed by the U.S. Department of Agriculture, Natural Resources Conservation Service. Ranchers grazing the allotment are issued use permits for five-year intervals. Some ranchers using the allotments have access to the pastures only through the Park, and permits for movement of livestock through the Park, locally known as "trailing," are required and issued on an annual basis. Overnight stops during trailing are allowed only at a holding pasture near Layout Creek or in the common allotment corrals located at the north end of the holding pasture, where water piped underground from Layout Creek is provided. Layout Creek and this water diversion are in the State of Montana, and water use in Montana associated with grazing allotments and trailing activities is supported by Park water rights.

NAVIGATIONAL AIDS

Navigational aids are present in Bighorn Lake. Their establishment, operation, and maintenance are covered under a June, 1972 agreement, revised April 1977 (No. 1320-82-02) between the U.S. Coast Guard and the NPS. The devices conform to established navigational standards.

FACILITIES AT FORT SMITH GOVERNMENT CAMP

The Bureau of Reclamation and NPS first entered into a cooperative agreement on December 31, 1964 to coordinate reclamation activities of the bureau with recreation activities of the NPS. This agreement has been superseded by several similar agreements, the most recent being Interagency Agreement No. 7-AA-60-00340, which became effective in 1987. Under this agreement, maintenance and operation functions of the Fort Smith Camp at the north end of the Park are shared between the bureau and the NPS. The Fort Smith Camp is the location of administrative facilities of the NPS and bureau, and both agencies own housing and other buildings there. Several points of the agreement relate to water resources. Up-keep of facilities at the Fort Smith Government Camp is performed by whichever agency has custody of a particular facility. Main water and sewer system lines are maintained by the bureau, with takeoff lines to individual buildings the responsibility of the agency owning or using the building. The NPS has custodial responsibility for automotive repair shop buildings, gasoline-dispensing facilities and shop-related equipment for service of motorized equipment. Snow removal responsibilities are shared between the NPS and the bureau. These arrangements are considered adequate for meeting the current needs of the NPS services at the Fort Smith facilities.

PRYOR MOUNTAIN WILD HORSE RANGE

The Secretary of the Interior established the Pryor Mountain Wild Horse Range in 1968. The area encompasses about 14,800 ha (36,600 ac), mostly on lands administered by the BLM, but 3,680 ha (9,100 ac) are within the Congressional boundary of the Park. The BLM manages for a carrying capacity of the wild horse herd at 121 animals under the Pryor Mountain Wild Horse Management Plan. The BLM has overall responsibility for herd management and removes horses from the herd in an effort to meet the numerical standard for carrying capacity.

WATER RIGHTS IN VICINITY OF MASON-LOVELL RANCH

The Mason-Lovell Ranch Site consists of partial reconstructions of a bunkhouse, blacksmith shop, and the married employees cabin built in the late 1800s as part of a classic open-range cattle operation. Old cottonwood trees at the ranch are either dead or dying. The major change in the immediate vicinity of the ranch that could be influencing the health of the trees is the diversion of flow in a nearby creek, Willow Creek, for livestock watering by the holder of the creek's water right.

Civil case no. 4929 addressed rights to the water of Willow Creek and several other nearby streams. The final judgment in Civil Case No. 4929 between the United States of America as the plaintiff and the Bishoff family, Board of County Commissioners of Big Horn County, Wyoming, unknown owners, et al. for parcels no. 46 and 69 filed November 18, 1965 clarifies water rights and livestock use of parcels of land on the southern portion of the Park. Parcels No. 46 and 69 were purchased by the United States via Land Purchase Contract No. 14-06-600-8660, and the court found this purchase to be valid and binding. The defendants and their heirs specifically retained appropriated rights owned and held by them in and to the waters of Five Springs Creek, Willow Creek, and Harmon Springs and their tributaries. The United States agreed not to interfere with the defendants' use of the premises conveyed to water livestock at such times as the water covers all or a portion of the land conveyed. The right to use these lands for the watering of livestock was not to interfere with the use, operation, and maintenance of Yellowtail Dam and Bighorn Lake. Such interference would constitute grounds for termination of the right. The United States agreed to fence any development area used for recreation or fish and wildlife purposes with which this stock watering right might interfere.

II. HYDROLOGIC ENVIRONMENT

LOCATION AND TOPOGRAPHY

Bighorn Canyon National Recreation Area and the adjoining Bighorn and Pryor mountain ranges are located along the Montana and Wyoming border in the Middle Rocky Mountain Physiographic Province of the western United States. The southern portion of the Park lies within the arid Bighorn Basin Uplands of Wyoming. Principal topographic features are rocky prominences on the northeast and southwest rising from 60-90 m (200-300 ft) above the surrounding terrain, separated by a broad saddle or valley with flat-to-gently undulating slopes. Travelling northward along Bighorn Lake, the central portion of the Park is bounded by the Pryor Mountains on the west and Bighorn Lake on the east. The land slopes generally from northwest to southeast over a distance of about 5.5 km (3.5 mi) between talus slopes and the rim of the Bighorn Canyon. The talus slopes reach a maximum elevation of 2,100 m (7,000 ft), and the canyon rim reaches a maxi-mum elevation of 1,500 m (5,000 ft). Undulations in the plain vary from 8 to 25 percent in slope. Streams originating in the Pryor Mountains have carved deep, narrow channels resulting in slopes ranging from 25 to 60 per-cent from the bottom of the stream channel to the adjoining plain. At its northern end, the Park divides naturally into two distinct physiographic units; one unit is the canyon and the other is an upland section extending upstream from the mouth of Bighorn Canyon and includes the gently rolling-to-level floodplain of the Bighorn River below the canyon. Topography of the canyon section is characterized by sheer canyon walls, pediments, and steep talus slopes. Numerous secondary drainages and canyons with steep side slopes reach back into the upland prairie plateau above and on both sides of the canyon. The upland areas have an undulating topography with gentle slopes. Below the canyon, the topography is typical of most floodplains and is characterized by a series of terraces that developed during periodic floods which once inundated the valley floor.

CLIMATE

The climate of the Bighorn Basin is characterized as cool temperate and semi-arid (Martner 1986; Natl. Oceanic & Atmosph. Admin. 1995a,b). Climate data for the Park are available from U.S. weather stations at Lovell, Wyoming at 1,170 m (3,837 ft) in elevation and near Ft. Smith, Montana at a site, listed as "Yellowtail Dam" in National Weather Service records, at 1,007 m (3,305 ft) in elevation. The general climate is characterized by abundant sunshine, low relative humidity, moderate-to-sometimes-heavy wind, light precipitation, and wide daily and seasonal variations in temperature. Droughts are common. The southern end of the Park is drier and slightly warmer than the northern end, with a corresponding gradual change in climate.

Average annual temperatures at Lovell and Yellowtail Dam are 7°C (45°F), and 10°C (50°F), respectively. Extremes range from highs of over 40° C (100° F) to lows of less than -25°C (-15° F) at both stations. January is typically the coldest month with mean daily temperatures averaging -8°C (17°F) at Lovell and -2°C (28°F) at Yellowtail Dam. Periods of extreme cold are brief and frequently broken by warm chinook winds followed by lengthy periods of mild weather. July and August are the hottest months with mean daily temperatures averaging about 21-24°C (70-75°F). Normal maximum daily temperatures during July and August are about 6°C (10° F) warmer than daily average temperatures.

The average annual total precipitation ranges from 18 cm (7 in) at Lovell, Wyoming to 48 cm (19 in) at Yellowtail Dam. Precipitation is generally in the form of snow from November through February. Spring and early summer thunderstorms account for most of the other precipitation. Evaporation measured at Ft. Smith from May to September is usually 115-127 cm (45-50 in).

GEOLOGY AND SOILS

The geological history of the Park is complex (NPS 1981, Richards 1955). Most of the topographic relief of the region in which the Park resides resulted from uplift of the Rocky Mountains beginning about 70 million years ago. Seas covered most of this area before then, resulting in the many layers of marine and sedimentary rock incorporated in the mountains (Table 6). Underlying the sedimentary rocks are some extremely old crystalline rocks formed when molten rock material cooled to form a coarse-grained red granite. Some metamorphosed schist and gneiss also are present. Uplift beneath essentially horizontal beds of sedimentary rock have created the numerous anticlines, synclines, and domes evident in the area. Bighorn Canyon is a dramatic erosional feature through the uplifted layers, with the sharp bends in the canyon today indicating the past meanders of the river.

Table 6. Formations and rock types in the vicinity of Bighorn Canyon National Recreation Area ordered from oldest to youngest (from Richards 1955).

Formation Name	Period	Thickness	Rock Type
Gros Ventre Formation and Gallatin Limestone	Cambrian	305 m (1,000 ft)	Limestone with thin layers of siltstone and flat-pebble conglomerate.
Bighorn Dolomite	Ordovician	87-146 m (285-480 ft)	Massive dolomitic limestone, forms prominent cliffs in Bull Elk Basin
Jefferson Limestone and Three Forks Shale	Devonian	91 m (300 ft)	Limestone and dolomite with greenish-gray shale and sand; has brachipods and corals
Madison Limestone	Mississippian	215-226 m (705-740 ft)	Marine limestone divided into four units, forms step-like series of cliffs with some pinnacles and massive top rim layer; some caves
Amsden Formation	Mississippian and Pennsylvanian	70-85 m (230-280 It)	Interbedded sandstone, limestone, and red shale formed in shallow marine and beach environments
Tensleep Sandstone	Pennsylvanian	23 m (75 ft)	Light-gray, cross-bedded sandstone from shore and near-shore environments; outcrops marked by stands of pine.
Embar Formation	Permian	30 m (100 ft)	Limestone, dolomites, and red shales
Chugwater Formation	Permian and Triassic	114-206 m (375-675 ft)	Red sandstone, nearshore and beach environments; has some gypsum; striking red formation at Horseshoe Bend
Piper formation	Jurassic	46 m (150 ft)	Red sandstone and siltstone
Rierdon and Swift Formation	Jurassic	81-171 m (265-560 ft)	Marine fossiliferous sandstone and shale
Morrison Formation	Jurassic	43-85 m (140-280 ft)	Siltstone, sandstone, and variegated shale, stream and continental deposits, dinosaur fossils in other areas
Cloverly Formation	Cretaceous	91-122 m (300-400 ft)	Continental, conglomeritic sandstone and variegated shale
Thermopolis Shale	Cretaceous	130m(425ft)	Dark-gray shale with bentonite
Mowry Shale	Cretaceous	107-122 m (350-400 ft)	Dark-gray shale; abundant fish scale impressions; bentonite from volcanic ash deposits
Frontier Formation	Cretaceous	79 m (260 ft)	Dark-gray, concretionary sands shale; large concretions
Cody Shale	Cretaceous	793 m (2,600 ft)	Dark-gray, concretionary, partly sandy shales; in basins to east and west of mountains
Parkman Sandstone	Cretaceous	76 m (250 It)	Sandy shale and sandstone
Bearpaw Shale	Cretaceous	259 m (850 It)	Dark-gray marine shale

The Pryor Mountains to the west of the Park are an example of fault-block mountain formation. The sheer cliff face of these mountains west of the Park is the first in a series of major faults that were part of the uplift of the Pryor Mountains. Sedimentary rocks have been broken along nearly vertical planes instead of being folded. The Sykes Spring fault zone extends 8 km (5 mi) along the foothills east of the Pryor Mountains and west of the Horseshoe Bend and ranger station at Layout Creek. Faults in this zone account for the series of springs along the Pryor Mountains, some of which are in the Park.

Many geologic landforms are associated with erosional processes following uplift. Glaciation did not occur in the Park during the Pleistocene, but slow-moving mud slides did occur. Most of the debris from these slides has eroded away. Alluvium was deposited in major tributaries and along the sides of the Bighorn River. Subsequent uplift and down-cutting of the Bighorn River has eroded these deposits into terraces, some of which are visible downstream of Yellowtail Dam.

Detailed geological mapping has not been accomplished for most of the Park. Geological resources are thought to be mostly intact with a few exceptions linked to small-scale mining operations for sand, gravel, and bentonite (NPS 1994b)

An unpublished soil survey has been completed for the portion of the Park in Wyoming except for two sections on the east side of Bighorn Lake. Records of this survey are avail-able in the office of the U.S. Department of Agriculture, Natural Resources Conservation Service (previously the Soil Conservation Service) in Lovell, Wyoming (T. Gustafson, U.S. Dept. Agric., Nat. Resour. Conserv. Serv., Riverton, WY, pers. comm., May 1995). An order-2 soil survey of Carbon County, Montana has been conducted, including the portion of the Park in Montana (C. Gordon, Acting State Soil Scientist, U.S. Dept. Agric., Nat. Resour. Conserv. Serv., Bozeman, MT, pers. comm., May 1995).

In general, most of the soils in the Park are formed in place and are derived from sandstone, siltstone, limestone, and shale bedrock. Variations in the texture of soils throughout the area are usually associated with the parent bedrock and are noticeable and often abrupt. All soils are relatively rocky and gravelly, with depth to bedrock often less than 0.6 m (2 ft). The organic content of the soil is fairly low, and the surface organic layer is usually shallow and often not distinguished by any evident color change. Alkalinity and salinity of the soil are fairly high, and the reaction pH ranges from *7.7* to 8.5. Salts are acquired from parent material. Permeability of the soil by water runoff is moderate at 1.5 to 5 cm/hr (0.6-2 in/hr) because of the limited permeability of clays in the soil. Layers of clay are interspersed through most of the parent bedrock formations. The shrink/swell potential for most soils is moderate to low, except where there is bentonite. Frost action is moderate in general and high in some areas (Kroenberger et al. 1977, Parker et al. 1975).

VEGETATION

A wide variety of plant species and plant communities exist within the Park (Lichvar et al. 1984, Knight et al. 1987, Akashi 1988, Files, Bighorn Canyon Natl. Rec. Area). The plant communities of the Park consist of over 73 families, 320 genera, and 733 species. The elongate nature of the Park coupled with environmental changes from southern to northern locations within the Park lead to considerable differences in the vegetation mosaic of the area. In general, the flora of the Park is composed of Rocky Mountain, Great Basin, and Great Plains floristic elements. The Great Basin element is the major component of the flora and includes species such as grease-wood *(Sarcobatus vermiculatus)*, various species of saltbush *(Atriplex)*, curlleaf mountain-mahogany *(Cercocarpus ledifolius)*, and Utah juniper *(Juniperus osteosperma)*. This element approaches the northern edge of its range in the Park. The Rocky Mountain element is the second major component of the flora, is common at high elevations, and becomes increasingly evident progressing northward in the Park. Some of the species associated with this element are Douglas-fir *(Pseudotsuga menziesii)*, limber pine *(Pinus flexilis)*, ponderosa pine *(P. ponderosa)*, Englemann spruce *(Picea engelmannii)*, and subalpine fir *(Abies lasiocarpa)*. The smallest element of the Park's flora represents the Great Plains region. This element is found in the northeast portion of the area, and includes sideoats grama *(Bouteloua curtipendula)*, big bluestem *(Andropogon gerardii)*, blazing star *(Liatris punctata)*, and purple prairie-lover *(Petalostemom purpureum)*.

The distribution of the three floristic elements is correlated to some extent with climatic patterns. The south end of the Park is the most arid and is dominated by Great Basin flora, whereas the Rocky Mountain element dominates at cool, high elevations spanning from near the south end of the Park to the region in the north end of the Park known as Bull Elk Basin. Coniferous forests dominate the high north slopes of the Park. The flora is most representative of the Great Plains element in the area of Fort Smith at the north end of the Park where precipitation during the period of June through September averages about 2 cm (7 in) (Lichvar et al. 1984,1985; Natl. Oceanic & Atmosph. Admin. 1995a,b).

Two species of plants in the Park are currently listed as Category C-2 under the Endangered Species Act (Wyoming Rare Plant Technical Committee 1994). Based on information in The Nature Conservancy's Wyoming Natural Diversity Database, rabbit buckwheat *(Eriogonum brevicaule* var. *canum) is* an inhabit-ant of barren sandy or clay soils and rock outcrops in juniper woodlands and sagebrush-steppe communities. Two separate records exist for this plant in the Park, one near Horseshoe Bend on the rocky limestone slopes, the other in an upland area on the east side of Bighorn Lake just north of the confluence of the Shoshone River with the lake. Persistent sepal yellowcress *(Rorippa calycina)* occurs on riverbanks and shorelines, usually on sandy soils near the high-water line. It has been found along the sandy littoral edge of Bighorn Lake at Horseshoe Bend. Some consideration is being given to a change in its status from C-2 to C-3 because it may be more common throughout its range than suspected at the time it was first listed (G. Jones, The Nature Conserv. WY Nat. Diversity Prog., pers. comm., May 1995).

Twenty-one plant communities, plus agricultural and developed lands have been identified and mapped for the Park (Knight et al. 1987) (Table 7). The major community classes and their percent relative abundance are 40% juniper/curleaf mountain-mahogany woodland, 16% riparian vegetation, 15% desert shrubland, 12% sagebrush steppe, 8% grassland, 6% coniferous woodland, 2% agricultural land, 1% marsh, and 0.1% Great Plains shrubland. About 60 exotic plant species are in the Park, several with the potential to become nuisance species (Files, Bighorn Canyon Natl. Rec. Area). All plant communities of the Park face threats from exotic plant invasions, but most threatened are the riparian areas and wetlands. Purple loosestrife *(Lythrum salicaria)*, for example, was recently discovered in the Bighorn Drainage upstream of the Park. This plant has the potential to cause major changes in understory terrestrial communities and aquatic plant communities of the Park's wetlands and aquatic systems should it invade from upstream locations to the Park (Stuckey 1980, Thompson et al. 1987).

FAUNA

A variety of wildlife inhabit the various plant communities of the Park. Species lists include 47 mammals, 212 birds, 6 amphibians, 14 reptiles, and 28 fish. These records have been compiled through systematic surveys and general sightings. Species compositions and habitat associations are reasonably well documented for vertebrates (Patterson et al. 1985, Redder et al. 1986), but most invertebrates remain poorly studied in the Park.

As with the plants, the mammals of the Park are a mix of species found in the Great Basin, Great Plains, and Rocky Mountain regions. Rocky Mountain bighorn sheep *(Ovis canadensis canadensis)*, are frequently seen associated with very steep, rocky habitats along the Bad Pass Road on the western edge of the Park. The Park's herd numbers approximately 150-200 individuals and has the potential for partial dietary overlap with wild horses *(Equus caballus)* (Coates and Schernnitz 1988; Irby, Mackie, and Kissell, Univ of WY, Laramie,

Table 7. Plant communities or vegetation types and percentage of total land area within Bighorn Canyon National Recreation Area covered by the different types (Knight et al. 1987). Values presented by Knight et al. have been rounded to whole percentage figures.

Plant Community	Percentage	Percentage Subtotals
Marsh	1	1
Riparian Vegetation		16
Floodplain meadow	7	
Floodplain shrubland	5	
Floodplain woodland	3	
Creek woodland	1	
Desert Shrubland		14
Saltbush desert shrubland	4	
Sagebrush desert shrubland	4	
Greasewood desert shrubland	3	
Mixed desert shrubland	3	
Grassland	9	
Mixed-grass prairie	2	
Basin grassland	6	
Windswept plateau	1	
Great Plains shrubland	< 1	<1
Sagebrush steppe	12	12
Juniper and mountain-mahogany woodlands		41
Juniper woodland	30	
Juniper/mountain-mahogany woodland	8	
Mountain-mahogany shrubland	3	
Coniferous woodland or forests		<8
Limber pine woodland	4	
Douglas fir woodland	2	
Ponderosa pine woodland	< 1	
Spruce-fir woodland	<1	
Agricultural land	2	2

unpubl. data). Mule deer *(Odocoileus hemionus hemionus)* are common in the rough broken topography of canyon and upland areas, and white-tailed deer *(Odocoileus virginianus)* are infrequently seen along river floodplains. Beaver *(Castor canadensis)* are common in streams and along floodplains. Yellow-bellied marmot *(Marmota flaviventris),* porcupine *(Erethizon dorsatum),* striped skunk *(Mephitis mephitis),* badger *(Taxidea taxus),* black bear *(Ursus americanus cinnamomum),* mountain lion *(Felis concolor),* bobcat *(Fells rufus pallescens),* mink *(Mustela vison),* and muskrat *(Ondatra zibethicus)* are other fairly large, common-touncommon mammals present in the Park. Black bear are not numerous, but individuals are sighted several times each year in the Park. Some individuals have become nuisances in remote campgrounds along the Bighorn floodplain because of a propensity to raid garbage cans and campers' food supplies. Wild horses are not native, but they have been present for a long time and have a protected status on the Pryor Mountain Wild Horse Range.

The 212 species of birds in the Park include large raptors like the bald eagle *(Haliaeetus leucocephalus),* large and small species of waterfowl (e.g., Canada goose, *Branta canadensis;* wood duck, *Aix sponsa;* and pintail, *Anis acuta),* shorebirds, and many small songbird species, the latter often inconspicuous but constituting the majority of birds present. The aquatic and riparian habitats are especially important to birds during spring and fall migrations. A bird species posing a nuisance is the rock dove *(Columba Livia)*, which poses a significant problem with operation and management of the Yellowtail Powerplant (T. Felche, Bur. of Reclamation, pers. comm., Oct. 1995).

Two bird species currently listed under the Endangered Species Act use habitats within the Park. The American peregrine falcon *(Falco peregrinus anatum)*, listed as "Endangered," has nested in canyon habitat in recent years within boundaries of the Park and forages in a variety of habitats in the area. The NPS, in cooperation with the Bureau of Reclamation and the Peregrine Fund, Inc., has successfully reared and released peregrine falcon chicks from 1990 to 1994. The bald eagle (listed as "Threatened") winters in significant numbers along the Bighorn River downstream of Yellowtail Dam. Some individuals nest in mature riparian habitat in the Yellowtail Habitat Management Area, and others may be year-round residents. Small rookeries of great blue herons *(Ardea herodias)* nest on the Yellowtail Habitat Management Area in mature cottonwood trees. Exact nesting locations, rookery sizes, and nesting activities are well documented in the portion of the Park included in the Yellowtail Wildlife Habitat Management Area (A. Cerovsky, WY Game & Fish Dept., Landers, pers. comm., Apr., 1995).

A number of native bird species are the target of active management programs, primarily in the portions of the Park managed as part of the Yellowtail Wildlife Habitat Management Area, including Canada goose, American white pelican, and a wide variety of ducks. Introduced bird species include ring-necked pheasant *(Phasianus colchicus)* and Merriam and Rio Grande subspecies of wild turkey *(Meleagris gallopavo)*. Gray partridge *(Perdix perdix)* and chuckar *(Alectoris chuckar)* have never been intentionally introduced in the area, but have migrated to the area from other locations nearby where they were introduced (J. Radzay, Yellowtail Wildl. Habitat Manage. Area, pers. comm., April 1995). The introduced birds and many of the native species are actively man-aged for sport hunting in the Yellowtail area.

The native fish community of the Bighorn River includes, but is not limited to, sauger *(Stizostedion canadense)*, channel catfish *(Ictalurus punctatus)*, burbot *(Lota Iota)*, several suckers (Catastomidae), and many minnow species (Cyprinidae). With the completion of Yellowtail Dam, the Wyoming Game and Fish Department and Montana Department of Fish, Wildlife and Parks began intensive programs of fish stocking in Bighorn Lake. The fish community of the Park is now a mix of about half introduced and half native species. One native species, the sturgeon chub *(Macrhybopsis gelida)* is listed as a "Category 2" species in Wyoming under the Endangered Species Act and may be considered for listing as "Threatened" or "Endangered" in the future *(Federal Register*, Nov 15, 1994). Additional information on fish and other water-dependent organisms is present in other sections (see pages 36–37 and 46-49).

SURFACE-WATER RESOURCES

Surface-water resources of the Park are diverse. They include about 8-16 km (5-10 mi) of the Bighorn River above the pool of Bighorn Lake, about 3-6 km (2-4 mi) of the Shoshone River above its confluence with the pool of Bighorn Lake, several small ponds constructed in the Yellowtail Wildlife Habitat Management Area and in other Park locations for wildlife and water management, the extreme lower reaches of several small streams that flow into east and west sides of Bighorn Lake, a small number of seeps and springs primarily located at the base of the Pryor Mountains in the western portion of the Park, and the wetland and riparian areas associated with these aquatic systems (Figure 4). The physical, chemical, and biological information available for these systems is described in this section. Information is first presented about the rivers and streams of the area, including portions of the Bighorn and Shoshone rivers upstream of Bighorn Lake. Characteristics of Bighorn Lake and the Afterbay system are described separately from those of the rivers and streams flowing into these reservoir systems. Discussion of characteristics of the Bighorn River below the Afterbay Dam is not included in this plan because of ongoing negotiations to return lands to the Crow Indian Tribe (see page 12). To the

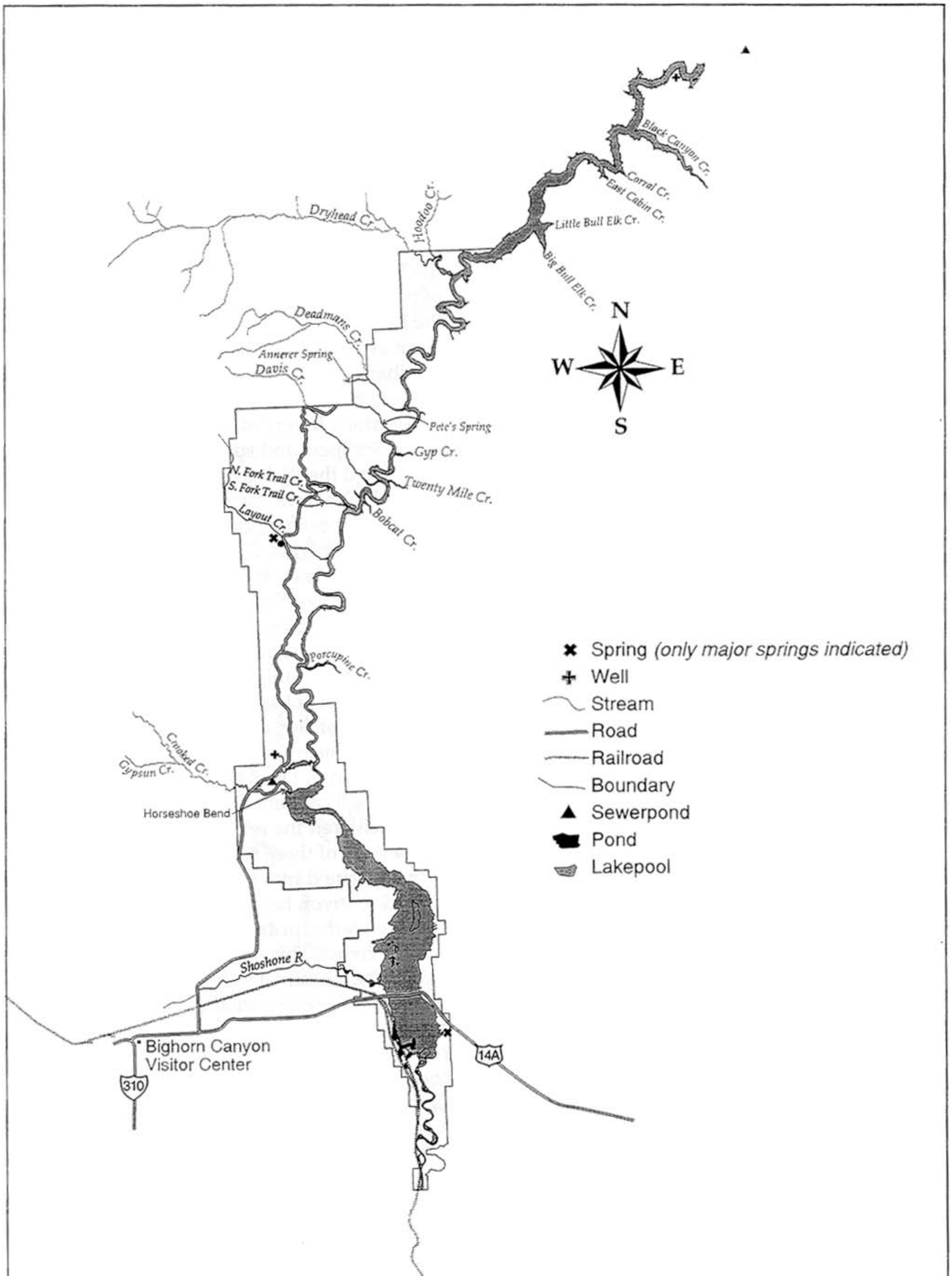

Figure 4. Surface water resources of Bighorn Canyon National Recreation Area.

extent they are known, characteristics of ponds, seeps, springs, and riparian and wetland sites are described in respective sections.

Bighorn River

The Bighorn River and its tributaries are part of the Bighorn/Wind River Basin of the Missouri River Basin. The Wind River, named by Indians because of strong prevailing winds in the drainage basin (Urbanek 1988), originates in the Absaroka and Wind River Mountains of west-central Wyoming (Figure 5). Initially, the Wind River flows in a southeast direction toward central Wyoming, but then turns northward at the confluence with the Popo Agie River near the town of Riverton, Wyoming. The river soon enters Wind River Canyon, about 47 km (30 mi) north of Riverton, and changes in name to the Bighorn River at a place called Wedding of the Waters. The Bighorn River was named by Lewis and Clark, based on a translation of the Indian name for the bighorn sheep present along the river (Urbanek 1988). The Bighorn River flows through the canyon, travels further northward about 177 km (110 mi) along the eastern side of the Bighorn Basin in Wyoming, crosses through the Bighorn Canyon, and finally flows into the Yellowstone River in Montana. The principal tributaries of the Bighorn River in Wyoming include the Nowood River on the east and the Greybull and the Shoshone Rivers on the west. The drainage area upstream of the Park is about 40,831 km^2 (15,765 mi^2), and elevations of the drainage area range from 1,110 m (3,640 ft) to 4,200 m (13,785 ft) (Gumtow et al. 1994).

Early written accounts documenting the conditions of the Bighorn River Drainage are scarce and extremely general. In late August and September of 1805, Francois Larocque, a Canadian explorer, travelled through portions of the Missouri River Drainage including the Bighorn Drainage downstream of the current site of the Park. His journal indicates that he was somewhere between the current site of Bighorn Lake and the confluence of the Bighorn River with the Yellowstone River when he described the Bighorn river as " broad deep and clear water strong current, bed stone and gravel..." (Larocque 1981). Some have described his account as the first written eye-witness description of the Bighorn and its canyon (Bearss 1970), although Lorocque's journal account indicates that he was downstream of the canyon a considerable distance. Larocque acknowledged the presence of sand islands in the river and cottonwoods along the bank downstream of the canyon. William Clark explored the lower several miles of the Bighorn River, just above the confluence with the Yellowstone, in the summer of 1806 on his return from his trip to the Pacific Coast. He observed that the current of the Bighorn was rapid and regular, and like the Missouri River, constantly shifting so as to wash away the banks on one side, leaving sandbars on the other. He recognized that the Bighorn River contained less gravel than the Yellowstone River, but carried more silt (Bearss 1970). Trappers and surveyors intermittently frequented the Bighorn Drainage, but primarily focused in their few written descriptions on the challenges posed by the rapids and the difficulties of their travels. Gillette (1891) traveled the canyon, mostly on ice, in early March, 1891, starting south of the Montana-Wyoming state line and continuing to Ft. Smith in Montana. At the start of his journey, he stated that cedar trees (probably junipers) monopolized most of the canyon. He observed a few cottonwoods at the mouths of side drainages and a scraggy pine or two near the mouth of the canyon. Downstream of Devil Canyon he commented on the small canyons formed by small streams as they entered the main canyon, and observed that several of these streams formed waterfalls as they drained into the river. Just downstream of Black Canyon he commented on the "innumerable warm springs that pour their waters into the river." This influx of warm water melted the ice sufficiently that most of the rest of the trip was completed along the shoreline instead of on ice cover. George Tinker provided a January 1893 account of a surveying expedition down the canyon, but focused on the logistics of the work and the experiences of the surveying crew, rather than the physical and biological characteristics of the river (unpubl. account filed at Bighorn Canyon Natl. Recreation Area, Lovell, WY). Boating trips were commercially offered through the Bighorn Canyon as far back as 1913, starting at Horse-shoe Bend and commonly ending at the

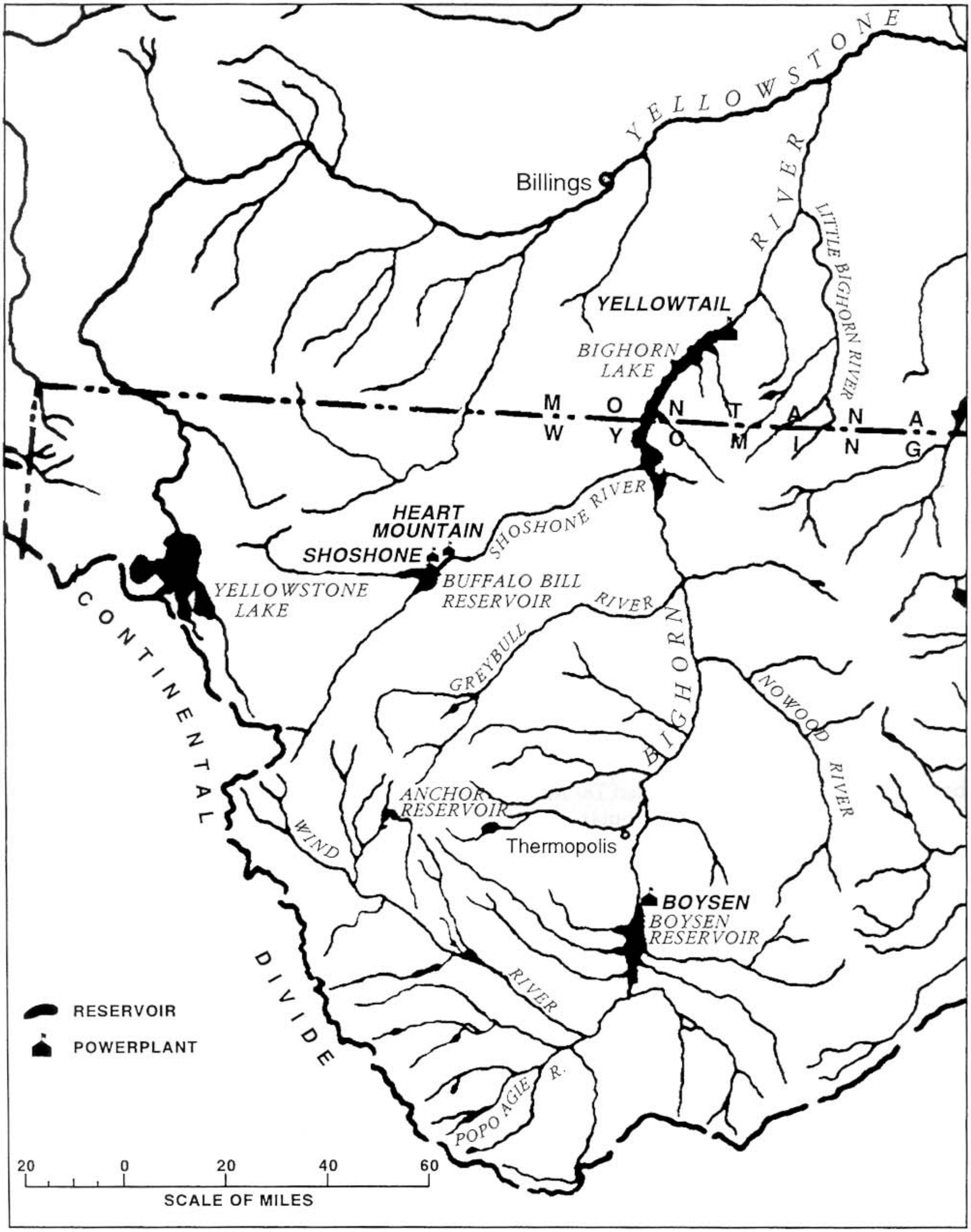

Figure 5. Major drainages of the Bighorn River system.

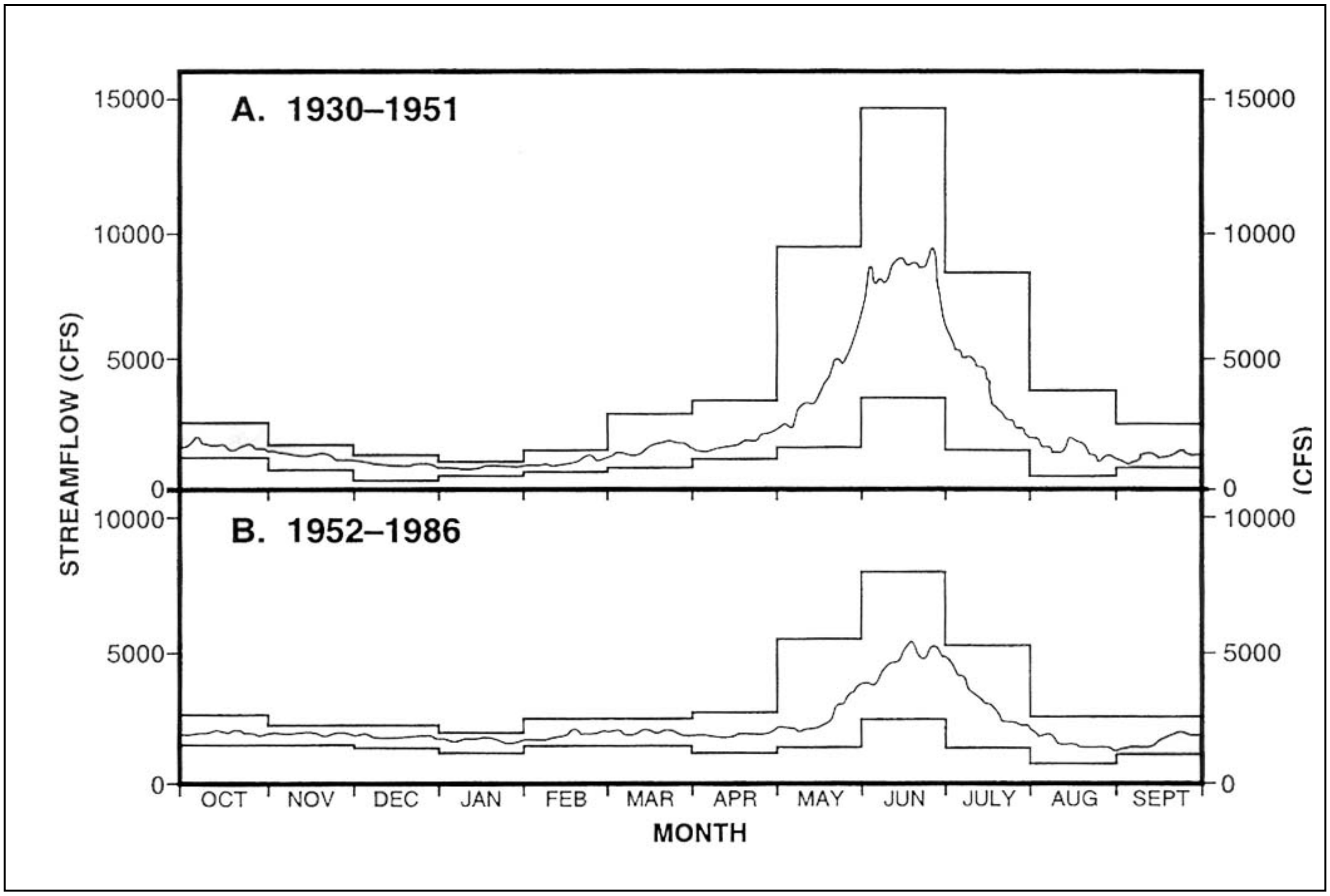

Figure 6. Comparison of pre- and post-impoundment hydrographs for the Bighorn River (from Akashi 1988).

Yellowstone River. The major rapids are described in general in a periodical called *The Red Lodge Picket* (Bearrs 1970) and in a popular account published in the Denver Post on August 30, 1951 (Files, Bighorn Canyon Natl. Rec. Area, Lovell, WY). The Park also maintains a film record of a river trip completed before completion of Yellowtail Dam. A thorough review of written and spoken legends and lore of the Crow Indians would likely reveal information about historic conditions of the Bighorn Drainage, but such a review is beyond the scope of this report.

The average discharge for the Bighorn River has been measured at Kane, Wyoming 1928 by the U.S. Geological Survey. The gaging station is about 1 km (0.5 mi) upstream from the normal high-water line of Bighorn Lake at an elevation of 1,098 m (3,660 ft). Flow at this station is influenced by Boysen Dam and Reservoir, which first started water storage in October, 1951. River flow also is affected by diversions for irrigation of about 152,000 ha (376,000 ac) of agricultural lands upstream from the station and return flow from irrigated areas (U.S. Geol. Surv. 1993). Based on recent records (water years 1989-1993, Table 8), discharge of the Bighorn River measured just upstream of the Park boundary fluctuates between a low monthly average of 31 m^3sec^{-1} (1,078 cfs) in April and a high monthly average of 147 m^3sec^{-1} (5,204 cfs) in June. Annual average discharge is about 51 m^3sec^{-1} (1,788 cfs). The timing of high and low discharge was similar before filling of Boysen Reservoir, but storage and releases from the reservoir have dampened the magnitude of discharge events (Figure 6). Typical of reservoir operations in general increasing flows during former low-flow periods (Leopold et al. 1964), reservoir storage tends to flatten hydrographs depicting discharge by and decreasing them during former high-flow periods. The highest and lowest annual mean flows on record are 100 m^3sec^{-1} (3,524 cfs) in water year 1947 and 26 m^3sec^{-1} (915 cfs) in water year 1989. The maximum

Table 8. Monthly discharge patterns for the Bighorn River at Kane, Wyoming and the Shoshone River near Lovell, Wyoming based on U.S. Geological Survey flow data (USGS 1989-1993). The average discharge reported is for five recent years. The flow is influenced by a major dam upstream of the gaging stations.

Month	Avg. Discharge 1989-1993[1] cfs	Stand. Dev.	Max.	Yr of Max.[2]	Min.	Yr of Min.[2]
Bighorn River at Kane, Wyoming						
Jan	1300	462.50	2871	1972	580	1937
Feb	1243	410.35	3164	1983	550	1933
Mar	1154	231.10	3171	1972	740	1989
Apr	1078	212.26	3454	1943	696	1961
May	2568	1254.02	7505	1947	1005	1960
Jun	5204	3493.60	14680	1944	1032	1934
Jul	2322	997.58	11650	1967	501	1961
Aug	1126	275.91	6388	1930	305	1940
Sep	1472	567.05	3673	1973	386	1935
Oct	1346	303.12	3994	1983	524	1936
Nov	1341	357.03	2871	1984	737	1961
Dec	1298	464.75	2506	1983	627	1961
Shoshone River near Lovell, Wyoming						
Jan	424	128.54	1065	1973	226	1991
Feb	405	135.83	1139	1973	228	1989
Mar	410	144.66	1133	1973	249	1989
Apr	504	125.08	1877	1976	248	1981
May	721	234.87	1909	1975	193	1977
Jun	1160	464.8	4935	1981	203	1977
Jul	1365	550.42	4686	1982	149	1977
Aug	770	208.53	1305	1982	207	1977
Sep	691	66.96	1354	1991	245	1977
Oct	636	141.79	1251	1972	369	1989
Nov	543	129.43	1146	1969	297	1986
Dec	475	130.26	1168	1969	330	1989

[1] For these averages, n=5.

[2] The periods of record for maximum and minimum monthly discharges are 1930-1993 for the Bighorn River station and 1966-1993 for the Shoshone River station.

daily discharge on record is 702 m^3sec^{-1} (24,800 cfs) observed on July 15, 1935; the lowest daily mean discharge on record is 5 m^3sec^{-1} (179 cfs) observed on July 22, 1934. Annual runoff currently averages about 1.9 $x10^9$ m^3 (1,612,000 ac-ft). Ten percent of flows on record exceed 114 m^3sec^{-1} (4,040 cfs), 50 percent exceed 46 m^3sec^{-1} (1,640 cfs), and 90 percent exceed 22 m^3sec^{-1} (785 cfs). For the most part, the system of dams and reservoirs on the Bighorn and Shoshone rivers and the proper operation of this system minimizes flooding hazards in the Park within the floodplains of these two rivers and minimizes threats to life and property. A major failure within this system, although extremely unlikely, would pose major hazards to residential, industrial, and recreational developments in the floodplains.

One of the outstanding characteristics of the Bighorn River is the amount of sediment carried by the river, especially as it nears Bighorn Lake (Soil Conserv. Serv. 1994, Figure 7) (Table 9). On the average, these sediment loads are considered to be sufficient to impair water

Table 9. Mean and range (in parentheses) of water chemistry for the waters of Bighorn River immediately above and below Bighorn Lake as measured by Soltero (1971). Sample size is 19 for each parameter and is based on bi-weekly sampling from February 22 through December 20, 1968.

Chemical constituent or physical characteristic	Above Bighorn Lake[1]		Below Bighorn Lake	
Ca^{++} (meq/1)	3.66	(1.45-4.66)	3.82	(2.00-4.98)
Mg++ (meg/1)	2.09	(0.49-5.17)	1.86	(0.91-2.60)
Na^+ (meg/1)	3.35	(1.12-4.75)	3.23	(1.99-4.25)
K^+ (meg/1)	0.14	(0.06-0.27)	0.15	(0.08-0.42)
HCO3 (meq/1)	3.03	(1.92-3.82)	3.18	(2.81-3.97)
Cl- (meq/1)	0.35	(0.12-0.57)	0.29	(0.20-0.41)
SO_4^{-2} (meq/1)	5.95	(1.04-8.28)	6.17	(5.25-7.42)
F- (meq/1)	0.04	(0.02-0.11)	0.04	(0.02-0.10)
Soluble organic C (mg/1)	7.7	(1.2-14.2)	6.4	(0.0-10.3)
Particulate C (mg/1)	7.0	(0.8-31.7)	2.0	(0.0-3.9)
NO_3--N (mg/1)	0.35	(0.09-0.79)	0.54	(0.25-0.83)
NO_2--N (mg/1)	0.008	(0.003-	0.005	(0.001-0.017)
NH_3N (mg/1)	0.35	(0.00-1.36)	0.17	(0.00-0.50)
Soluble organic NH_3-N (mg/1)	0.33	(0.00-0.95)	0.47	(0.00-1.50)
Particulate NH_3-N (mg/1)	0.34	(0.00-1.88)	0.09	(0.00-1.18)
Ortho-PO4 ^{3} (mg/1)	0.11	(0.00-0.40)	0.04	(0.00-0.16)
Soluble Organic PO_4^{-3} (mg/1)	0.04	(0.00-0.35)	0.02	(0.00-0.16)
Particulate $PO4^{-3}$ (mg/1)	1.90	(0.00-3.39)	0.04	(0.00-0.21)
Turbidity (JacksonTurbidity Units)	816	(30-4,900)	13	(4-30)
Silica (mg/1)	9.4	(6.3-12.9)	10.0	(6.7-14.0)
Total iron(mg/1)	0.138	(0.004-0.885)	0.009	(0.003-
Mn^{++} (meg/1)	0.021	(0.004-0.119)	0.004	(0.000-
Cu^{++} (µg/^{1})	1.60	(0.70-3.80)	1.10	(0.80-1.70)
Zn^{++} (mg/1)	0.094	(0.007-	0.057	(0.006-
Conductance (microomhs)	837	(412-1,125)	870	(669-932)
pH (range only)		(7.49-8.55)		(6.98-8.10)

[1]This site is influenced by the floodpool of Bighorn Lake at high pool levels. Soltero (1971) referred to this site as the influent to Bighorn Lake.

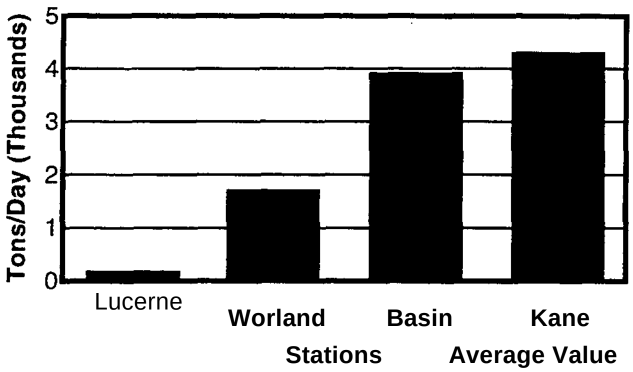

Figure 7. Suspended sediment loads in the Bighorn River at four locations (from SCS 1994).

quality in the Bighorn River system although they do not violate state standards for water quality (Soil Conserv. Serv. 1994). The sediments lower the quality of fish habitat, decrease storage volume of Bighorn Lake, deposit in canal systems, and degrade water-based recreation. The Shoshone River is one of the main contributors of suspended sediments to the Bighorn River, and the major sources of sediment in the Shoshone are erosion from irrigated croplands, rangelands, and stream banks (Soil Conserv. Sew 1994). These sources are also present along the Bighorn River and along most small tributaries to the Bighorn River. The average daily load of suspended sediments in the Bighorn River at Kane, Wyoming (at the southern end of the Park) is about 3,600 metric tons (4,000 tons) per day (Figure 7). The Shoshone River contributes an average of about 636 metric tons (700 tons) per day (Soil Conserv. Serv. 1994). With the completion of Boysen and Yellowtail dams and the filling of their reservoirs, large amounts of the river's silt load are now trapped, and the turbidity of the river downstream of Yellowtail Dam is low. There can be as much as a 60-fold decrease in mean turbidity of the Bighorn River as waters pass through the reservoir (Soltero 1971). In effect, the river water is transformed by impoundment from a warm, silty, prairie river upstream of Bighorn Lake to a cold, clear river system downstream of Yellowtail Dam.

The temperature of water flowing in the Bighorn River is influenced by residency in the lake (Figure 8). Waters flowing into Bighorn Lake are at or near freezing in December, January, and February; downstream of the dam, water temperatures never reach freezing. Minimum temperatures in the river down-stream of the dam occur in March and April, followed by a maximum in September. The effect of impoundment and deep water discharge is to displace the maximum and mini-mum temperatures of water below the reservoir two months behind the temperature of river water flowing into the reservoir, reduce the maximum temperature of the water flowing out of the reservoir, and increase the minimum temperature of the water flowing out of the reservoir.

Measurements of other water quality characteristics of the Bighorn River indicate values that are generally acceptable for Class II waters under State of Wyoming standards for water quality (Soltero 1971, Soil Conser. Serv. 1994). The pH ranges from 7.5 to 8.6. Maximal conductivity values occur in late summer and early fall, and coincide with periods of low flow. Average conductivity is around 900 1.tS cm-' (Soltero et al.1973, Soil Conserv. Sere 1994). A lag of two to four months is evident between conductivity values for waters upstream of Bighorn Lake compared to waters downstream of the lake (Soltero et al. 1973).

The chemical composition of the Bighorn River. above Bighorn Lake is consistent with the sedimentary geology and climate of the area (Table 9). Calcium and sodium are the most abundant cations, and sulfate is the most abundant anion. Water downstream of the dam is slightly lower in dissolved solids than influent water, indicating that the reservoir is acting as a salinity trap. A large fraction (75%) of the total amount of nitrogen entering the reservoir is discharged, with the largest inorganic nitrogen loss being ammonia. An increase in nitrate-nitrogen occurs from influent to effluent, which indicates that nitrification and nitrogen fixation within the reservoir are probably in excess of nitrogen assimilation and denitrification. Less than 20 percent of the total phosphorus entering the reservoir is discharged. Heavy metals decrease in concentration between influent and effluent water, probably due to settling out of suspended sediments carried into the reservoir (Soltero et al. 1973).

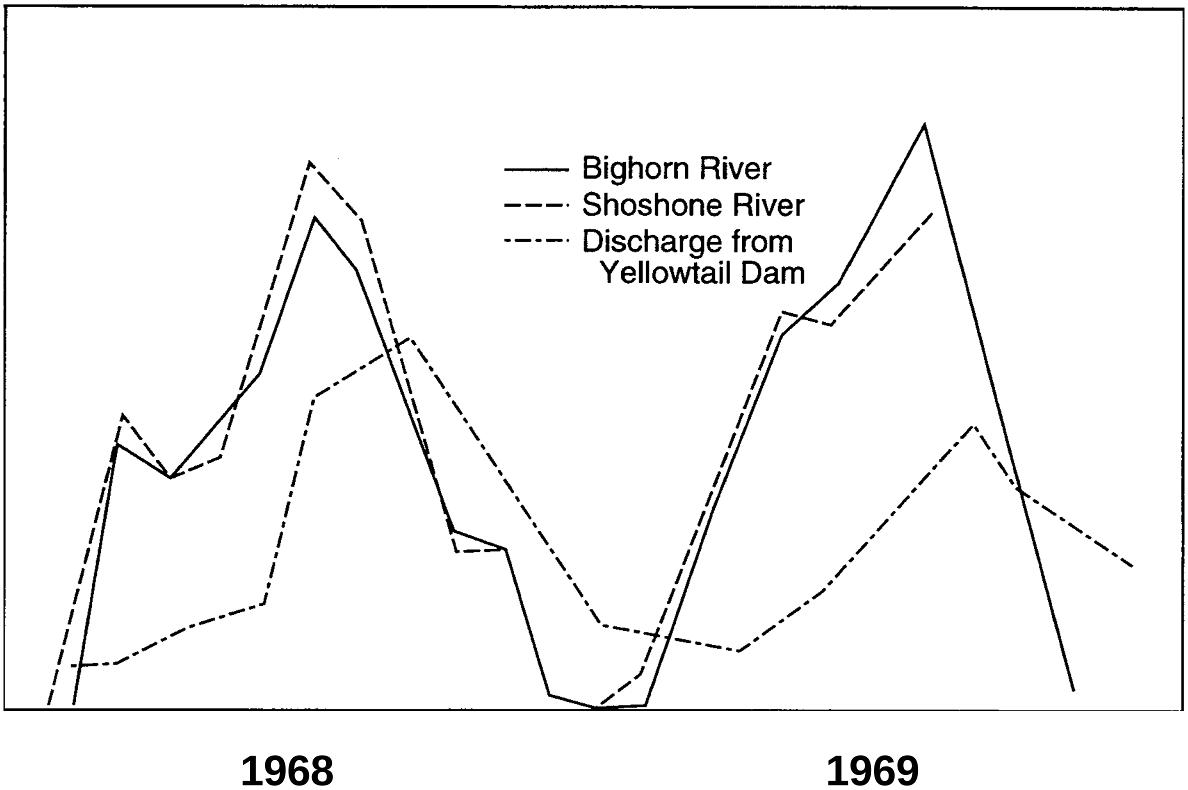

Figure 8. Monthly average temperature (C°) for the Bighorn River (measured 10.5km south of Kane, Wyoming) and for the Shoshone River (measured 2.4km upstream of its mouth) based on Soltero (1971).

Table 10. Brand names of pesticides and herbicides recently applied to lands of Bighorn Canyon Recreation Area under agreements with the Wyoming Department of Fish and Game and local farmers.'

Year	Brand Name of Compounds
1983	Weedar 64, Banvel
1984	Treflan, Eptan 7E, Amitrol T, Banvel, Formula 40, Bladex 4L, Furadan 10G, Tordon 2K
1985	Banvel, Weedar 64, Rodeo, Phorate 15G, AATRAX 80W, Malation ULV, Tordon 2K
1986	Banvel, Weedar 64, Phorate 15G, AATRAX 80W, Tordon 2K, Amitrol T
1987	Amitrol T, Weedar 64, Malathion ULV, Banvel, Rodeo, Lasso EC, Bladex 4L
1988	2,4 DB Ester, Malathion 57EC, Nortron E.C., Banvel, Weedar 64, Bladex 4L, Lasso E.C.
1989	Poast, Atrazine 80W, Malathion 57EC, Lasso E.C., Bladex 4L, Amitrole 2, Rodeo
1990	Weedar 64A, Nortron E.C., Antor 4ES, Amitrole 2, Malathion 57EC
1991	Lasso E.C., Bladex 4L, Weedar 64A, Butyrac ester, Amitrol T, Sonalan E.C. Basagran
1992	Eptam 7-E, Curtail, Weedar 64A, Express, Stinger, Eradacane Extra, Curtail, Banvel, Rhonox
1993	Express, Stinger, Eradacane Extra, Butryac Ester
1994	Transline, Rhonox, MCPA (Ester), Roundup, Banvel, Weedar 64, Curtail

This is not a complete list of products applied within the Bighorn Lake drainage.

Recent sampling of water quality characteristics is limited. Measurements and calculations of nitrogen and phosphorus concentrations by the U.S. Geological Survey (1993) and others (Soil Conserv. Serv. 1994) near the confluence of the Bighorn River with Bighorn Lake have yielded results in common with the range of values reported by Soltero et al. (1973). A major general omission is current information on occurrence of compounds or metabolites that can occur as a result of pesticide and herbicide applications in the Bighorn and Shoshone river drainage basins. Use of chemical compounds in the agricultural industry in the vicinity of the Park presumably is extensive, although local users in Wyoming are not required to report the compounds used and rates of application (Table 10). From 1984 through 1992, the U.S. Geological Survey sampled for several herbicides and herbicide byproducts in the Bighorn River at the gaging station at Kane, Wyoming (Table 11). Concentrations of the substances sampled were low. More limited sampling for the same compounds was conducted on the Shoshone River near Garland, Wyoming, and comparable results were obtained. Limited studies have been conducted in Bighorn Lake to detect concentrations of PCBs and concentrations and sources of some heavy metals (see page 44). The possibility of accumulations of organic and inorganic compounds in sediments and biota as episodic high concentrations of organic and inorganic compounds in the rivers and streams as a result of application practices is a concern of Park staff. A study unit of the National Water-Quality Assessment Program being conducted by the U.S. Geological Survey will border or include Bighorn Lake. The National Water-Quality Assessment Program is designed to describe the status and trends in the quality of ground- and surface-water resources and to provide a sound understanding of the natural and human factors that affect the quality of these resources (Leahy et al. 1990). Development of sampling plans for this region is scheduled to begin in 1997 as part of the Yellowstone Basin Unit. Physical, chemical, and biological properties of ground water and surface water are part of the national program, including some organic and inorganic compounds in sediments and selected biota associated with use of herbicides and pesticides.

Shoshone River

The Shoshone River is a major warm, silt-laden tributary of the Bighorn River that joins the Bighorn River in the upstream portion of the pool of Bighorn Lake. The annual average discharge from the Shoshone River measured near Lovell, Wyoming is 25 m^3sec^{-1} (899 ft^3sec^{-1}) based on a 26-year period from water years 1967 through 1993. Flow at this site has been influenced by Buffalo Bill Dam and Reservoir located about 100 km (60 mi) upstream of the Park boundary near Cody, Wyoming since 1910.

Table 11. Results of herbicide sampling conducted by U.S. Geological Service from 1984 through 1992 at Kane gaging station on the Bighorn River. The sample size is 34 for each compound sampled.

Compound	Mean	Stds	Range'	No. values at detection level
Picloram	0.01	0.006	DL-0.03	11
2,4-D	0.05	0.051	DL-0.26	8
2,4,5-T		all values at detection level		
Silvex		all values at detection level		
Banvel	0.03	0.023	DL-0.10	5
2,4-DP		all values at detection level		

DL indicates detection level.

This dam recently underwent a modification project to increase the reservoir storage capacity to 646,565 ac-ft (Bur. of Reclamation 1994). Natural flow also is affected by power development at the Buffalo Bill Dam, diversions upstream for irrigation of about 57,900 ha (143,000 ac), and return flow from irrigated areas. Based on recent discharge data (Table 8), flows fluctuate between a low monthly average of around 11 m^3sec^{-1} (405 cfs) in February and a high monthly average of 39 m^3sec^{-1} (1,365 cfs) in June. The maximum annual average discharge on record is 37 m^3sec^{-1} (1,313 cfs) observed in water year 1976; the lowest annual mean on record is 10 m^3sec^{-1} (359 cfs) observed in water year 1988. The maximum recorded daily discharge is 430 m^3sec^{-1} (15,200 cfs) observed on June 10, 1981 and the lowest daily mean discharge on record is 0.8 m^3sec^{-1} (27 cfs) on May 31, 1977. For observations spanning water years 1967-93, ten percent of flows exceed 41 m^3sec^{-1} (1,450 cfs), 50 percent exceed 19 m^3sec^{-1}(674 cfs), and 90 percent exceed 9 m^3sec^{-1} (326 cfs). As for the Bighorn River, the dam and reservoir system on the Shoshone River and the proper operation of this system minimizes flooding hazards in the Park within the floodplains of the Shoshone River and minimizes threats to life and property. A major failure within this system, although extremely unlikely, would pose major hazards to residential, industrial, and recreational developments in the flood-plain.

The drainage area of the Shoshone River comprises about 6,087 km' (2,350 mi.') at an elevation greater than 1,173 m (3,850 ft) above mean sea level. As mentioned on page 31, this river is a major contributor of sediments to the Bighorn River. The river also has a high salt load, as indicated by the common occurrence of conductivity values of over 1,000 $\mu S\ cm^{-1}$ during winter and spring months (U.S. Geol. Surv. 1993).

Other Tributaries

Several tributaries much smaller than the Shoshone River enter the Bighorn Drainage in the vicinity of the Park from the Pryor Mountains to the west and the Bighorn Mountains to the east and flow into Bighorn Lake. Some reconnaissance-level information on drainage area and flow data for these small streams is cited in EPA (1977). Drainage area and discharge are reportedly 300 km' (116 mi^l) and 0.3 m^3sec^{-1} (10 cfs) for Crooked Creek, 198 km^2 (76 mi.') and 0.3 m^3sec^{-1} (10 cfs) for Dry Head Creek and 3,470 km' (1340 mi^l) and 11.4 m^3sec^{-1} (403 cfs) , respectively, for other minor tributaries plus immediate drainage. These are mostly small, coldwater streams that have downcut channels in steep, narrow canyons as they flow from the mountains. Their peak runoffs usually occur in the spring, coinciding with snow melt. Localized thunderstorms in summer may cause flooding in these tributaries, but the absence of site-specific discharge and precipitation data makes it difficult to generalize about flooding magnitude and frequency. Wyoming biologists have conducted some drainage surveys in these tributaries to document the status of fish populations and fish habitat (M. Welker, WY Game & Fish Dept, Cody, pers. comm., Dec. 1994, see page 36). Other physical and chemical characteristics of most of these streams have not been sampled.

A short segment of Crooked Creek, one of the tributaries flowing into the Bighorn Canyon, flows across NPS land at the southern end of the Park. Conditions experienced by Crooked Creek provide a general index to conditions of other tributaries on and adjacent to the Park lands. The portion of the creek flowing through the Park has eroded to a deep and narrow channel because of rapid runoff of irrigation water from local fields (Files, Bighorn Canyon Natl. Rec. Area, Lovell, WY based on site evaluation by staff of Dept. Range Manage., Univ. WY, Laramie). The stream channel cannot erode much more because it has reached bed-rock. The silt load in the stream appears to be very low, and some channel rehabilitation is slowly occurring coincident with the building of beaver dams along the channel and development of streamside vegetation. High flows associated with major rainstorms periodically scour sediments from the channel bottom, setting back the rehabilitation of the stream channel. The Park staff encourage beaver use of the stream but have installed wire fencing around mature trees and some shrubs to reduce the loss of cottonwood trees due to beaver damage. The stream channel is occasionally

Table 12. Fish species found in the Bighorn Canyon National Recreation Area with codes for native versus exotic status, relative abundance, habitat associations, and sources of information (adapted from Redder et al. 1986, with new species added based on files of Bighorn Canyon National Recreation Area and Wyoming Dept. Fish and Game).

Family	Species	Native or Exotic to Bighorn Drainage	Abundance	Habitat Association'
Salmonidae	brown trout *(Salmo trutta)*	exotic	common; stocked in reservoir	
				reservoir, stream
	lake trout *(Salvelinus namaycush)*	exotic	uncommon; stocked in reservoir	
				reservoir
	mountain whitefish *(Prosopium williamsoni)*	native	uncommon	
				reservoir, rivers
	cutthroat trout *(Oncorhynchus clarki)*			
		native	probably rare; stocked in Shoshone River in 1978	streams
	rainbow trout *(Oncorhynchus mykiss)*	exotic	common; stocked in reservoir and some streams	reservoir, streams
	brook trout *(Salvelinus fontinales)*	exotic	common	
		native	uncommon	
Cyprinidae	lake chub *(Couesius plumbeus)* common			streams
		exotic	abundant	
	carp *(Cyprinus carpio)* sturgeon chub			reservoir, rivers, streams
		native	uncommon to rare'	
	(Macrhybopsis gelida) flathead chub			reservoir, rivers
		native	common	
	(Platygobio gracilis) fathead minnow			rivers
		native	common	
	(Pimephales promelas) spottail shiner			reservoir, rivers, streams
		exotic	common	
	(Notropis hudsonius) emerald shiner			reservoir, rivers, ponds
		exotic	rare; first captured in 1992 in reservoir	
	(Notropis atherinoides)			reservoir, ponds reservoir
		native	unknown	
		native	rare	reservoir, rivers, streams
	sand shiner *(Notropis stramineus)*			
				streams
	Mississippi silvery minnow *(Hybognathus nuchalis)*			
				reservoir, rivers, streams
	plains minnow *(Hybognathus placitus)*	native	common	reservoir, rivers, streams
	longnose dace *(Rhinichthys cataractae)*	native	common	reservoir, rivers reservoir,
Catastomidae	river carpsucker *(Carpoides carpio)*	native	common	rivers, streams reservoir,
	longnose sucker *(Catostomus*	native	common	rivers, ponds reservoir
	catostomus) white sucker *(Catostomus*	native	common	reservoir, rivers
	commersoni)			
	mountain sucker *(Catostomus platyrhynchus)*	native	uncommon	
				rivers, ponds
			common	
	shorthead redhorse *(Moxostoma macrolepidotum)*	native		reservoir, rivers
				reservoir, rivers
		native	common	
Ictaluridae	black bullhead *(Ameiurus melas)*			reservoir, rivers
		native	common	
	channel catfish *(Ictalurus punctatus)*			reservoir
		native	uncommon	
	stonecat *(Noturus flavus)*			reservoir
		native	uncommon	
Gadidae	burbot *(Lota Iota)*			reservoir
		extotic	rare	
Cyprinodontidae	plains killifish *(Fundulus zebrinus)*			
			uncommon	
Centrarchidae	largemouth bass *(Micropterus salmoides)*			reservoir
			rare; first captured in reservoir in 1992	
	smallmouth bass *(Micropterus dolomieui)*			reservoir, ponds
	exotic green sunfish *(Lepomis*			reservoir, rivers, ponds
	cyanellus)	exotic	common	reservoir
	bluegill *(Lepomis macrochirus)*	exotic	common	reservoir, rivers
	black crappie *(Pomoxis nigromaculatus)*	exotic	common	reservoir, rivers
	white crappie *(Pomoxis annularis)*	exotic	stocked	reservoir, rivers
Percidae	yellow perch *(Perca flavescens)* sauger	exotic	common	
	(Stizostedion canadense) walleye	native	common, stocked	
	(Stizostedion vitreum)	exotic	abundant, stocked	

'Reservoir refers to Bighorn Lake, rivers refers to the Bighom and Shosone rivers, ponds refers to constructed ponds,and streams refers to any tributaries of the Bighorn River.
'Currently listed as a Category-2 species under the Endangered Species Act.

nearly dry because of irrigation withdrawals by upstream water users who hold senior water rights (Files, Bighorn Canyon Natl. Rec. Area, Lovell, WY)

Aquatic Biota of Rivers

A variety of fish species occupy the rivers and streams of the Park (Table 12). Redder et al. (1986) conducted surveys of 16 streams in addition to the Bighorn River, in June of 1985, and found fish in only 7 of them (Table 13). Staff of the Wyoming Game and Fish Department and the Montana Department of Fish, Wildlife and Parks occasionally survey these waters,

Table 13. Fish species found in permanent streams that drain into Bighorn Canyon National Recreation Area during a survey conducted in 1985. Fish species found, with number found in parentheses, are listed for those streams where fish were found.'

Lime Kiln Creek	none
Black Canyon Creek	brook trout *(Salvelinus fontinalis) (7)*
Corral Creek	none
East Cabin Creek	none
Little Bull Elk Creek	none
Big Bull Elk Creek	brook trout *(Salvelinus fontinalis)* (11)
Hoodoo creek	none
Dry Head Creek	brown trout *(Salmo trutta) (2)*
Deadman Creek	longnose sucker *(Catostomus catostomus) (7)*
Gyp Creek	longnose dace *(Rhinicthys cataractoe) (2)*
Davis Creek	none
Trail Creek - North Fork	none
Trail Creek - South Fork	none
Layout Creek	none
Porcupine Creek	brook trout *(Salvelinus fontinalis)* (13) longnose dace *(Rhinicthys cataractoe)* (1) longnose sucker *(Catostomus catostomus) (2)*
Cottonwood Creek	none
Bighorn River	flathead chub *(Hybopsis gracilis) (4)*

' Fish were captured by electrofishing in all streams except the Bighorn River, which was seined. Insufficient effort is the reason for the poor representation of fishes for the Bighorn River.

and have documented a slightly larger array of species than detected by Redder et al. (1986). Species are stocked in some of the Wyoming tributaries of Bighorn Lake (Table 5) and in the lake itself (see page 47). The sturgeon chub *(Macrohybopsis gelida) is* listed as a "Category 2" species in Wyoming under the Endangered Species Act and may be considered for listing as Threatened or Endangered in the future *(Federal Register*, Nov. 15, 1994).

A nationally popular trout fishery exists for rainbow trout *(Oncorhynchus mykiss)* and brown trout *(Salmo trutta)* on the Bighorn River downstream of the Yellowtail Afterbay. This fishery is managed by the Montana Department of Fish, Wildlife and Parks under the Upper Bighorn River Fisheries Management Plan. The plan (MT Dept. Fish, Wildl., & Parks 1987) was written to cover management from 1987 through 1992 and it is in the process of being revised (J. Darling, MT Dept. Fish, Wildl., & Parks, Billings, pers. comm., Nov. 1994). Two public access points to the river and its fishery are managed by the NPS. Stable flows, silt retention, and clear, cold releases from the Afterbay Dam (see page 49) generally are accepted as primary influences in the development of the trout fishery. The Bureau of Reclamation, Western Area Power Administration, and Montana Department of Fish, Wildlife and Parks have entered into a memorandum of understanding to meet the varied needs that influence flows and water quality in the Big-horn River downstream of the Afterbay. These needs include, (1) comply with state water-quality codes, (2) allow the power administration to meet firm power accreditation within the Mid-Continent Area Power Pool and Inland Power Pool in the interim between contract renegotiation, (3) allow operation of the Afterbay Dam and Reservoir to provide constant flows in the Bighorn River, and (4) improve water quality by releasing water from the Afterbay Dam in a manner that reduces gas supersaturation in the Bighorn River down-stream of the dam.

Information is extremely limited about aquatic species other than fish in the rivers and streams of the Park. The Park has a list of aquatic macro-invertebrates identified to family or genus based on extremely limited sampling of

10 sites in streams, ponds, and the reservoir during the summer of 1985 (Table 14). Five species of amphibians are known to inhabit the Park, all of which are native to the area. The plains spadefoot toad *(Scaphiopus bombrifrons) is* classified as rare in the Park, although region-ally the species is considered to be common (Baxter and Stone 1985). Wetlands and riparian areas associated with rivers and streams are the most important habitats in the Park for amphibians (Redder et al. 1986, Table 15).

Bighorn Lake

Bighorn Lake is a reservoir created by Yellowtail Dam, a 162-m-high (525-ft-high) concrete-arch darn designed to impound water for power production, municipal and industrial use, irrigation, flood control, sediment retention, recreation, and fish and wildlife enhancement (Bur. of Reclamation 1994). Construction of the dam began in 1961 and was completed in 1966. Water storage behind the dam began November 2, 1965, with total impoundment reached in June of 1967. Total drainage area behind Yellow-tail Dam is 50,827 km^2 (19,626 mi^l) (U.S. Geol. Surv. 1993). At capacity storage (defined at the maximum level retained for purposes of flood control), the dam impounds 7,000 surface ha (17,300 surface ac) of water (Table 16). The reservoir has three discharge outlets: the spill-way (elevation 1,095 m, 3593 ft), the power penstocks (elevation 1,052 m, 3,450 ft), and the river outlet invert (elevation 1,006 m, 3,296 ft), with all discharges made through the power penstocks except in emergencies (Figure 9). Electric energy is produced at the 250,000-kilowatt Yellowtail Powerplant at the base of Yellowtail Dam.

Bighorn Lake reached its maximum storage recorded on July 6, 1967 with contents of 1.7 x 10^9 m^3 (1,346,000 ac-ft) and an elevation of 1,115 m (3,656 ft) (U.S. Geol. Surv. 1993). This high water level early in the history of the develop-ment was unexpected and inundated briefly several thousand acres of valley lands at the southern end of the pool, which since have not been inundated. The minimum storage since first filling was 7.9 x 10^8 m^3 (641,900 ac-ft) on April 14, 1989 with an elevation of 1,092 m (3,583 ft).

LAKE-LEVEL MANAGEMENT

The Bureau of Reclamation is responsible for water storage and management within Bighorn Lake. Power generation and irrigation are the top two priorities for management (Bureau of Reclamation 1994). Although the Bureau of Reclamation strives to regulate water levels based on the collective needs of all water users (Table 17), dissatisfaction among user groups is common because of the diverse and sometimes incompatible needs for water. The power plant at Yellowtail Dam is operated as a peaking plant, with maximum power produced during times of the year when electrical power is most needed—usually winter months. Other factors that influ-ence water levels include weather, depth of snowpack in the mountains surrounding the Bighorn Basin and Wind River Drainage, flow-rate adjustments at dams upstream from Bighorn Lake and at Yellowtail dams to meet needs of water users and to conduct flow and safety evaluations, and evaporation rates.

The common pattern is for water to be evacuated from Bighorn Lake in fall and winter and for the reservoir to fill in spring and early summer from snowmelt runoff (Table 18). Maximum levels are often achieved in late summer, and lowest levels usually occur during early spring. Changes in the surface area of the reservoir with changes in lake levels are small at the north end of the Park because of the steep canyon walls. The opposite is true at the south end where the reservoir inundates large, shallow areas along the Bighorn and Shoshone rivers when lake levels are high and leaves these areas dry when lake levels are low. Over 2,000 ha (5,000 ac) of the floodplain in Wyoming are watered and de-watered each year with manipulation of the reservoir's water levels (Kent *1977).* These changes influence aesthetic, recreational, fisheries, and wildlife values of the reservoir.

PHYSICAL AND CHEMICAL CHARACTERISTICS

Differences are evident in physical and chemical properties of the lake between the southern end (upper pool) and northern end (lower pool). The poorest water quality in terms of sediment loads and trophic conditions occurs in the upper pool where some of the major recreational use is concentrated.

Table 14. List of aquatic invertebrates collected at locations throughout Bighorn Canyon National Recreation Area during 1985 (Bighorn Canyon National Recreation Area files, Lovell, Wyoming).

ORDER	FAMILY	GENUS	LOCATIONS[1]
Amphipoda			9
Coleoptera	Carabidae		1,2,5,6,11
	Dryopidae	*Helichus*	3
	Dytiscidae	*Uvarus*	11
	Elmidae	*Cleptelmis*	6
	Gyrinidae	*Gyrinus*	1, 7
	Halipidae	*Brychius*	2, 11
		Haliplus	1, 11
		Peltodytes	1
	Tenebrionidae		6
Dipteria	Athericidae	*Atherix*	3
	Ceratopogonidae		3, 6
	Chaoboridae	*Chaoborus*	5
		Euorethra	1
	Chironomidae		2, 4, 5, 10, 11
	Dixidae	Dixa	4, 6
	Muscidae		11
	Simulidae		2, 3, 4,10
		Metacnephia	6
		Simulium	6
	Tipulidae	*Dicranota*	4, 10, 11
		Hexatoma	2, 3, 6, 10, 11
Ephemer-optera	Behningiidae	*Dolania*	6
	Baetidae	*Baetis*	1, 2, 5, 6, 10, 11
	Ephemerellidae	*Drunella*	10
		Serratella	10
	Heptabeniidae	*Cinygmula*	4
		Epeorus	10
		Heptagenia	3
		Leucrocuta	3
		Stenonema?	10
	Leptophlebiidae	Choroterpes	2
		Paralepto-phliebia	4, 5, 6, 10, 11
	Siphlonuridae	*Ameletus*	4
		Para me! etus	10
	Tricorythidae	*Tricorythodes*	2, 10, 11
Hemiptera	Belostomatidae		5
	Corixidae		5
		Hesperocorixa	1
	Gerridae	*Gerris*	1
		Trepobates	1, 2, 4, 5
	Mesoveliidae	*Meovelia*	4
	Notonectidae	*Notonecta*	1, 5

ORDER	FAMILY	GENUS	LOCATION
Hydracarina[2]			1,2,5
Mollusca		*Gyraulus*	1, 2
		Lymnaea	1
		Physa	1, 2, 5, 6
Odonota			
Anisoptera			
	Aeshnidae	*Anax*	1, 5
	Gomphidae	*Ophiogompus*	2
	Libelluidae	Belonia	5
Zygoptera			
	Coenagrionidae	*Agrionidae*	9, 11
		Coenagrion	1
		Enallagma	1
		Zoniagrion	5
Plecoptera	Chloroperlidae	*Suwallia*	4, 5
	Perlidae	Beloneuria	6
		Eccoptura	4
		Claassenia	3
		Hesperoperla	4, 10
		Perlesta	10
		Per/me/la	3
	Perlodidae	*Isoperla*	3, 11
Trichop-tera	Brachycentridae	Megarcys	10
		Amiocentrus	6
		Brachycentrus	6
		Eobrachycentrus	4, 6
	Hydropsychidae	*Arctopsyche*	3, 10
		Ceatopsyche	
		Cheumato-	2, 3, 6, 8, 9, 10
		psyche	2, 11
		Leptonema	11
	Hydroptilidae	*Ochrotrichia*	10
	Leptocheridae	Triaenodes	1
	Limnephilidae		1, 7
	Odontoceridae	*Namamyia*	11
	Philopotamidae	Dolophilodes	3, 10
	Polycentro-podidae	*Cernotina*	11
		Cyrnellus	11
	Rhyachphilidae	*Rhyacophila*	3, 11

[1]Location are (1) Visitor Center Pond in Lovell, WY, (2) Crooked Creek, (3) Porcupine Creek, (4) Layout Creek, (5) Pond at Layout Creek Ranger Station, (6) South Fork of Trail Creek, (7) Bighorn Lake at Barry's Landing, (8) Medicine Creek, (9) Davis Creek, (10) Big Bull Elk Creek, (11) Lime Kiln Creek.

[2]Hydracarina is a taxonomic unit intermediate between a superfamily and a suborder (Thorpe and Covich 1991).

Table 15. Five species of amphibians known to inhabit Bighorn Canyon National Recreation Area (from Redder et al. 1986).[1]

Species	Abundance	Habitat Association
blotched tiger salamander *(Ambystoma tigrinum melanosticum)*	common	riparian areas, including lanceleaf cottonwood/understory shrubs and riparian boxelder/water birch/choke cherry subhabitats
boreal chorus frog *(Pseudacris triseriata maculata)*	common	palustrine wetlands
northern leopard frog *(Rana pipiens)*	common	residences, upper perennial/rocky shores along rivers, littoral zones of lakes, palustrine wetlands, and caves
Woodhouse's toad *(Bufo woodhousei woodhousei)*	common	mixed riparian shrub, residences, lower perennial riverine areas, littoral zones of lakes, palustrine wetlands, rock outcrops, and rock piles
plains spadefoot toad *(Scaphiopus bombifrons)*	rare	sagebrush grasslands
boreal (western) toad *(Bufo boreas boreas)*	identification uncertain	reportedly observed at a residence in the recreation area

[1]Documentations of the presence of the species are in the form of observations by Redder et al. (1986), files of the NPS, and observations of staff of Wyoming Game and Fish Department or Bighom Canyon National Recreation Area.

Table 16. Morphometric data for Bighorn Lake at maximum capacity (elevation 1,116 m, 3,660 ft) from Soltero 1971 and current files of Bureau of Reclamation, Billings, MT.

	Metric Units	English Units
Maximum length	115 km	71mi
Maximum width	3.2km	2.0mi
Mean width	739 m	2,425 ft
Maximum depth	140 m	459 ft
Mean depth	24 m	80ft
Area	7,004 ha	17,300 ac
Volume	170×10^7 m^3	1,381,189 ac-ft
Active Capacity	108×10^7 m^3	829,687 ac-ft
Length of shoreline	206 km	128 mi
Shoreline development[1]	11.8 (no units)	
Slope of basin	0.14% (no units)	

[1]The ratio of the length of the shoreline to the length of the circumference of a circle of area equal to that of the lake.

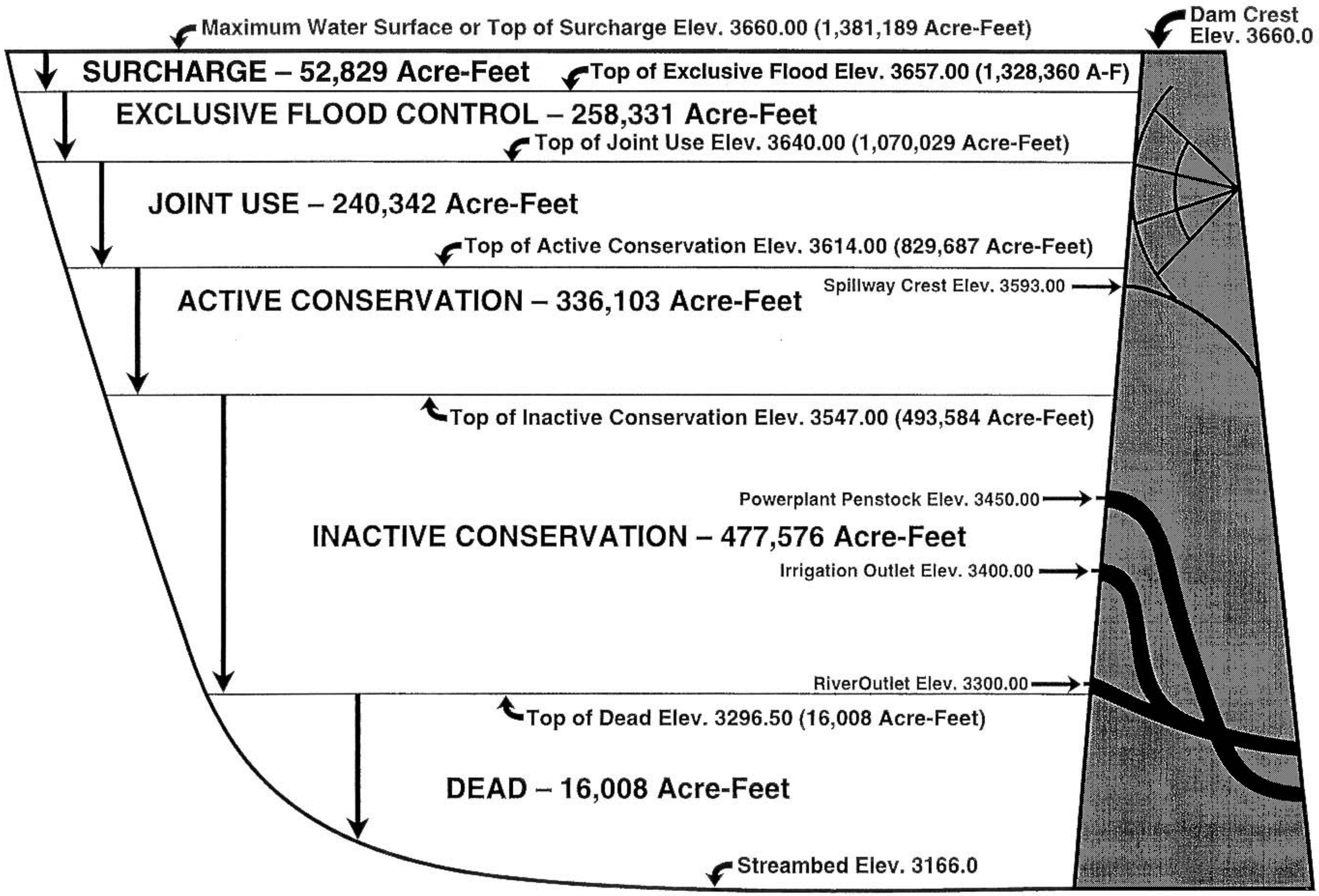

Figure 9. Bighorn Lake allocations (from Bur. of Reclamation 1994).

Table 17. Bureau of Reclamation operating criteria for Bighorn Lake (Bureau of Reclamation files, Billings, MT).

Operating criteria for Bighorn Lake:

- Whenever an adequate water supply is available, maintain a minimum release to the river of 71 m^3sec^{-1} (2,500 cfs) to protect the quality and quantity of the river fishery. When there is not an adequate water supply available, the next critical flow levels are 57 m^3sec^{-1} (2,000 cfs) and 42 m^3sec^{-1} (1,500 cfs).
- During a series of dry years, filling the reservoir is restricted in order to protect the bureau's ability to maintain minimum flow levels.
- Based on monthly forecasts prepared during January through June, releases are set to allow storage to fill to elevation 1,109 m (3,640 ft) (top of joint-use pool) by the end of July.
- After storage has peaked, usually June or July, releases are adjusted to evacuate storage to no less than elevation 1,109 m (3,635 ft) by mid-October and to elevation 1,106 m (3,630 ft) by the end of November.
- During October-early November, maintain releases to the Bighorn River at minimum desired flows for fishery to protect spawning of brown trout.
- During November-March, a uniform winter release is set to evacuate storage to elevation 1,100 m (3,610 ft) by the end of March or to an elevation of 1,102 m (3,614 ft), if the inflow is forecast to be equal to low-flow years. This protects desired reservoir levels for summer lake recreation.
- Avoid dropping the reservoir level during April and May to protect walleye spawning in the reservoir.
- Avoid dropping the reservoir level below the elevation 1,108 m (3,635 ft) prior to mid-October to protect recreational interests in waterfowl hunting and viewing.
- All flood-control operations are closely coordinated with the U.S. Army Corps of Engineers.

Sediment accumulation in Bighorn Lake is extremely high, especially in the south end of the reservoir. In general, the highest rates of sediment deposition in reservoirs occur in the upper portions of reservoir basins and embayments. Suspended particles transported into reservoirs by tributaries settle out as the flow velocity decreases in such areas (Kimmel and Groeger 1986). The high levels of accumulation in Bighorn Lake are due in part to the erodible quality of the bedrock, lack of ground cover, and steep stream gradients (Blanton 1986). Local land-use practices that have diminished vegetative cover in floodplains coupled with flood irrigation have enhanced the already high sediment loads carried by streams and rivers flowing into the lake (Soil Conserv. Serv. 1994). Sediment deposition in the upper (southern) portion of the reservoir has been estimated to be about 3636 metric tons (4,000 tons) per day (Soil Conserv. Serv. 1994).

Martin (1995b) provides an excellent review of the sedimentation patterns in the reservoir as well as recent information about rates of accumulation. During the first 17 years after impoundment, the reservoir accumulated 6.7×10^{7} m^3 (53,950 ac-ft) of sediment, resulting in a loss in storage capacity of 3.9 percent, with over 70 percent of the total sediment deposited in the southern end of the reservoir (Blanton 1986). Blanton's survey, conducted in 1982, also indicated that one particular location in the southern end of the reservoir, Horseshoe Bend, had accumulated the greatest thickness of sediment (13 m or 43 ft) at a rate of about 0.9 m (3 ft) per year. Horseshoe Bend

Table 18. Month-end elevation and contents of Bighorn Lake at 2400 for the water year from October 1992 to September 1993 (U.S. Geological Survey 1993).

Month and Year	Elevation (ft)	Contents (acre-ft)	Change in contents (acre-ft)
Sep 1992	3,638	1,026,000	
Oct	3,640	1,049,000	+23,000
Nov	3,636	1,003,000	-46,000
Dec	3,628	920,400	-82,600
Jan 1993	3,619	848,700	-71,700
Feb	3,614	815,000	-33,700
Mar	3,614	814,900	-100
Apr	3,612	800,200	-14,700
May	3,631	958,100	+157,900
Jun	3,642	1,081,000	+122,900
Jul	3,639	1,044,000	-37,000
Aug	3,637	1,021,000	-23,000
Sep	3,639	1,039,000	+18,000

is an extremely pronounced, incised meander located about 72 km (45 mi) upstream of Yellowtail Dam. Compared to the rest of the reservoir, the large cross-sectional area of the canyon at this bend results in lower flow velocities and, consequently, greater sediment deposition than elsewhere in the reservoir. Large expanses of these sediments are exposed as mud flats when lake levels are low. A conservative estimate of additional accumulation at Horseshoe Bend over the last 12 years is 1.8-3.7 m (6-12 ft), depending on location of measurements. Even when the conservative nature of these estimates is discounted, the recent data suggest that the sedimentation rate in the southern portion of the reservoir is non-linear and has decreased over the last six years compared to the first 15 years of reservoir operation (Martin 1995b).

The accumulation of sediments in Bighorn Lake has positive and negative consequences. The recreational fishery in the Bighorn River below the Yellowtail and Afterbay dams has greatly benefitted by the efficient sediment trapping. Conversely, resources and resource users at the southern end of the lake have experienced some distinct disadvantages. For example, boat launching from the only developed access to Bighorn Lake in Wyoming, Horseshoe Bend, can become impossible if lake levels are low. For instance, exceptionally low water levels in 1994 precluded boat launching from early June through the remaining summer season. Using a conservative estimate of sedimentation rate for recent years, the Horseshoe Bend site will likely be usable during the middle and late summer season under normal reservoir conditions for as few as 4 years or maybe as many as 20 years (Martin 1995b). Given the dynamic nature of the Bighorn System, the transition from a functional to a nonfunctional site for boat launching could be rapid and nonlinear.

LAKESHORE SLUMPS

Because of the topography of Bighorn Canyon, most of the shoreline of Bighorn Lake is backed by steep, rocky terrain with few areas suitable for shoreline use such as camping. A major exception is the Bull Elk Basin at the north end of the lake, where small beaches are available along the lake shoreline. This basin is situated in the Gallatin Gros Ventre Formation, which contains unstable shales and thinly bedded limestones that are susceptible to slumping and sliding. Bureau of Reclamation geologists continue to monitor several of the major slumps located high above the lake using measurements and photo-points (NPS 1992). There appear to be several areas of mass movement in the form of creep as evidenced by many scarps, some 3 m (10 ft) or more in height and several hundred feet long. Movement appears to be slow. Smaller slumps at the water's edge are not systematically monitored, but casual observation suggests their movement may be dependent on seasonal moisture and may be difficult to predict (NPS 1992). At one time, Park staff signed the beaches at Bull Elk Basin as possibly hazardous areas for recreational use, but in recent years the signs have not been replaced as they have deteriorated. In general, the area is not perceived as an immediate and major threat to reservoir recreationists.

TROPHIC STATUS

The trophic status of Bighorn Lake has been a subject of several studies and some minor disagreement (Soltero 1971, Lee and Jones 1981, and EPA 1977). The overall trophic quality of the reservoir ranges from mesotrophic near the dam to eutrophic in the upper pool (EPA 1977). Some have argued that a hypereutrophic classification is warranted for the upper pool of the reservoir, whereas waters near the dam could be considered oligotrophic to mesotrophic (Lee and Jones 1981). Phillips and Bahls (1994), in a recent study of contaminants in Montana reservoirs, classified Bighorn Lake as eutrophic based on summertime Secchi disk depth and concentration of total phosphorus at a sampling site in Montana. Whatever the classification, there is agreement that trophic conditions change progressively from the upper (southern) to the lower (northern) portion of the lake, and the upper pool experiences eutrophic conditions. Horseshoe Bend and Barry's Landing, two major points of access for water-based recreational use in the Park, are in the southern eutrophic region. Phosphorus is the element most likely controlling phytoplankton growth in the reservoir in summer months, with phosphorus fertilization of the reservoir derived from non-point sources (e.g., runoff from crop, range, and forest lands), as well as identifiable sources such as discharge points for municipal and industrial wastes.

TEMPERATURE

As summarized in Kent (1977), reservoir water temperatures were collected on a regularly scheduled basis by Soltero (1971) shortly after impoundment and about a decade after impoundment by Swedberg (1970-1975, 1978). Less regular sampling has subsequently occurred (e.g., surface water temperatures collected in the 1980s at Barry's Landing, Horseshoe Bend, and the Bighorn River Causeway; Files, Bighorn Canyon Natl. Rec. Area, Lovell, WY), but the early work provides the primary basis for this summary of temperature information.

Maximum surface water temperatures around 24°C (75°F) are reached in July or August. Thermal stratification is regularly evident near the dam, with an indistinct thermocline usually forming in late summer or early fall (August to October) at a depth of about 60 m (200 ft). A narrow thermocline may develop in upper portions of the reservoir as far south as the Wyoming-Montana state line at depths ranging from 6-21 m (20-70 ft) and in various months from May through October. Water temperatures, at least above the 61 m (200-ft) depth, are similar throughout the reservoir in June, July and August. During the fall, the upper reservoir cools much more rapidly than the lower portion. Ice forms on the upper reservoir in December and progressively later toward the dam. The lower reservoir is often ice-free throughout the year. Water temperatures in winter differ slightly between upper and lower reaches of the reservoir (Swedberg 1972, 1973). As spring inflows increase in volume, the upper reservoir warms more rapidly than the lower end, and the upper reservoir is usually ice-free by early April.

CLARITY

Light penetration varies between upper and lower pool locations. Under average conditions, the euphotic zone extends to a depth of about 10 m (33 ft) near the dam and a depth of 1 m (3 ft) at the upper pool (Soltero 1971). Measured Secchi disk depth tends to be around 0.5 m (1.5 ft) in the upper pool and around 1-1.5 m (3-5 ft) near the dam (EPA 1977). Calculated Secchi depth based on the measurements by Soltero of euphotic-zone depth is about 0.5 m (1.6 ft) in the upper pool and 3.5 m (11 ft) near the dam (Lee and Jones 1981). The transition in clarity from the upper to lower pool is probably the result of two factors: a decrease in inorganic turbidity associated with the settling of large amounts of sediments brought into the reservoir by the Bighorn and Shoshone rivers and a decrease in phytoplankton abundance progressing from the upper pool toward the dam (see page 46).

OTHER PHYSICAL AND CHEMICAL PROPERTIES

Most sampling of physical and chemical properties of Bighorn Lake occurred shortly after impoundment (Table 19). Reservoirs are dynamic aquatic systems, exhibiting changes at a variety of time scales (Thornton et al. 1990), thus the early data may not accurately represent current conditions. An excellent source of physical and chemical data spanning the history of the impoundment is available from the Wyoming Water Resources Center at the University of Wyoming.

Although some of the chemical conditions in Bighorn Lake may influence trophic dynamics and indirectly influence the aesthetics of Bighorn Lake for recreation, none of the values appear to be limiting to fish production in the lake. Except for mercury levels (see page 44), hazards to human health have not been documented (Kent 1977, Lee and Jones 1981). Physical conditions in the reservoir, primarily fluctuating lake levels, sediment accumulation, floating driftwood, and high water temperatures do pose negative conditions for some fish species and for some recreational uses. Some of the conditions are positive for one or more components of the reservoir but negative for others. Driftwood, for example, is probably a positive feature of the system for many of the biological resources because it provides attachment sites, refugia, or nutrients for some biota, particulary when it becomes submerged

(Kimmel et al. 1990, O'Brien 1990); however, it can be a hazard for boat traffic on the reservoir.

In terms of water chemistry, Bighorn Lake water has a high dissolved-solids content, compared to most freshwater systems, and the water is of moderate hardness. Calcium, sodium, sulfate, and bicarbonate are the most common constituents of the dissolved solids present. The pH of the water is in the range of neutral to slightly alkaline. Water flowing through the impoundment undergoes certain physical and chemical changes. Turbidity is greatly reduced and most dissolved constituents lose concentration. Nitrate-nitrogen and ortho-phosphate are relatively high in the reservoir compared to average natural waters, and nitrate-nitrogen is augmented from upper to lower pool regions. These nutrient conditions are conducive to algal blooms in the lake. Photosynthetic reduction of alkalinity is not apparent, and the mass of stored water is much more resistant to seasonal temperature changes than the river waters upstream and down-stream of the reservoir.

Limited studies have been conducted in Big-horn Lake to detect concentrations of PCBs and concentrations and sources of some heavy metals. Sampling of sediments and water from Bighorn Lake for PCBs and mercury in 1992 yielded concentrations of both substances below detection levels of standard analysis techniques (Phillips and Bahls 1994). In the same study, mercury concentrations in walleye were moderately high in Bighorn Lake, but PCBs were below detection levels (Table 20). The source of the mercury was not specifically

Table 19. Mean and range (in parentheses) of water chemistry for the waters of Bighorn Lake measured at sites in the southern and northern ends of the reservoir by Soltero (1971). Sample size is 19 for each parameter and is based on bi-weekly sampling from February 22 through December 20, 1968.

Chemical constituent or physical characteristic	S. End of Reservoir)		N. End of Reservoir)	
Ca^{++} (meq/1)	4.62	3.48-8.96	3.99	2.55-8.26
Mg++ (meg/1)	2.13	0.52-4.75	2.10	0.75-4.33
Na^{+} (meg/l)	3.50	1.97-4.55	3.14	1.90-4.40
K^{+} (meg/1)	0.13	0.11-0.18	0.11	0.07-0.27
HCO3 (meq/1)	3.10	2.16-3.38	2.97	2.09-4.55
Cl- (meq/1)	0.27	0.14-0.35	0.26	0.17-0.37
$SO4^{-2}$ (meq/1)	6.39	3.54-7.54	5.62	2.83-8.83
F- (meq/1)	0.06	0-0.17	0.05	0-0.18
NO_3--N (mg/1)	0.44	0.13-0.73	0.52	0.11-0.89
NO_2--N (mg/1)	0.011	0.004-0.030	0.008	0-0.051
NH_3 -N (mg/1)	0.06	0-0.22	0.08	0-0.33
Ortho-PO_4 3 (mg/1)	0.18	0-0.72	0.08	0-0.63
Turbidity (JacksonTurbidity Units)	558	44-3350	17	8-44
Silica (mg/1)	11.4	9.8-12.9	10.2	6.7-14.6
Dissolved oxygen	8.3	6.2-12.6	6.2	1.4-10.7
Conductance (microomhs)	882	460-1070	798	540-1000
pH (range only)		(8.10-8.72)		7.65-8.63

'The site at the south end (upper pool) is listed as Station 5 by Soltero and is south of the Montana-Wyoming border but north of the confluence of the Shoshone River with the Bighorn River. The site at the north end is listed as Station 1 by Soltero and is 16 km (10 mi) south of Yellowtail Dam.

Table 20. Mercury and polychlorinated biphenyl (PCB) concentrations (wet weight basis) and percent lipid of muscle tissue from walleye *(Stizostedion vitreum vitreum)* taken from Bighorn Lake in 1992 (nd indicates none detected) (Phillips and Bahls 1994).

Walleye size range (in)	No. Samples	Concentration µg/g Hg	Concentration µg/g PCB	Percent Lipid
9.8-15.1	12	0.2	nd	0.3
19.2-20.7	4	0.58	nd	0.8
27.0-27.5	*2*	1.4	nd	4.4

addressed in this study, but the researchers believed the source to be a result of the unique physical and chemical condition that can occur in impoundments, rather than human-caused contamination. The Preventive Health Services Bureau of the Montana Department of Health and Environmental Sciences has issued a statewide advisory for fish consumption because of high levels of mercury, and less commonly PCBs, found in Montana reservoirs (Montana Dept. Health & Env. Sci. 1995.)

It is likely the majority of the mercury in Bighorn Lake is from nonpoint sources, probably mostly weathering of landforms and erosion of soils in the drainage basin. From 1978-1981, factors controlling the mobilization, transport, and bioavailability of mercury in Upper Missouri River Basin reservoirs were studied (Phillips et al. 1987). Measurements of mercury and selenium concentrations in surficial sediments, and sediment cores from Bighorn Lake were part of this research (Table 21). For the most part, mercury concentrations in sediments were uniformly low and did not significantly differ among the 10 reservoirs sampled. Selenium concentrations were low and tended to increase with downstream distance in the Missouri River watershed, although the trend was not statistically significant. Mercury concentrations were higher in walleye *(Stizostedion vitreum vitreum)* from headwater reservoirs with unregulated inflows than in fish of the same size from downstream reservoirs. Erosion and leaching during flooding apparently facilitated mercury accumulation by fish in reservoirs. Tongue River Reservoir, an irrigation and flood-control impoundment in southeastern Montana and about 120 km (75 mi) east of Bighorn Lake, was intensively studied to evaluate sources of mercury. About 93% of the mercury transported into the Tongue River Reservoir was in river water. Point sources included 1% mines, 9% sewage treatment plant, less than 1% ground water, 1% dry deposition, and 4.5% precipitation. Nonpoint sources, including weathering and erosion, accounted for most of the mercury, emphasizing the importance of land management to control erosion and leaching (Phillips et al. 1987). The U.S. Geological Survey has sampled intermittently for a very limited array of compounds derived from pesticide use, and this sampling has not revealed specific hazards to human health or aquatic biota (Soil Conserv. Serv. 1994).

Table 21. Mercury and selenium concentrations in surficial sediments (top 5 cm) from Bighorn Lake during the period 1978-81 (from Phillips et al. 1987).

Location	Distance of site from inflow (km)	No. of samples	Water depth (m)	Mercury conc. (ug/g dry wt) Mean	Mercury conc. Range	Mercury conc. SD	Selenium conc. (1.tg1 g dry wt) Mean	Selenium conc. Range	Selenium conc. SD
Upper Reserv.	17	15	2.0-11.0	0.03	0.01-0.05	0.02	0.17	0.04-0.44	0.1
Lower Reserv.	87'	10	12.0-58.0	0.04	0.01-0.06	0.02	0.84	0.08-2.26	0.6 9

' Transect located on side arm 1.5 km southeast of main channel.

DRIFTWOOD

Driftwood is a prominent feature of Bighorn Lake. Logs, trees, and other forms of woody debris enter the lake from the Bighorn and Shoshone rivers and their tributaries and add to the accumulation of woody debris already present in the reservoir. Much of this debris is perched on the lakeshore when lake water levels are low and then is deposited back into the lake as water levels rise when the reservoir fills each year. Various methods have been used to remove portions of this driftwood because it poses hazards to boaters and to the operation of the dam. Densities of accumulation can be extensive enough to block lake access from the two boat ramps at the south end of the lake—Horseshoe Bend and Barry's Landing. High density of floating driftwood and the spring and summer recreational season coincide.

The management strategy for driftwood has been variable. In the mid 1980s, Park crews located concentrations of driftwood on the lake and along the shoreline, loaded the wood into barges, hauled it to designated sites, and stacked and burned it. This effort was labor-intensive and was repeated throughout the entire spring and summer season. It was eventually discontinued due to lack of funding. From 1971-1975, the Park used a floating log boom to attempt to prevent driftwood from moving north from the south end of the lake. The structure was assembled near the "south narrows," south of Horeshoe Bend, and was aligned across the channel at an angle calculated to guide and trap driftwood into a natural cove. Logs accumulating in the cove were held there as the lake level dropped and were disposed of the following winter. The structure captured driftwood effectively, but such large amounts were caught, 0.8-1.2 ha (2-3 ac) every 3-5 days, that winds from the south and south-west would forced driftwood under the log boom and back into the lake, where it was free to float northward beyond the structure. The log boom solved the collection problem, but the needed efforts to remove the accumulations were too costly. Since 1976, the Park has relocated the log boom to create a protected, en-closed area around the immediate vicinity of the Horseshoe Bend marina. Wood still needs to be removed periodically from Barry's Landing. Driftwood that is removed either at Horseshoe Bend or Barry's Landing is pushed onto the shoreline using a bulldozer in the winter when the ground and shoreline are frozen. The public is allowed to cut firewood from the piles, and the remainders of the piles are burned on site. This practice probably eliminates less than 10 percent of the total accumulation (T. Peters, Bighorn Canyon Natl. Rec. Area, Lovell, WY, pers. comm., May 1994).

PLANKTON

The bulk of information about phytoplankton in the lake is based on studies within the first 10 years after impoundment (Soltero 1971). The phytoplankton community includes at least 58 taxa, and based on cell biovolume, the community is dominated by diatoms, especially *Fragilaria crotonensis* (Table 22). *Rhodomonas lacustris,* a cryptophyte, is the most frequently

Table 22. The major phytoplankton species from Bighorn Lake according to absolute mean cell volumes based on collections throughout the lake by Soltero (1971) in 1968 and 1969.

Taxon	Cell Volume (mm^3 per liter)
Fragilaria crotonensis	1.222
Cryptomonas ovata	0.658
Stephanodiscus niagarae	0.518
Asterionella formosa	0.513
Aphanizomenon flos-aquae	0.487
Melosira granulata	0.173
Cyclotella spp.	0.165
Pediastrum duplex	0.143
Rhodomonas lacustris	0.105
Ceratium hirundinella	0.088
Navicula spp.	0.087
Microcystis aeruginosa	0.087
Melosira italica	0.073
Diatoma vulgare	0.060
Synedra ulna	0.052

Table 23. Rank of the major phytoplankton species of Bighorn Lake according to presence based on collections throughout the lake in 1968 and 1969 (from Soltero 1971).

Taxon	Presence (%)
Rhodomonas lacustris	85.4
Cryptomonas ovata	84.8
Asterionella formosa	53.9
Fragilaria crotonensis	52.7
Stephanodiscus niagarae	36.3
Cyclotella spp.	33.7
Navicula spp.	32.7
Ankistrodesmus falcatus	31.3
Aphanizomenon flos-aquae	30.9
Ocystis spp.	26.8
Melosira italica	25.9
Scenedesmus quadricauda	25.7
Melosira granulata	23.5
Diatoma vulgare	20.6
Schroederia setigera	18.8
Pandorina morum	17.9
Scenedesmus acuminatis	15.5
Ankistrodesmus braunii	14.6
Anabaena sp.	12.2
Synedra ulna	12.2
Diatoma elongatum	10.7

occurring phytoplankton (Table 23). Spatial and temporal changes in phytoplankton communities are evident between southern and northern portions of the reservoir. Again based on the early studies, algal cell biovolumes tend to decrease from southern reaches toward the dam, but the decline is not always incremental or predictable. Cell biovolumes typically are highest in spring and summer months. Diatom cell biovolumes are predominant in spring, summer, and late fall; bluegreen algae dominate in the fall. Primary production is at a maximum in summer and tends to be greatest in the southern end of the reservoir. Interannual variation in production is great and can change by an order of magnitude.

The zooplankton community of the lake was systematically studied during the summers of 1968-70 soon after impoundment (Horpestad 1977). A highly productive period occurs in reservoirs before the establishment of a trophic equilibrium (Kimmel and Groeger 1986). Furthermore, Bighorn Lake has been stocked extensively for a recreational fishery (see below), and fish predation can have an effect on species composition of zooplankton (Bahls 1992, Liss et al. 1995). Thus, the species present early in the impoundment period may not reflect current conditions.

Twenty-six taxa were identified in the reservoir in the early years of impoundment: 10 cladocerans, 3 copepods, and 13 rotifers (Table 24). The cladoceran, *Daphnia galeata mendota* numerically was the most abundant species and contributed more to the total standing crop of zooplankton than any other taxon. *Daphnia pulex* and *Diaptomus ashlandi* became less abundant, whereas, *Daphnia galeata mendota, Cyclops bicuspidatus thomasi* and rotifers became more abundant over the three-year period during which they were studied (Horpestad 1977).

FISH

Thirty fish species inhabit Bighorn Lake (Table 12), about half of which have been introduced to the Bighorn River Drainage. Several of the introduced species—walleye *(Stizostedion vitreum),* rainbow trout *(Oncorhynchus mykiss),* and white crappie *(Pomoxis annualris)—are* important game species targeted for catch by recreational users. Natural resources management staff from Montana and Wyoming continue to stock several of these species in the lake (Wyoming Dept. Fish and Game files, Cody, Wyoming; Montana Department of Fish, Wild-life and Parks files, Billings, Montana). Montana first stocked the reservoir with rainbow trout and lake trout *(Salvelinus namaycush)* fry in late 1965 immediately after impoundment began. Wyoming conducted its first stocking with fingerling rainbow trout in 1967. Fish stocking has continued with releases of one or more species, including rainbow trout, brown trout *(Salmo trutta),* cutthroat trout *(Oncorhynchus clarki),* sockeye salmon (0. *nerka),* lake trout, walleye, and channel catfish *(Ictalurus*

Table 24. Zooplankton taxa observed in Bighorn Lake during sampling from 1968 through 1970 (from Horpestad 1977).

Cladocera		
Daphnia galeata mendota	*Daphnia pulex*	*Diaphanosoma leuchtenbergianun*
Ceriodaphnia reticulata	*Moina spp.*	*Bosmina longirostris*
Macrothrix rosea	*Kurzia latissima*	*Leydigia quadrangularis*
Chydorus sphaericus		
Copepoda		
Diaptomus ashlandi	*Cyclops bicuspidatus thomasi*	*Eucyclops spp.*
Rotifera		
Polyarthra spp.	*Hexarthra spp.*	*Filinia spp.*
Anuraeopsis app.	*Ascomorpha spp.*	*Keratella cochlearis*
Keratella quadrata	*Asplanchna spp.*	*Brachionus spp.*
Conochilus unicornus	*Synchaeta spp.*	*Euchlanis spp.*
Notholca spp.		

punctatus) (Kent 1977). Only walleye, channel catfish, and spottail shiners *(Notropis hudsonius)* are currently stocked (M. Welker, WY Game & Fish Dept., Cody, pers. comm., Dec. 1994). Walleye is the most commonly stocked species, and as an indication of stocking intensity, an annual average of 7 million fry and fingerlings, mostly fry, were released in the reservoir by the states of Wyoming and Montana from 1989 through 1993 (Wyoming Dept. Fish and Game files, Cody, Wyoming). Most stocking of wall-eye occurs in reservoir waters in Montana because of low water levels and eutrophic conditions in Wyoming waters at the time of stocking. Spottail shiners are intermittently stocked as a forage species for walleye.

The fish stocking programs and changes in characteristics of the aquatic habitat following impoundment of the Bighorn River have undoubtedly affected native fish populations. The native sauger *(Stizostedion canadense),* for example, commonly declines after impoundment, probably because of a reduction in river spawning habitat and changes in water clarity (Nelson and Walburg 1977). Sauger also have the potential to hybridize with the introduced walleye (Nelson and Walburg 1977, Billington et al. 1988), which jeopardizes the genetic purity of native sauger stocks. Walleye now stocked in Bighorn Lake come from hatcheries in South Dakota or from fry raised locally from eggs taken from fish captured at the north end of the lake. Some contribution from natural reproduction also is suspected (Frazer et al. 1992). Walleye are an extremely popular sportfish, and neither state has plans to stop stocking of this species out of concern for the hybridization potential. Channel catfish are native to the Bighorn River System, but the stocks of channel catfish planted in the Bighorn Drainage have mostly been from outside sources, often Oklahoma (M. Welker, WY Game & Fish Dept., Cody, pers. comm., Dec. 1994). A study has been proposed by the University of Wyoming to assess the status of channel catfish and sauger stocks in the Bighorn River, and specifically to assess the genetic purity of sauger stocks (M. Welker, WY Fish & Game Dept., Cody, pers. comm., Dec. 1994).

The only current intentions for fish introductions on the part of either Montana or Wyoming is the reintroduction of the shovelnose sturgeon *(Scaphirhynchus platorynchus)* to the Bighorn River upstream of Bighorn Lake (Annear and Braaten 1995). A migratory population of shovelnose sturgeon likely inhabited the Big-horn Drainage prior to 1900, but since have disappeared. The State of Wyoming prepared an environmental assessment for the reintroduction project and received approval to proceed from the Wyoming Commission of Fish and Game (M. Welker, WY Game & Fish Dept., Cody, pers. comm., Mar. 1995; Minutes, Annual Bighorn Lake and River Coordination Meeting, Mar. 21, 1995). The existing habitat and hydrologic conditions of the Bighorn River are presumed to be adequate for the species. Stocking of fry and fingerlings taken from the Yellowstone River and reared in a Federal hatchery will begin in the summer of 1996. Some sturgeon will likely enter Bighorn Lake.

Initial discussions have taken place about the possibility of introducing gizzard shad *(Dorosoma cepadianum)* in the Bighorn Drainage as a forage species for walleye and sauger, but this possibility has raised objections from several interest groups, including the NPS (Minutes, Annual Bighorn Lake and River Coordination Meeting, Mar. 22, 1994). The NPS strives to protect and preserve species of native flora and fauna within units of the National Park System, and with rare exception does not support the introduction of nonnative plants and animals (NPS 1991). Additional fish introductions still have the potential to occur with-out the sanction of the state fisheries management agencies and the NPS. For example, an angler caught a striped bass *(Morone saxatilis)* in the Montana portion of the reservoir in 1992, with the identification of the fish verified by staff of the Montana Department of Fish, Wild-life and Parks. The same year, staff of the Wyoming Game and Fish Department received an unconfirmed report of a brook stickleback *(Culaea inconstans)* caught in a seine (1994 Progress Report on 1993 Sampling, Report 22-745-02, Wyoming Game and Fish Department, Cody). Small-mouth bass *(Micropterus dolomieui)* have moved into the reservoir from upstream segments.

OTHER ANIMAL GROUPS

Benthic invertebrates remain poorly studied in Bighorn Lake. Siltation, turbidity, and fluctuations of water levels probably limit any extensive development of these invertebrates. Absence of littoral habitats, particularly in the lower canyon, probably also limits invertebrate production. Very limited information on the amphibians associated with Bighorn Lake is described on page 37.

Yellowtail Afterbay Dam and Reservoir

Yellowtail Afterbay Dam is located 3.5 km (2.2 mi) downstream of Yellowtail Dam. It is a 22-m-high (72-ft-high) concrete dam built to impound water and regulate the peaking power discharges from Yellowtail Powerplant to the Bighorn River. The body of water impounded by this dam, known as the Yellowtail Afterbay Reservoir, has a capacity of 1.37×10^8 m^3 (3,150 ac-ft) (Files, Bureau of Reclamation, Billings, MT). The Afterbay Reservoir receives some recreational use, primarily fishing, even though water levels fluctuate dramatically, coinciding with releases from Yellowtail Dam. The fishery is primarily for stocked rainbow trout *(Oncorhynchus mykiss)*, with some brown trout *(Salmo trutta)*, walleye *(Stizostedion vitreum)*, and possibly yellow perch *(Perca flavescens)* present along with some nongame species, primarily suckers *(Catastomus)* (Fredenberg 1985, K. Fraser, MT Dept, Fish, Wildl. & Pks., Billings, pers. comm., May 1995).

Ponds in Yellowtail Wildlife Habitat Management Area

The Yellowtail Wildlife Habitat Management Area has 15 ponds created and maintained for fish and wildlife management and public education. Seven of the ponds are on Park property. Cemetery Pond north of the confluence of the Bighorn and Shoshone rivers is the largest pond on Park property, with 30 surface ha (75 surface ac) of water and an additional 28 ha (70 ac) of wetlands. All of the other ponds on Park property are located south of the confluence of the two rivers, and range in size from 0.4-8 ha (1 to 19 ac) (Table 25), with additional areas of wetland habitat. The ponds are located within the extreme high-water flood pool of Bighorn Lake. Several of the ponds are inundated when lake levels are high, and others are filled with lake water flowing through canals and ditches. Although not systematically monitored with gauges, water levels in the ponds are known to fluctuate drastically in response to changing levels of Bighorn Lake. Many of the ponds are dammed and diked to maintain some control of lake levels. The species composition of the fish community of

Table 25. Ponds of Bighorn Canyon National Recreation Area created and managed as part of the Yellowtail Wildlife Habitat Management Area.

Pond Name	Surface Ha	Surface Ac
Cemetery Pond	30.0	75
Railroad Pond	7.7	19
Pond 6½	0.4	1
Pond 7	1.6	4
Pond 8	1.2	3
Pond 9	0.8	2
Pond 10	0.8	2

the ponds is a mix of introduced species and others that have migrated into the ponds from Bighom Lake and its tributaries. Cemetery Pond contains spottail shiners *(Notropis hudsonius)*, fathead minnows *(Pimephales promelas)*, white suckers *(Catostomus commersoni)*, black bullhead *(Ameiurus melas)*, flathead chub *(Platygobio gracilis)*, black crappie *(Pomoxis nigromaculatus)*, shorthead redhorse *(Moxostoma macrolepidotum)*, common carp *(Cyprinus carpio)*, and bluegill *(Lepomis macrochirus)*. One pond in the Yellowtail Unit, but not on Park property, has received experimental stockings of largemouth bass *(Micropterus salmoides)* and rainbow trout *(Oncorhynchus mykiss)* to evaluate the potential for a recreational fishery in this pond (M. Welker, WY Game and Fish Department, pers. comm., Dec. 1994). An exchange of fish species occurs between many of these ponds and Bighorn Lake at high water levels (Files, WY Game & Fish Dept., Cody). Use of these ponds by birds is significant, especially during spring and fall migrations. Several species of amphibians are also abundant along the shoreline and in the wetlands surrounding the ponds (Redder et al. 1986., Table 16).

GROUNDWATER RESOURCES

Some areas in the Park have been surveyed for possible water-supply sources (Lowry et al. 1976). Madison limestone is the major water-bearing formation in the region, and along with alluvial deposits and the Tensleep Sandstone Formation, are the major sources of groundwater. Aquifers in the Madison Formation can be 210 m (700 ft) to 465 m (1,500 ft) deep and are extremely productive sources of groundwater. Generalizations about groundwater reported in this section are based on a series of water-resources reconnaissance studies conducted throughout the Bighorn Basin and adjacent mountains in northwestern Wyoming (Lowry et al. 1976). Local deviations from the conditions described here may well be present within the Park, but systematic surveys within the Park have not occurred.

Aquifers are present throughout the Bighorn Basin. Those capable of yielding more than 3,785 liter per min (1,000 gal per min) underlie the area everywhere, except in the mountains on the periphery of the basin; however most of these are at depths too great for development. In general, the yield of aquifers to wells depends on the permeability of thickness of the aquifer penetrated. The permeability of essentially non-fractured clastic sedimentary rocks depends on size and sorting of the grains and the amount of cementation between the grains. Secondary permeability is developed in both clastic and nonclastic rocks by fractures or solution. The water-bearing properties and chemical characteristics of the ground water of major formations in the vicinity of the Park as well as elsewhere in the basin are described in Table 26.

Aquifers in the Bighorn Basin receive recharge from precipitation, streamflow, infiltration, and from adjacent formations. Natural discharge may be by flow from springs or seeps or by evapotranspiration from plants whose roots penetrate the aquifer, by inflow to streams, and by movement to adjacent formations. It is assumed that movement of water in consolidated aquifers of the basin is similar to that in the Tensleep Sandstone Formation. Some of the water in the Tensleep Sandstone is discharged by spring in areas of outcropping and some of the water moves basinward, i.e., toward the Bighorn River. The river has eroded completely through the Tensleep at the Wyoming-Montana border; therefore, water does not move northward out of Wyoming in the Tensleep Sandstone. Increases or decreases in the flow of perennial streams, which can be attributed to

Table 26. Formations and water-bearing properties of rock types found in the vicinity of Bighorn Canyon National Recreation Area (Lowry et al. 1976).

Formation Name[1]	Water-bearing properties and chemical type of water[2]
Gros Ventre Formation & Gallatin Limestone Bighorn Dolomite Jefferson Limestone & Three Forks Shale Madison Limestone Amsden Formation Tensleep Sandstone	In addition to the primary permeability in the Tensleep Sandstone, this section of rocks has the greatest development of secondary permeability. This large section of competent rocks has developed fracture permeability, and solution along some of these fractures in carbonate rocks has further increased permeability. In addition, the Madison Limestone was in a favorable environment for development of solution openings before the Amsden Formation was deposited. Some wells in the Madison and Bighom formations obtain most of their water from a comparatively short vertical interval. For example, one well yields 2650 liters per min (700 gal per min) from a 3-m (10-ft) cavernous zone with a head loss of 7.5 m (25 ft). In contrast, another well penetrates 269 m (895 ft) of Madison and Bighom having no large cavernous zones and yields 628 liters per min (166 gal per min) with 138 m (461 ft) of head loss. Most wells reportedly yield either more than 3,785 liters per min (1,000 gal per min) or less than 1,893 liters per min (500 gal per min). Nine chemical types of water were represented in 46 analyses. Calcium bicarbonate is the dominant type (67 percent), and calcium sulfate is next most abundant (13 percent).
Embar Formation Chugwater Formation Piper Formation Rierdon &'Swift Formation Morrison Formation Cloverly Formation Thermopolis Shale Mowry Shale Frontier Formation Cody Shale	Sandstones that will yield water to wells are present principally in the upper part of this section of rocks. Large-scale solution occurs in the gypsum beds in the lower part of this section, from which potentially large yields could be developed. The source of large-yield springs, which issue in the outcrop areas of these rocks, is attributed to underlying Paleozoic rocks because of the temperature and quality of the water. Five chemical types of water were represented in 14 analyses. Calcium sulfate and sodium sulfate types each compose 36 percent of the samples. The next most abundant type was sodium bicarbonate. The calcium sulfate type is present in the gypsiferous formations. The Frontier Formation, which contains somewhat less than 50 percent sandstone, and the Muddy Sandstone member of the Thermopolis Shale are the most dependable sources of water in what is otherwise a shale section. The shales are, for the most part, incompetent and yield plastically. The Mowry Shale is brittle and fractures when subjected to stress, and yields water to wells and springs in some locations. Seven chemical types of water were represented in 18 analyses. Sodium sulfate is the dominant type (44 percent). The next most abundant type is sodium bicarbonate (28 percent).
Alluvium	The permeability of these deposits is dependent on sorting and size of grains. Cementation that would decrease the permeability is not of general occurrence. Alluvium derived from formations in the basin is predominantly fine grained and will not yield large supplies of water; however, yields of 4-5 gal per min may be developed at relatively shallow depth where deposits are saturated. Alluvium derived from the mountainous areas contains a higher proportion of coarse-grained material and, where saturated, will yield water readily to wells. The thickness of the saturated zone is generally small. The dominant chemical type of water in 80 analyses is sodium sulfate (26 percent), next most abundant types are sodium calcium sulfate (21 percent), and calcium sodium sulfate (10 percent). Eleven types compose the remaining 43 percent.

[1] The water-bearing properties of two formations described by Richards 1955 as present in the vicinity of Bighorn Canyon National Recreation Area are not described by Lowry et al. 1976 — Parkman Sandstone and Bearpaw Shale.

[2] Generalization about water-bearing properties are based on observations in the portion of the Bighorn Basin in Wyoming not strictly the location of Bighorn Canyon National Recreation Area. Local variations in these generalizations should be expected.

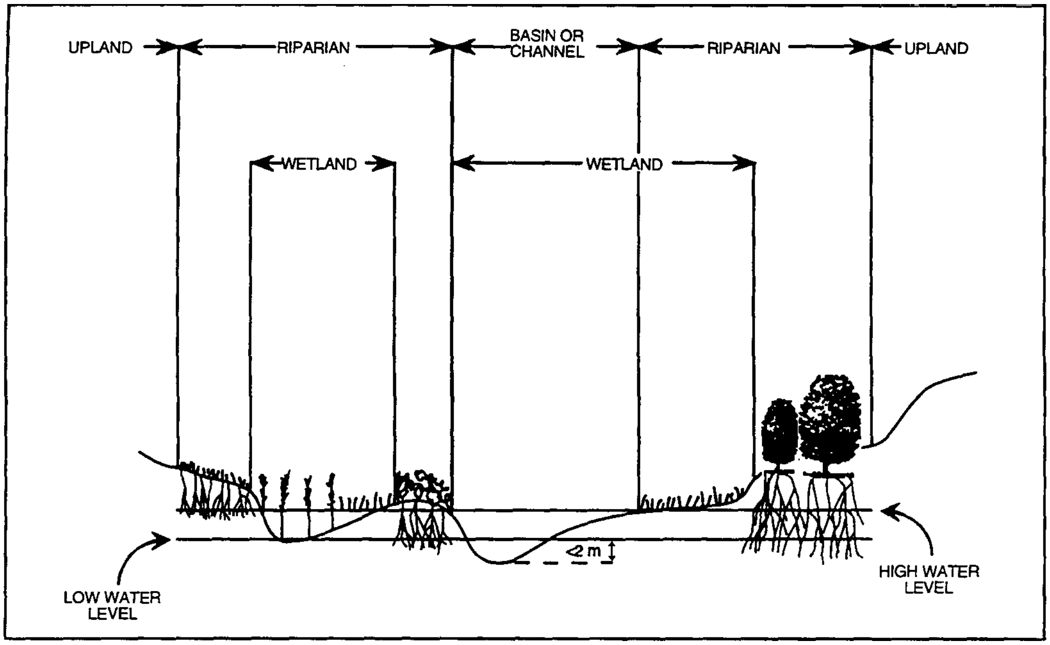

Figure 10. The riparian zone (adapted from Minshall et al. 1989).

discharge from or recharge to sandstone aquifers in the center of the basin, are not great enough to be discernible from other minor factors affecting streamflow, such as evapotranspiration.

Fault zones are known to exist in or near the recreation area, and springs surface along several of these zones (NPS 1977). The Sykes Spring fault zone, for example, is located near the southern end of the recreation area and is approximately 2.4 km (1.5 mi) west in the vicinity of Horseshoe Bend. The fault zone is approximately 8 km (5 mi) long and 0.4 km (0.25 mi) wide, extending southward from the east Pryor Mountains to Sykes Mountain. Several springs surface along the zone, some with substantial flow as indicated by the State of Wyoming's operation of a fish-rearing facility (Tillett) using water from one of these springs for hatchery operations. Another of these springs has a yield of about 152 liters (40 gal) per minute and serves as the water supply for facilities at Horseshoe Bend. Other springs associated with this fault and other geologic features have been tapped for domestic, recreational, and livestock use. Numerous springs also occur on the northeast side of Bighorn Lake in the vicinity of Ok-A-Beh. Of particular value to the Park are the series of springs named Ok-A-Beh along a hill in the immediate vicinity of the Ok-A-Beh marina. These springs are on Crow Tribal lands, but access to the water by the NPS is provided through a memorandum of agreement.

RIPARIAN-WETLAND SITES

Following the broad wetland categories defined by Cowardin et al. (1979) for the National Wetlands Inventory conducted by the U.S. Fish and Wildlife Service, the Park contains three major classes of wetlands: riverine, lacustrine, and palustrine. Major portions of these wet-lands can be encompassed under the broader term of "riparian zone" (Figure 10). Wetlands associated with the streams, lake, ponds, and springs of the Park are generally a subset of this broader site category. Riparian zones are a form of wetland transition between permanently saturated wetlands and upland sites. A variety of definitions exist for a riparian zone, often with an emphasis on the components present, but the NPS has not formally adopted a single definition. Functionally, a riparian zone can be defined as a three-dimensional region of direct interaction between terrestrial and aquatic ecosystems. Functional boundaries of riparian zones extend outward to the limits of flooding and upward into the canopy of streamside, spring-side, or lake-side vegetation (Gregory et

Table 27. Classification of the riparian vegetation along the Bighorn River based on measurements of a 536 ha (1,325 ac) area in the southern portion of Bighorn Canyon National Recreation Area (Akashi 1988).1

Populus deltoides woodlands
Very old
Old
Young
Very young
Shrublands
Rhus trilobata
Rhus trilobata-Chrysothamnus nauseosus
Rhus trilobata-Chrysothamnus nauseosus-Sarcobatus vermiculatus
Rhus trilobata-Symphoricarpos occidentalis-Rosa woodsii
Artemisia tridentata
Sarcobatus vermiculatus
Salix exigua
Tamarix chinensis
Tamarix chinensis-Salix exigua
Tamarix chinensis-Rhus trilobata
Tamarix-Chrysothamnus-Artemisia
Meadows
Sandbar
Sand
Saline
Marsh
Agricultural lands

[1]Common names of plants: cottonwood *(Populus deltoides),* sumac *(Rhus trilobata),* rabbit brush *(Chrysothamnus nauseosus)* wolfberry *(Symphoricarpos occidentalis),* greasewood *(Sarcobatus vermiculatus),* rose *(Rosa woodsii),* sagebrush *(Artemisia tridentata), willow (Salix exigua),* tamarisk *(Tamarix chinensis).*

al. 1991). This functional view recognizes that boundaries and components of riparian zones are dynamic; dimensions of the zone of influence for any specific ecological process, such as plant community succession, sedimentation, or flooding, are determined by patterns in space and changes through time of the process. Because of the similarities and overlap between riparian zones and wetlands, these sites will be referred to as riparian-wetland sites in this section.

Throughout the arid and semi-arid west, riparian-wetland sites are known for their high productivity, diversity, and other unique factors when compared to the surrounding uplands (Kauffman and Krueger 1984). They occupy an extremely small percentage of the landscape of arid and semi-arid regions but often contain the highest resource values. Functions of riparian-wetland sites include physical filtering of sediment, bank stability, water storage, and recharge of subsurface aquifers (Elmore and Beschta 1987). Historic evidence in general indicates that most riparian-wetland sites of the arid and semi-arid west have changed dramatically within about the last hundred years, and that the major cause has been improper livestock grazing (Elmore 1992).

All riparian-wetland sites of the Park have not been systematically classified and mapped, but it can be presumed that they occur throughout the Park adjacent to all aquatic habitats (streams and rivers, springs, seeps, ponds, and portions of the shores of Bighorn Lake). The U.S. Fish and Wildlife Service's National Wet-lands Inventory has been completed for the region encompassed by the Park at a scale of 1:24,000 for most quads that include the Park, and the remaining quads are scheduled by the Service for completion in the next five years. A particularly large area of cottonwood-dominated riparian habitat exists in the floodplain of the Bighorn and Shoshone rivers upstream of Bighorn Lake. These woodlands are extremely valuable because they are Federally owned and readily accessible for research, which is not characteristic of most riparian woodlands in the Rocky Mountain region, and because they are one of the most extensive tracts of cottonwood-dominated riparian woodlands in the Rocky Mountain Region (D. Knight, Univ. WY, Laramie, pers. comm., May 1995). Akashi (1988) classified the vegetation of a portion of the Bighorn River floodplain into woodlands, shrublands, meadows, marshes, and agricultural lands (Table 27) based on an analysis of current and historic conditions. She provided evidence that several major changes have occurred in the riparian vegetation of the

Bighorn floodplain over the last 50 years because of altered river hydrology tied to construction and operation of dams on the river and its tributaries. Most notably, cottonwood *(Populus deltoides)* woodlands have decreased in distribution and abundance and shrublands have become more prevalent, particularly shrublands dominated by tamarisk *(Tamarix chinensis)* and sumac *(Rhus trilobata).* Although the species may differ slightly, comparable changes have occurred at other locations in the western United States, coinciding with a loss of mature cottonwood woodlands (Rood and Mahoney 1990). The onset of these changes correlates well with the development and operation of dams on major rivers. Operation of these dams generally has decreased the magnitude of flood events, altered the frequency and timing of flooding, and changed patterns of sediment deposition within the floodplain. These changes often cause reductions in channel length, sinuosity, and surface area, which can have negative consequences for natural riparian vegetation.

In addition to the cottonwood habitat along the Bighorn River, several springs and their wet-land communities have been specifically identified as significant in the Park and in need of protection (T. Peters, Bighorn Canyon Natl. Rec. Area, Lovell, WY, pers. comm., Apr. 1994) (Figure 4). The Lockhart Springs are a series of three or four small seeps along an access trail to the Lockhart Ranch known as Lockhart Lane. The springs are fenced to prevent use by cattle, but some use by cattle occurs when cattle move through the Park. Two or three small springs known as the Willow Springs are located east of the buildings of the Mason-Lovell Ranch. Cattle trespass affects these springs, although some fencing is present. There is also concern about the effects of water diversions from Willow Creek on the spring. Two small, separate springs are in South B pasture of the Dryhead Grazing Allotment and are affected by grazing.

An array of classification and inventory techniques for aquatic and riparian-wetland sites have emerged over the last several decades. Some have focused solely on aquatic systems such as lakes and streams, others have focused on wetland or riparian systems, and others have integrated aspects of both (Gebhardt et al. 1990). It is beyond the scope of this plan to review all of these techniques, but it is relevant to note that development of these techniques continues. Anticipating that additional classification and inventory work in the Park will not begin immediately, sufficient time needs to be allowed for reviewing current methods before implementing any new programs for aquatic and riparian-wetland sites.

PARK OPERATIONS AND DEVELOPMENTS

The Park is divided into two administrative units for management of Park operations and developments—the Lovell Area and the Fort Smith Area. Each district has a visitor center, administrative facilities, and access to Bighorn Lake. The Lovell Area also includes access to the Bighorn River upstream of Bighorn Lake.

Lovell Area Water Supplies and Treatment Facilities

Adequate potable water supplies and treatment of waste water are provided in the Lovell Area at the visitor and administrative facilities located in Lovell, Wyoming, at Horseshoe Bend, and at the Layout Creek Ranger Station. These three water supplies are tested following standard protocols every two weeks for coliform bacteria, with the samples processed in Powell, Wyoming. The water supply for the visitor and administrative facilities located in Lovell is provided under an agreement with Cody, Wyoming, and wastewater treatment is provided by the municipal system for Lovell. A small pond has been constructed at the visitor center to reflect sunlight and enhance the operation of the center's solar heating system. The pond receives water from the Shoshone River via an irrigation canal, and some of the water in the pond has been used to irrigate the plantings at the center.

The water supply for facilities at Horseshoe Bend is Sykes Springs located about 3 km (2 mi) from Horseshoe Bend. Water is chlorinated as it is piped from the spring to the campground, marina, fish-cleaning station, and seasonal housing facilities located at Horseshoe Bend. The water is periodically sampled for turbidity in addition to the coliform sampling. Flow from the spring is 152 liters per min (40 gal per min), and the portion of total flow used by the Park varies with season and numbers of visitors. Spring water that is not diverted for Park use flows onto private and state lands. Wastewater from the sites that receive water, as well as from a dump station for recreational vehicles, is piped to a nearby lagoon, which is sealed by a plastic membrane liner to prevent contamination of ground water. The lagoon does not have a discharge point, and annual evaporative losses on the average equal wastewater additions.

A ranger station at Layout Creek obtains water from an unnamed spring located on Park land near the main building. Wastewater is treated in an underground septic tank and leach field at the station.

A water supply is not available at Barry's Landing, the other developed boat-launching site in the Lovell Area. A floating vault toilet is provided at this site, and wastes from this facility are transported to the lagoon at Horse-shoe Bend. Neither Horseshoe Bend nor Barry's Landing has wastewater collection or treatment facilities for boats. Rarely are the boats that use Bighorn Lake large enough to contain portable toilets, mounted toilets, or wastewater holding tanks. Thus facilities specifically for disposal of boat wastewater are not needed at the lake at this time. Disposal sites for wastewater from recreational vehicles are occasionally used by visitors with boats.

Developed water supplies and waste treatment facilities are not provided at the other campsites in the Lovell Area. Wastes from sealed vault toilets at the Trail Creek Campground and a primitive fishing access named Abercrombie are transported to Horseshoe Bend for treatment.

Fort Smith Area Water Supplies and Treatment Facilities

The Fort Smith Area's water supplies and treatment facilities for the NPS administrative complex, visitor center, and Afterbay Camp-ground are part of the facilities developed by the Bureau of Reclamation. Use is governed by a memorandum of understanding between the agencies. Water supplies for the facilities come from a spring located near the Afterbay Camp-ground. This water is filtered, chlorinated, and piped to various locations. Wastewater is piped to a lagoon, which is sealed by a plastic membrane liner to prevent contamination of ground water. The lagoon does not have a discharge point, and annual evaporative losses on the average equal wastewater additions.

The Ok-A-Beh facilities of the NPS at the north end of Bighorn Lake receive their water from a series of springs, also named Ok-A-Beh, along a hill in the immediate vicinity of the marina. A 1967 memorandum of agreement between the NPS and Crow Indian Tribe governs access to the water by the NPS. Water is collected from the springs, chlorinated, filtered, and pumped to the Ok-A-Beh marina. From late May through early September, the water supply is sampled twice a month for total coliform bacteria, with the samples processed in Helena, Montana. A well has been drilled near the Ok-A-Beh parking lot for a water supply but has never been put into service. A septic tank and leach field system are used to treat wastes from toilets and a fish-cleaning station located at Ok-A-Beh. Wastes from sealed vault toilets at boat-in campsites in the Fort Smith Area are trans-ported to Ok-A-Beh and disposed of in the treatment facility there. Facilities for collection and treatment of wastes from boats are not available at any locations in the Fort Smith Area.

BOAT SUPPLIES

Visitors travelling on the lake usually bring their own boats or can rent boats from marinas at Horseshoe Bend and Ok-A-Beh (NPS 1992). Both marinas provide gas, rental docks, food, and boater supplies from Memorial Day through Labor Day. Tour boats currently operate at Ok-A-Beh and Horseshoe Bend marinas.

CAMPGROUNDS

Designated campgrounds range in character from developed sites with water supplies and water treatment facilities to primitive sites with only fire rings present. The Park has a total of 156 developed sites at Horseshoe Bend in the Lovell Area and the Afterbay Campground in the Fort Smith Area. Twelve semi-primitive campsites are located along Trail Creek in the vicinity of Barry's Landing, and 15 primitive sites, reached by hiking or boating, are available at Medicine Creek and Black Canyon. Undesignated camping sites are primarily limited to the Lovell Area along the floodplain of the Bighorn River. The camping sites along the North Fork Trail Creek in the Lovell Area are in a floodplain that seems to be particularly vulnerable to flash flood events (T. Peters, Bighorn Canyon Natl. Rec. Area, Lovell, WY, pers. comm., May 1994). A request by the Park for a floodplain delineation through hydraulic modeling revealed that these campgrounds are not at risk from a 100-year event (Martin 1995a).

SWIMMING BEACHES

Two beaches at Horseshoe Bend and Ok-A-Beh are used for recreational swimming. The Park designates the swimming beaches with signs, ropes, and floats as boat-exclusion areas. Lifeguard services are regularly provided at the beach at Horseshoe Bend during the summer season. Lake water samples are taken periodically during the swimming season at Horseshoe Bend and shipped to a water quality laboratory in Powell, Wyoming for processing to deter-mine density of total coliform bacteria. The site at Ok-A-Beh presents the park with a number of conflicting uses among the marina, the boat launch, and recreational swimming. Although the current site used for swimming is not in a good location, it is used by the public because no other sites are available. The Park is undertaking some major rehabilitation work in 1995 and 1996 to resolve conflicts between boating and swimming uses. The Park provides a lifeguard at Ok-A-Beh if funding is available to do so. Bacteria sampling has not been conducted at the Ok-A-Beh beach.

HAZARDOUS MATERIALS MANAGEMENT

The Park has experienced several oil spills and near spills in recent years (NPS 1992), and the potential for additional spills, including major spills, is high. The Shoshone and Bighorn rivers drain watersheds containing numerous oil fields and pipelines. Several state highways and numerous county roads run parallel to and across these two rivers and their tributaries upstream of Bighorn Lake. The tracks of the Burlington Northern Railroad run parallel to the Bighorn and Shoshone rivers for consider-able distances upstream and pass near Bighorn Lake at several points. These highways and railways are major thoroughfares for vehicles carrying fuel oil, diesel fuel, gasoline, and other hazardous materials. The agricultural industry uses these thoroughfares to transport pesticides and fertilizers in sufficient quantities to cause contamination of water if spill should occur. The Park does not have a contingency plan for dealing with spills of hazardous materials.

III. WATER-RESOURCES MANAGEMENT ISSUES AND PROGRAM

Specific actions to address water resources issues are presented in this section of the Water Resources Management Plan. Each issue is examined briefly, and actions to address the issues are proposed. A project statement is included in each case when an action is proposed that will require an additional commitment of staff time or funding.

Extensive discussions and reviews accompanied development of the project statements included in this plan. Park staff developed a study plan in 1993 as a precursor to this plan (Peters 1993). The task of compiling information and revising drafts of the plan was assigned to biological staff at the Cooperative Park Studies Unit at Oregon State University under a cooperative agreement between the National Park Service (NPS) and the university. A draft of the first two sections of the plan was completed early in 1995. This draft and the issues identified in the study plan (Table 28) were discussed during a meeting in March, 1995 at the Park attended by Darrell Cook (Park Superintendent), James (Terry) Peters (Natural Resources Management Specialist), Dave Sharrow, (NPS Water Re-sources Division), and Ruth Jacobs (Oregon State University). The issues identified during a November, 1994 public meeting hosted by the Park (NPS 1994a) were given careful consideration in the process of deciding which projects to address in this plan. The list of project statements included in this plan (Table 29) was developed at the March, 1995 meeting, except for the addition of the proposal to address health effects posed by exposure to blue-green algae, which was added as the planning process neared completion. Tentative priorities were assigned to the projects, and development of the project statements followed.

These projects are considered to represent an array of issues of concern to the NPS, to users of the Park, and to local and regional neighbors of the Park. The recommended activity to address each issue is considered to be the most reasonable action at this time based on a host of considerations, induding policies of the NPS, public concerns, published scientific evidence, current technical advice of experts in a variety of fields, and funding options. It is important to recognize that the fifteen proposed projects are an ambitious program, the full implementation of which is beyond the current capabilities of the Park. The degree to which each project is implemented is contingent on obtaining funding from a number of sources. Until funding is identified, the actions proposed will not be initiated, or they will be undertaken on a limited basis as staff time and other resources are available.

Project statements are the basic unit used to propose resource management actions in the NPS. They are considered part of a park's comprehensive Natural and Cultural Resources Management Plan and are incorporated there for funding and programming purposes. It is important to note that because the Natural and Cultural Resources Management Plan is a dynamic plan, the same is true for this plan. Specific issues and priorities may change as new information becomes available. Consequently, programming sheets and project statements will be revised regularly, although the general scope and direction of the plan will remain valid and guide management activities in the Park for the next 10 to 15 years.

OVERVIEW OF ISSUES AND PROPOSED ACTIONS

Current management issues related to water resources at the Park generally fall into one of two categories: (1) needs related to providing a safe and aesthetic recreational experience for Park visitors, and (2) water-related management issues brought about by past and present land-use practices. These categories are reason-ably broad, as is the complex array of public and private interests that influence Park management. Because so many parties and interests influence Park management, interagency coordination is a common theme throughout the plan.

Table 28. Water resources issues for Bighorn Canyon National Recreation Area identified in Peters (1993).

Water resources issues are:

- Irrigated Park lands, including canal maintenance and use of herbicides, pesticides, and fertilizers for plant control and crop production on Park lands.
- Inventory of the full spectrum of water resources within the Park.
- Water-quality monitoring to detect trends due to land-use practices, operation and maintenance of facilities, municipalities and industries in the vicinity of the Park, and natural processes.
- Management of flow diversions affecting streams and springs.
- Park water rights in Montana and Wyoming.
- Floodplain delineation for public campgrounds.
- Impacts of livestock grazing and herding on Park water resources.
- Consolidation of Park information on domes-tic and groundwater supplies.
- Review and clarification of the status of livestock water agreements.
- Inventory, classification, and mapping of wetlands.
- Nonpoint pollution to water resources of the Park due to agricultural practices on private lands.
- Sediment accumulation in Bighorn Lake.
- Streambank stabilization and restoration of Crooked Creek.
- Lakeshore slumps and slides in the Bull Elk Basin.
- Eutrophication of Bighorn Lake.
- Interagency coordination of Bighorn Lake water-level management.
- Interagency coordination for fisheries management.
- Inventories of mollusk, crustacean, and aquatic macro-invertebrates.
- Hazards to navigation caused by driftwood.

Interagency Coordination

Interagency coordination is a high priority in the Park due to the Park's location, physical characteristics, and complicated management jurisdictions. Multiple Federal and state agencies, the Crow Indian Tribe, other Wyoming and Montana residents, and private organizations constitute some of the diverse regional interests in the Park's water resources. It is vital to a program of informed and collaborative management that Park staff interact extensively with representatives of other interested parties in the management of Bighorn Lake and other water resources of the Park. Two projects specifically address this need. The project Interagency Cooperation in Basin-Wide Management of Water Resources has been developed because it is important for Park staff to participate in local and regional meetings that concern water resources management in the Bighorn River Basin. Currently such participation is collateral to other responsibilities and can be inadequate when priorities are directed at other resource management needs. The Park needs to seek additional staff and base funding to enhance its participation. The project Cooperate with State Agencies in Fisheries Management acknowledges that Park staff currently assist Wyoming and Montana fisheries biologists in a variety of ways as the states carry out their responsibility to manage the recreational fishery of Bighorn Lake, the Bighorn River, and tributaries to these systems. Continuation of this assistance, with defined responsibilities and funding, is proposed. Almost all other projects in this plan indirectly require inter-agency coordination to maximize the value of the efforts of Park activities and to avoid actions that conflict with actions of other parties.

Staffing

The natural resources management staff of the Park consists of a resource management specialist at a GS-12 level and another resource man-

Table 29. Water resources management project statements.

Project Number	Title	Servicewide Issue	RMAP Program Code	Priority
BICA-N-001.000	Sediment Accumulation at Horseshoe Bend	N11, N13	QOl, Q02	High
BICA-N-035.000	Prepare Hazardous Substance and Spill Contingency Plan	N11, N16	H00, EOO	High
BICA-N-044.000	Interagency Cooperation in Basin-wide Management of Water Resources	Nil, N13	QOl, Q02	High
BICA-N-046.000	Control of Non-indigenous Plants in Wetland and Riparian Areas	N05	VO4	High-Medium
BICA-N-019.000	Cooperate with State Agencies in Fisheries Management	N19	WOS	High-Meium
-- BICA N 049.000	Bacterial Monitoring at Beaches	Nil	E00	High-Medium
BICA-N-045.000	Contaminate Reconnaissance in Bighorn Lake	Nll	QOl	Medium
BICA-N-048.000	Flow Characterization, Mapping, and Protection of Springs	N11, N20	QOl, Q02	Medium
BICA-N-032.000	Water-Quality Inventory and Monitoring	N11	Q01	Medium
BICA-N-012.000	Stabilization and Restoration of Crooked Creek	N11	E00	Medium
BICA-N-050.000	Monitoring of Blue-green Algae at Swimming Beaches	Nil	EOO	Medium
BICA N-011.000	Qualitative Survey of Selected Aquatic Invertebrates	N20	QOi	Medium-Low
BICA-N-047.000	Protection of Wetlands	N13	QOl, WOl	Low
BICA-N-005.000	Driftwood Management	N11	EOO	Low
BICA-N-040.000	Perpetuate Riparian Vegetation Dynamics, Bighorn River Upstream of Bighorn Lake	NH, N13	EOO	Low

agement specialist at a GS-9 level, both located at the administrative unit in Lovell, Wyoming. These individuals work closely with the Assistant Superintendent in the Park's Lovell Area Office and the Superintendent in the Park's Fort Smith Area Office to represent the interests of the Park throughout the region. Additional staff time is needed to be effective in meeting current commitments and to implement many projects identified in this plan. This conclusion is supported by the figure generated by the NPS Resources Management Assessment Program (RMAP) for a staff increase of 2.5 full-time equivalents in the base funding for water-resources management in the Park. Interagency coordination efforts, which are a priority, can only be carried out effectively by permanent staff. The Park will continue to seek an increase in base funding to meet these identified needs.

Visitors' Facilities and Safety

Water-based recreation is a major visitor activity at the Park, and a variety of conditions confront visitors engaging in this form of recreation. Some of the needs of the Park related to visitor safety and access to the lake are simple and essential, such as routine coliform monitoring at swimming beaches. Other needs are of high priority, but extremely difficult to resolve, such as the deterioration of the site of the marina at Horseshoe Bend due to sediment accumulations. The project statements briefly described below relate specifically to visitor facilities and safety.

High levels of sediment accumulation at the only developed access to Bighorn Lake in Wyoming, Horseshoe Bend, prohibit boat launching when lake levels are extremely low. Although the Bureau of Reclamation considers the needs of the Park in decisions related to lake water levels, the bureau is not always able to maintain sufficient lake levels to allow boat launching at Horseshoe Bend. Furthermore, sediment levels are expected to continue to rise until an equilibrium is reached, after which most incoming sediments are expected to move downstream towards Yellowtail Dam rather than accumulate at Horseshoe Bend. Time remaining until an equilibrium point is reached cannot be precisely defined due to the nature of sediment transport in aquatic systems. The most reasonable approach to this situation at this time is for the Park to acknowledge that the situation exists and to continue to coordinate with the Bureau of Reclamation as the bureau develops annual operating plans for the various reservoir systems that influence Bighorn Lake levels. The Park also will continue to maintain the facilities currently available at the site, with recognition that at some point in time it may become impractical to use Horseshoe Bend for boat launching.

Another issue related to visitor safety, as well as to the Park's responsibility to protect natural resources, is the possibility of spills of hazardous materials in Bighorn Lake and in tributaries feeding into the lake. Possible sources of spills are within the Park, primarily associated with marina operations, and outside of the Park, primarily associated with commercial traffic along roads and railroads, as well as stores of materials outside Park boundaries. The Park recognizes the need to develop a hazardous substance and spill contingency plan to define Park actions in the event of a spill and to enable the Park to obtain supplies and qualified people necessary to respond in an effective manner.

The Park also faces the possibility of accumulations of toxic organic and inorganic compounds and heavy metals in sediments and biota as a result of natural features and land uses in the Bighorn River Basin. High levels of mercury in a small sample of large walleye *(Stizostedion vitreum)* collected from Bighorn Lake and in other Montana reservoirs have resulted in a statewide advisory related to fish consumption issued in 1995. The Park could improve knowledge of the hazards to human health and to aquatic biota by conducting a broad screening of sediments and selected biota in Bighorn Lake for several compounds and elements. Collaboration with other agencies to conduct this work is proposed.

Overall, the Park needs to develop current information about water quality of Bighorn Lake and conduct a systematic program of water-quality monitoring. The Park will at-tempt to meet these needs by seeking participation in the National Water-Quality Assessment Program as this program begins to develop plans for the Yellowstone Basin.

In addition to fairly large inventory and monitoring efforts, the Park can protect visitors and obtain general information about water quality through efforts that are limited in scope. Because the Park operates two public swimming beaches, it is required to conduct routine monitoring of fecal coliform bacteria and to issue swimming advisories when swimming beach waters exceed bacterial standards. Although not mandated by state law, the Park also is interested in compiling information about any health-related incidents associated with exposure of visitors in the Park to blue-green algae. The Park will compile such information and alert visitors to the situation.

Driftwood is a prominent feature of Bighorn Lake and poses hazards to the safety and property of visitors as they boat and swim in the lake. Logs, trees, and other forms of woody debris enter the lake from the Bighorn and Shoshone rivers and their tributaries and add to the accumulation of woody debris already present in the reservoir. The Park removes debris from boat launches and uses a system of log booms to reduce the accumulations at several launch sites. More intensive actions have been tried in the past, with poor success. The Park plans to enhance the level of effort to inform visitors of the presence and dangers of driftwood in the lake through extensive signing at boat launches and the visitor centers and to continue the program of driftwood management at boat launches.

Historic Land Uses and Other Threats External to the Park

As is the case for most national parks, some of the water resources of Bighorn Canyon National Recreation Area are influenced by historic land-use practices and by other threats that originate primarily outside Park boundaries. These influences can be especially difficult to address. In general, the NPS attempts to maintain, rehabilitate, and perpetuate the inherent natural integrity of water resources and water-dependent environments within national parks. The ability of managers to achieve this goal in the Bighorn River Basin is greatly limited by the construction of major water impoundments, which have substantially changed the natural features of the Park and the land uses within the surrounding region. Even with these limitations, several projects have been identified that specifically address some threats related to historic land uses and influences on water resources that largely originate outside Park boundaries.

A short segment of a first-order stream, Crooked Creek, flows through the Park up-stream of the confluence of the stream with Bighorn Lake. It is the only major stream segment flowing through the Park. Historic land uses in the vicinity of the stream have resulted in a downcut channel through deep alluvial soils, in some cases, to bedrock. The Park has already initiated actions to stabilize and restore portions of this stream and its floodplain. The funding and staff support needed for this effort are identified in this plan.

A large section of cottonwood *(Populus deltoides)* woodlands persists in the floodplain of the Bighorn River in the southern end of the Park. The composition and distribution of vegetation in this floodplain has changed dramatically during the last 65 years. These changes seem to be related to altered discharge patterns of the Bighorn River because of operation strategies of Boysen Dam upstream of the site, coupled with invasions of non-indigenous vegetation. Restoring the floodplain vegetation to natural conditions appears to require major changes in the operation of the dam and monumental efforts to control tamarisk *(Tamarix chinensis).* Research is needed to better understand the discharge and sediment patterns needed for cottonwood germination and survival before the Park can begin efforts to explore the possibility of a request to the Bureau of Reclamation for a change in discharge patterns. These efforts have been identified in a project statement that has been assigned low priority, primarily because the factors that appear to influence the changes to the cottonwood woodlands are outside the control of Park managers.

Non-indigenous plants continue to spread throughout the region of the Park. Wetland and riparian habitats of the Park have been invaded by some of the species and have high potential to be invaded by others. Control of some species in some locations is possible, whereas attempts to control other infestations is futile with current methods because of the extensive areas colonized and the high potential for ongoing colonization. The Park has a variety of control efforts underway but limited resources to support these efforts, and the needed re-sources are identified in a project.

The Yellowtail Wildlife Habitat Management Area in Wyoming includes over 7,600 ha (19,000 ac) of wildlife habitat, including several ponds and associated wetlands within the Park. The Wyoming Game and Fish Department has advocated the use of water rights for existing and proposed wetland reservoir projects within the Yellowtail area. The Park also is interested in using water rights to protect wildlife habitat, and the general necessary steps to do so are defined in this plan.

Inventories

Guidance for the development of adequate natural resources inventory and monitoring activities for NPS units is found in NPS-75: the 1992 Natural Resources Inventory and Monitoring Guidelines. From the water resources perspective, hydrologic information summarized in the preceding section (The Hydrologic Environment) satisfies many, although not all, of the recommended "Phase I" inventory activities outlined in NPS-75. Most of the vertebrate populations of the Park have been included in baseline inventories conducted in the Park. The major omission in population surveys is invertebrates, including aquatic invertebrates. A cursory survey of selected groups is proposed. An inventory of current conditions of water quality is also proposed, with the expectation that ongoing monitoring of water quality will follow.

Locations of the major springs in Bighorn Canyon National Recreation Area are known, and limited information about the location and characteristics of these springs is stored in the Park's geographic information system. These springs are valuable to wildlife. Additionally, flow from several of them is used for some of the Park's water supplies. Several are associated with historic resources in the Park. The Park proposes to conduct a systematic inventory and monitoring of the flow from these spring and classify and map the wetland habitats associated with them. Fencing will be used to protect vulnerable springs from damage by cattle.

Last Update:
Initial Proposal: February 15, 1996

Priority: High
Page Number: 1

Sediment Accumulation at Horseshoe Bend

Funding Status: Funded: 40.00 Unfunded: 0.0
Servicewide Issues: N 11 WATER-QUAL-EXT N

13 WATER RIGHTS

Cultural Resource Type: NA

RMAP Program codes: Q01 Q02

10-238 Package Number:

PROBLEM STATEMENT

High levels of sediment accumulation at the only developed access to Bighorn Lake in Wyoming prohibit boat launching when lake levels are extremely low. Other sites are not available for developed access without very extensive site preparation and expense. Other alternatives to alleviate the situation such as dredging also are expensive or impractical at this time. The Bighorn Canyon National Recreation Area proposes to take no action to alleviate the situation and recognizes that it may no longer be economically feasible to operate a marina at Horseshoe Bend at some point in the future. It is the intent of the Park to work with other agencies and public-interest groups to seek reasonable alternatives to the problem.

Sediment accumulation in Bighorn Lake is high due to the erodible quality of the bedrock, lack of ground cover, and steep stream gradients in the Bighorn River Basin (Blanton 1986). Sediments flowing in the Bighorn River as it enters the southern end of Bighorn Lake have been estimated to be about 3,600 metric tons (4,000 tons) per day, with the identified sources being erosion of streambanks, flows returned to the river after cropland irrigation, erosion from croplands due to irrigation practices, and erosion from rangeland (Soil Conservation Service 1994). The reservoir has lost 3.9 percent of total storage capacity due to sediment accumulation since 1965, when reservoir filling began, with over 70 percent of the total sediment deposited in the southern end of the reservoir. One particular location, Horseshoe Bend, has accumulated the greatest thickness of sediment (13 m or 43 ft) since dam closure, at a rate of about 0.9 m (3 ft) per year during the first 17 years of the reservoir's existence (Blanton 1986). When a conservative 1994 estimate by Martin (1995) is included, the last 12 years of sedimentation account for an additional depth of about 1.8-3.7 m (6-12 ft), which can be averaged to a recent rate of accumulation of about 0.2-0.3 m (0.5-1.0 ft) per year.

Horseshoe Bend is an extremely pronounced, incised meander located about 72 km (45 mi) up-stream of Yellowtail Dam. Compared to the rest of the reservoir, the large cross-sectional area of the canyon at this bend results in lower flow velocities and, consequently, greater sediment deposition than at other locations. Large expanses of these sediments are exposed as mud flats when lake levels are low. Sediment accumulation is of particular concern at Horseshoe Bend because the major visitor-use facility with access to the lake for the south end of the Park is located there. Further-more, Horseshoe Bend is one of few suitable sites for recreational development because most of the lakeshore consists of deeply incised canyon walls where developed facilities for lake access are impractical.

Recreational facilities at Horseshoe Bend consist of a ranger station, public campground, swimming beach, day-use facilities, parking lots, boat-launch ramp, courtesy dock, and marina services operated by a concessionaire. The marina services include a marina building, docks, and an on-water fueling facility for boats. Many of the services and supplies are available only from Memorial Day through Labor Day, a time span that occasionally coincides with periods of low lake levels and extensive exposure of sediments. Use of marina services is greatly influenced by water levels. In 1994 for example, precipitation was below average and, consequently, summer reservoir levels were below average. By the end of August, Bighorn Lake was at a record low for that time of year with 9.5 x 10^3 m^3 (767,918 ac-ft) of storage at elevation 1,098 m (3,604 ft). Starting on June 10, boat launching at Horseshoe Bend became prohibitive and continued as such for the rest of the recreational season (Bureau of Reclamation 1994).

A recent review of sediment rates and patterns by the National Park Service's (NPS) Water Re-sources Division (Martin 1995), in conjunction with the Bureau of Reclamation, yielded an estimate that sedimentation will continue to accumulate until it reaches an elevation of approximately 1,103 m (3,620 ft). At that point, under the current operating constraints, it is thought that sediment accumulation in the Horseshoe Bend Area will reach a state of equilibrium with most incoming sediments moving downstream towards the dam, rather than accumulating at Horseshoe Bend. It is estimated that the remaining 3.4-3.7 m (11-12 ft) of sediment, before a state of equilibrium is reached, will accumulate over the next 4 to 20 years. The report points out that sediment transport can be highly episodic. Consequently, time remaining until an equilibrium point is reached could be less than 4 years or greater than 20 years. The sedimentation rate is dependent on numerous factors (Lyons et al. 1995), none of which are directly controlled by the Park.

The normal draw-down pool elevation for Bighorn Lake during the winter season is 1,100 m (3,612 ft). The elevation of the operating pool from Memorial Day to Labor Day varies from about 1,102-1,106 m (3,616-3,630 ft) (Files, Bureau of Reclamation, Billings, MT). A water depth of about 0.6 m (2 ft) is necessary to effectively use the marina at Horseshoe Bend. With the sediment level currently at an elevation of 1,099.7-1,100.0 m (3,608-3,609 ft), water must reach a minimum elevation of approximately 1,102 m (3,614 ft) before there is sufficient water to operate a boat safely, float the docks, and fuel boats. When sedimentation finally reaches an elevation of 1,103 m (3,620 ft), it will take a lake level of 1,105 m (3,624 ft) to safely operate boats. In terms of actual operation of the marina, these data mean that as sedimentation continues to accumulate, the period each year when water depth is sufficient at Horseshoe Bend will shorten. Based on the conservative estimate of current sediment elevation, at least another 0.6 m (2 ft) of sediment may accumulate during normal draw-down pool conditions before use of the marina is restricted. During normal operating pool conditions from May to August, about 1.2-6 m (4-20 ft) of sediment may accumulate before use of the marina be-comes marginal (Martin 1995).

Maintaining a normal pool elevation is highly dependent on the occurrence of near-normal snow melt and rainfall so that scheduled releases can occur from Yellowtail Dam. Additionally, sediment transport and deposition in a fluvial environment can be highly episodic, with the vast majority of sediments being added in a relatively short period of time. Consequently the time remaining until Horseshoe Bend is no longer suitable for boat launching must be viewed as a best estimate based on available information.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY

The Park will continue to coordinate with the Bureau of Reclamation as the Bureau develops annual operating plans for Bighorn Lake, Boysen Reservoir, and Buffalo Bill Reservoir. The Bureau will continued to be informed about the needs of the Park for adequate water levels for boat launching at Horseshoe Bend, but it is recognized that the NPS has limited leverage in influencing decisions related to management of water level. Although the Park was established to provide for public use of the reservoir and the surrounding park lands, and for the preservation of scenic, scientific, and historic features contributing to public enjoyment of the lands and waters within the Park, the Park cannot dictate reservoir levels to achieve these goals. This situation exists because the Park was created in conjunction with the reservoir for specific purposes of water storage and release. When decisions regarding lake levels and flow releases are made, the Bureau of Reclamation considers the Park's concerns and needs along with those of other groups using the water. The major dams that influence the levels of Bighorn Lake are Yellowtail and Boysen dams on the Bighorn River and the Buffalo Bill Dam on the Shoshone River. These dams and their impoundments are used for power production, municipal and industrial water supplies, irrigation, flood control, sediment retention, recreation, and fish and wildlife enhancement (Bur. Reclamation 1994).

With implementation of this alternative, it is recognized that the ability to launch boats and use Horseshoe Bend as a marina facility will gradually diminish. This will affect the economic viability of the concession operation at the marina. The ability to launch boats will gradually occur at later and later dates in the major recreational season. At some point, the season for the marina will be reduced to the point that operation of the facility no longer is economically feasible.

The budget for this project reflects costs needed to continue to monitor the current situation, evaluate alternatives, inform the public of any changes in the status quo, and cooperate with the Bureau of Reclamation as decisions are made about lake levels. Funding to maintain recreational facilities at Horseshoe Bend is identified in other Park budgets.

BUDGET AND FTES:

FUNDED

Source	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1995: PKBASE-OT	MIT		10.00	0.4
Year 1996: PKBASE-OT	MIT		10.00	0.4
Year 1997: PKBASE-OT	MIT		10.00	0.4
Year 1998: PKBASE-OT	MIT		10.00	0.4
		Total:	40.00	1.6

UNFUNDED

Source	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1995:				0.1
Year 1996				0.1
Year 1997:				0.1
Year 1998:				0.1
		Total:	0.00	0.4

Last Update: Priority: High
Initial Proposal: February 15, 1996 Page Number: 4

(OPTIONAL) ALTERNATIVE ACTIONS / SOLUTIONS AND IMPACTS

Development of Barry's Landing: Barry's Landing is 29 km (18 mi) to the north of Horseshoe Bend. The facility currently consists of a concrete launch and small parking lot. The walls of Bighorn Canyon extend close to the lakeshore at this site. With extensive funding and alteration of the natural shoreline, the site could be modified to provide additional facilities. No funding is currently available for marina developments at Barry's Landing, and given current funding trends, it is unlikely that any will be available in the foreseeable future.

Sediment Dredging: The NPS could dredge sediments from Horseshoe Bend and remove them to other locations. This would be a temporary, ongoing, and extremely costly undertaking. It also may be environmentally hazardous if the dredged material contains heavy metals, polychlorinated biphenyls (PCBs), or other toxic compounds. Initial estimates of the cost of dredging are in the range of $4 per m^3 ($5 per yd^3), with removal of an estimate of up to 0.7 million m^3 (1 million yd^3) needed in the initial effort and additional amounts for ongoing maintenance.

Request Flushing Flows: The objective of this alternative would be to obtain high flows of sufficient magnitude to scour and move tons of sediments from Horseshoe Bend and deposit them down-stream of the site. A feasibility study would be needed to develop estimates of the flows needed and the amount of material to be moved. The study would include the development of a scale model of the drainage system to refine predictions of the consequences of the action. Even if there were no constraints on dam operation, natural erosion of sediments in the Horseshoe Bend area would likely take much longer than one year. Because of the wide cross-sectional area of Horseshoe Bend, a great deal of lateral erosion would be required before sediments would scour from the specific vicinity of the marina. The NPS would request large releases of water from reservoirs upstream of Horseshoe Bend to accomplish the flushing, but would have to resolve issues of water rights and concerns of landowners in the floodplains of the Bighorn and Shoshone rivers as part of the request. It is unlikely that necessary flows could be achieved without upstream flooding and damage to existing facilities in the floodplain.

Implementation of the request could occur in unison with naturally high-volume discharge events to maximize the effect on sediment movement. Such events occur unpredictably depending on regional and local precipitation and temperature patterns, and their effects are diminished by the extensive development of reservoirs in the Bighorn River Drainage. The coordination of natural events with high releases from reservoirs would be difficult to time and would increase the difficulty of predicting the consequences of the action. If deemed technologically and practically feasible, the action could be conducted at periodic intervals to allow for recreational lake access at Horseshoe Bend.

Sediment Retaining and Deflecting Dikes: The objective of this alternative would be to construct a dike between the boat launch at Horseshoe Bend and Bighorn Lake to block the accumulation of sediments in the immediate vicinity of the boat-launching ramp. Coupled with this activity would be the development of a dam upstream of the site within the Bighorn River to trap sediments before they reached Horseshoe Bend. An open channel would be dredged and maintained as needed to accomodate boat access from the launch to the open waters of the lake. A feasibility study would be conducted to design the dike, design the sediment-retention dam, determine disposal sites for dredged material, and project changes in channel form and meander patterns. The ability of accu-rately modelling responses of stream flow and sediment deposition to a dike is limited, and this option would be difficult to comprehensively assess.

Develop New Marina in Wyoming: The objective of this alternative would be to develop a new marina in Wyoming on Bighorn Lake to replace the one at Horseshoe Bend. An analysis of existing sites and conditions has shown that no other suitable natural locations exist. Additional studies could be commissioned to evaluate locations, costs, and sources of funds for the development.

Detailed Modelling Study: The objective of this alternative would be to conduct a thorough survey of sedimentation patterns in the region of Horseshoe Bend. This information would be used to attempt to develop a more precise estimate of the site life of the marina at Horseshoe Bend than the estimate of 4-20 years prepared by Martin (1995). Assuming a more precise estimate of site life is attainable, the NPS would be in a better position to advise visitors and concessionaires about the future potential of the site. The major limitation to this action is that more modelling seems to be of little value because sediment transport is episodic, and therefore precisely unpredictable on a year-to-year basis.

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Compliance codes: EXCL Explanation:

516 DM6 App. 7.4 B(4) End of data.

Prepare Hazardous Substance and Spill Contingency Plan

Funding Status:	Funded: 0.00	Unfunded: 13.00
Servicewide Issues:	N11 WATER QUAL-EXT N16 NEAR-PARK DEV	
Cultural Resource Type:	N/A	
RMAP Program Codes:	H00 E00	
10-238 Package Number:	10-238	

PROBLEM STATEMENT

The potential for spills of hazardous materials to occur in the vicinity of Bighorn Lake is serious enough to warrant a contingency plan for a wide array of spill types. Bighorn Canyon National Recreation Area does not have such a plan, and development of the plan is proposed in this project statement.

The Park has experienced several oil spills and near spills in recent years, and there is a medium-to-high potential for additional spills to occur. For example, in May of 1995 the Environmental Protection Agency alerted natural resources management staff at the Park of a potentially serious oil spill on Sage Creek near its confluence with the Shoshone River. An oil salvage firm's attempts to re-claim oil from a nonfunctional oil refinery located on lower Sage Creek was discontinued about two years ago. Several pits at the site were almost overflowing with oil, and the oil was on the verge of flowing into Sage Creek. Once in the creek, the oil would travel a short distance to the Shoshone River and then downstream to the Park. The Environmental Protection Agency was attempting to resolve the situation.

Sources of contamination from hazardous materials in the Park are of three general types: (1) those associated with commercial traffic, primarily outside Park boundaries, (2) those associated with oil fields, oil pipelines, and stores of hazardous material outside Park boundaries, and (3) those associated with gasoline supplies sold to visitors in the Park. Spills from any of these sources, if sufficiently large, could have extremely negative consequences for water quality and biota in Bighorn Lake and the tributaries to the lake.

Upstream of Bighorn Lake, several state highways and numerous county roads run parallel to and across the Bighorn River, the Shoshone River, and their tributaries. The tracks of the Burlington Northern Railroad also run parallel to the Bighorn and Shoshone rivers for considerable distances upstream of the lake and pass very near Bighorn Lake at several points. About 13 km (8 mi) of track run through the Park or adjoin the Park boundary. Trucks and rail cars carry fuel oil, diesel fuel, gasoline, and a variety of agricultural and industrial chemicals along these road and rail corridors. Quantities of materials are sufficient to cause water-quality problems if spills should occur near Bighorn Lake or its tributaries.

In addition to the rail and road traffic, the Park is situated in a region of Wyoming and Montana containing numerous oil fields and miscellaneous supplies of toxic materials associated with agricultural and industrial operations. The Shoshone and Bighorn rivers and their tributaries drain large portions of this area. A major rupture in an oil pipeline or a leak at a refinery facility could result in contamination to Bighorn Lake, particularly if measures were not adequate to limit transport of the substances downstream to the lake. Similarly, a major spill from a storage tank at a farm or industry could rapidly enter the lake through a tributary. As an example of the potential for the latter, a 20,818 liter (5,500 gal) tank containing diesel fuel used in a farm operation sits next to a gravel road a short distance from the lake on the west side of the Bighorn River in the Yellowtail Wildlife Habitat Management Area. The tank is located on a parcel of private property within Park boundaries. A spill from this tank alone would impact Bighorn Lake and several of the ponds in the Yellowtail area.

A third source of hazardous materials is the supply of gasoline available for sale to visitors boating on Bighorn Lake. Most of the boats on the lake use small inboard and outboard motors and do not carry gasoline supplies of more than 75 liters (20 gal). A spill of this quantity, although undesirable, is not likely to cause significant pollution problems. However, the two marinas on the south and north end of the lake have sufficient stores of gasoline to cause water-quality problems if a major spill occurred. The marina at Ok-A-Beh has an underground storage tank with a capacity of 3,785 liters (1,000 gal). The tank is checked annually for leaks by the National Park Service. Gasoline is pumped about 15 m (50 ft) to the boat dock in a metal pipe, and pumped an additional distance of about 15 m (50 ft) in a rubber hose suspended under the boat dock. The rubber hose is equipped with safety couplers on it, which shut off flow if a rupture occurs in the line. The rubber hose connects to a gasoline pump on the dock, from which supplies are dispersed to boats. A barrel containing an absorbent rope is located next to the pump for deployment in the event of a small spill when boat motors or fuel cans are being filled. (E. Redding, Bighorn Canyon Natl. Rec. Area, pers. comm., May 1995). The gasoline supply for the marina at Horseshoe Bend is stored in an underground tank with a capacity of about 7,570 liters (2,000 gal). Gasoline is pumped under-ground about 152 m (500 ft) and then pumped another 152 m (500 ft) under the boat dock to the single gas pump located on the dock. Safety features are comparable to those at Ok-A-Beh, except the barrel and absorbent rope are stored in a shed about 0.4 km (0.25 mi) from the dock because of concerns that it may be stolen if left unattended on the dock (D. York, Bighorn Canyon Natl. Rec. Area, pers. comm., May 1995).

The Bureau of Reclamation's operations at Yellowtail Dam are a possible source of contaminants for the Afterbay Reservoir and the Bighorn River downstream of the Afterbay Dam. The responsibility for planning for handling of hazardous materials and spills associated with operations at the dam is the bureau's. The major chemical of concern is hydraulic fluids. The bureau has a general plan for responding to problems of this nature.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY

Park staff will prepare a contingency plan for dealing with spills of hazardous materials. Materials to be specifically addressed include petroleum products and agricultural chemicals. This plan will be developed to the extent practical in coordination with municipalities and other land management agencies in the region and with the Hazardous Materials Office of the National Park Service. Preparation of a Spill Contingency Plan will require coordination with Burlington Northern Rail-road, The U.S. Environmental Protection Agency, U.S. Coast Guard, Wyoming Department of Fish and Game, Bureau of Reclamation, and probably several other entities that will be identified during the planning process. Once the plan is completed, the Park will conduct safety meetings and preparedness drills annually. Costs identified for this project primarily reflect staff time and travel to develop the plan, including coordination efforts with local and regional agencies and businesses. Most of these costs and F'1'Es are included in the first year of the budget. Costs in years 2-4 are much less than the first-year costs, and largely support safety meetings, preparedness drills, and efforts needed to revise the plan as regulations and activities change.

BUDGET AND FTES:

FUNDED

Source	Activity	Fund Type	Budget ($1000s)	FTEs
		Total:	0.00	0.0

UNFUNDED

Source	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:			10.00	0.25
Year 2:			1.00	0.10
Year 3:			1.00	0.10
Year 4:			1.00	0.10
		Total:	13.00	0.55

(OPTIONAL) ALTERNATIVE ACTIONS / SOLUTIONS AND IMPACTS

No Action: The Park will continue to operate without a plan to handle spills of hazardous materials. Natural and cultural resources of the Park will be at risk should a major spill occur. The Park will rely on whatever response is available from the local and regional communities in which the Park resides. The Park will not be in compliance with requirements of the National Park Service for contingency planning for incidents involving hazardous materials and may not be in compliance with the Oil Pollution Act of 1990.

Compliance codes: EXCL Explanation:

516 DM2 App 7.4 B(11) End of data.

Interagency Cooperation in Basin-wide Management of Water Resources

Funding Status:	Funded: 0.00	Unfunded: 52.00
Servicewide Issues:	N 11 WATER-QUAL-EXT	N 13 WATER RIGHTS
Cultural Resource Type:	NA	
RMAP Program codes:	Q01 Q02	
10-238 Package Number:		

PROBLEM STATEMENT

Bighorn Canyon National Recreation Area cannot be effectively managed without a strong commitment toward interagency cooperation and a significant effort devoted to this need. The level of coordination would be greatly enhanced if, as proposed in this project statement, a portion of a permanent full-time position could be established with duties devoted primarily to facilitating interagency cooperation on issues related to natural and cultural resources.

The Park is located in a semi-arid portion of the United States where precipitation averages less than 50 cm (20 in) per year in wet locations and as little as 18 cm (7 in) per year in dry locations. Water resources are available in a variety of forms, and both natural and cultural systems depend on this water. The area is part of the Missouri River Drainage, with Yellowtail Dam creating one of the largest reservoirs—Bighorn Lake with a total capacity of 16.4 x 10^8 m^3 (1,328,360 ac-ft)—on this riverine system. The dam and reservoir were built for power generation, irrigation, flood control, fish and wildlife, and recreation. Land uses within the drainage basin reflect these priorities and include agriculture, urban and rural residential developments, fish and wildlife management, and recreational areas such as the Park. Water resources in the Park include Bighorn Lake, short portions of the Bighorn and Shoshone rivers as they flow into Bighorn Lake, springs, seeps, constructed ponds, canals, and groundwater.

Management of the Park's water resources is complicated because of the diverse regional interests in the resources and because of the complex array of administrative interests. The Park is administered by a superintendent, who maintains Park headquarters at Fort Smith, Montana. Fort Smith is also the location of offices of the Bureau of Reclamation, although regional administrative offices of the Bureau are located in Billings, Montana. Park staff are geographically separated by the 113-kmlong (70-mi-long) Bighorn Lake, with a Park management unit maintained at Lovell, Wyoming and another at Fort Smith, Montana. The natural resources management staff works out of the Lovell office. The Wyoming Game and Fish Department administers the Yellowtail Wildlife Habitat Management Area in the south end of the Park out of an office near Lovell, Wyoming. Most other local management projects on the part of the Wyoming Game and Fish Department are directed out of an office in Cody, Wyoming. Management projects conducted by the Montana Department of Fish, Wildlife and Parks tend to be directed out of the state office in Billings, Montana. A portion of the Pryor Mountain Wild Horse Range is located in the Park, and is administered by the Bureau of Land Management. The interests of the Crow Indian Tribe, whose reservation surrounds the north end of the Park are administered from Crow Agency, Montana, and the Crow Tribal Planning Office in Billings, Montana. These are only some of the parties with management interests related to the water resources of the Bighorn Drainage.

The Park's superintendent and the natural resources management staff currently participate in local and regional meetings that concern water resources management in the Bighorn River Basin. This participation is collateral to other responsibilities and is inadequate when priorities are directed at other resource management needs. The natural resources management staff consists of a resource management specialist at a GS-11 level and another resource management specialist at a GS 7/9 level. Additional staffing is needed to enable the Park to have adequate representation at meetings in which issues that influence water resources are addressed.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY

Additional staff and base funding will be sought to support the participation of staff of Bighorn Canyon National Recreation Area in interagency basin-wide management of water resources. The expertise for the position will be in the areas of hydrology and aquatic ecology. This person will also be available to assume some of the responsibilities related to water resources identified in other Park projects. This should be a permanent base-funded position in order to provide the continuity necessary to establish effective working relationships with staff in other agencies. It is assumed in the budgeting for this project that the individual identified for the interagency cooperation will devote about 25 percent of his or her time to the effort.

BUDGET AND FTES:

FUNDED

Source	Activity Fund Type Budget ($1000s)		FTEs
	Total:	0.00	0.0

UNFUNDED

	Source	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:				13.00	0.25
Year 2:				13.00	0.25
Year 3:				13.00	0.25
Year 4:				13.00	0.25
			Total:	52.00	1.00

Compliance codes EXCL

Explanation 516 DM2 App.2, 1.6

End of data.

Last Update: Priority: High-Med.
Initial Proposal: February 15, 1996 Page Number: 1

Control of Non-indigenous Plants in Wetland and Riparian Areas

Funding Status:	Funded: 6.00	Unfunded: 6.40
Servicewide Issues:	N05 NON-NAT PLANTS	
Cultural Resource Type:	N/A	
RMAP Program Codes:	VO4	
10-238 Package Number:	10-238	

PROBLEM STATEMENT

Non-indigenous plant species, defined as those found beyond their natural range and including alien and exotic species, are present in Bighorn Canyon National Recreation Area. Some are present as domesticated crops and are actively farmed in the Yellowtail Wildlife Habitat Management Area. Others have invaded the Park from adjacent areas and have the potential to cause significant economic and environmental damage. Control of the harmful species that have the potential to colonize riparian and wetland sites is the subject of this project statement.

Tamarisk or salt cedar *(Tamarix chinensis),* Russian olive, *(Eleagnus angustifolia)* leafy spurge *(Euphorbia esula),* Russian knapweed *(Centaurea repens),* and purple loosestrife *(Lythrum salicaria)* are the major non-indigenous plant species known to constitute a threat to riparian and wetland sites of the Park. Three of these species are in the Park, and the other two have high potential for invasion from areas outside the Park. Not all of these species are obligate riparian or wetland species, but they all have the ability to colonize such sites. Attempts to control these species in the Park vary, depending on where the infestations occur and the potential for recolonization if control is conducted. Al-though National Park Service policy is fairly stringent regarding control of non-indigenous species (NPS *1977),* control of some species is economically and biologically impractical. Tamarisk for example, now abundant in most western states, was introduced to the United States as an ornamental and for erosion control (Neill 1993). It forms thickets along waterways, crowding out indigenous plants, banking up sediments, and altering water flow (Loope and Sanchez 1988). A thicket of tamarisk shrubs can produce millions of seeds each year, which are readily transported by wind or water to moist sites where seedlings can establish readily. A 1992 estimate of the cost of removal of all of this species from the Lower Colorado River and the restoration of the indigenous vegetation was $45-450 million (Bur. Reclamation 1992).

Approximately 19,426 ha (48,000 ac) of the Park (70 percent) is zoned as natural and, as such, is managed to perpetuate native plant life as part of a natural ecosystem. Non-indigenous plants are controlled within the natural zone, provided control is achievable by reasonable means. The general strategy is to annually conduct a walking survey of stream banks in natural areas and remove individual plants if seed sources are not available upstream. Crooked Creek and the North and South Forks of Trail Creek are some of the streams included in this control effort. Shrubs that are too large for hand pulling are cut, and stumps are treated with a herbicide. This type of control is effective along the smaller tributaries and around springs because infestations are scattered, and any individual infestation has a low density of non-indigenous plants. Furthermore, upstream sources for seed introductions are few. Control is not attempted from the high-water line to the lakeshore along Bighorn Lake even within the natural zone because several non-indigenous species, primarily tamarisk, are extensively established and a vast source of seed exists upstream of the lake.

Fluctuations in lake level provide ample opportunities for seed distribution, which makes eradication impractical with current methods.

In addition to areas zoned as natural, a large portion of the southern end of the Park is zoned for wildlife management. This area includes the mosaic of cottonwood *(Populus deltoides)* riparian woodlands in the floodplain of the Bighorn River and the Shoshone River upstream of Bighorn Lake. These woodlands, which occupy over 400 ha (1,000 ac) of the Park, are riparian habitat and are extremely valuable because they constitute one of the most extensive tracts of this plant community in the Rocky Mountain Region under Federal ownership (D. Knight, Univ. WY, Laramie, pers. com., May 1995). The abundance of these woodlands has declined in many drainage basins in the West and Midwest (Rood and Mahoney 1990).

Akashi (1988) conducted a study of the state and dynamics of riparian vegetation in the Bighorn floodplain within the Park in 1985 and 1986. Of particular significance, she provided evidence that several major changes have occurred in the riparian vegetation of the floodplain during the last 50 years because of altered river hydrology associated with construction and operation of dams on the river and its tributaries. Most notably, cottonwood woodlands have decreased in distribution and abundance, and shrublands have become more prevalent, particularly shrublands dominated by tamarisk and a native sumac *(Rhus trilobata).* Russian olive also is prevalent in this floodplain. The Park does not attempt to erradicate or control invasion of tamarisk and Russian olive in these woodlands. Control is simply impractical because these species are so prevalent and because extensive seed sources exist upstream along the Bighorn and Shoshone rivers. Control of these species would be extremely desirable to rejuvenate and preserve the floodplain woodlands if practical techniques to do so became available.

Purple loosestrife, although not known to be in the Park, has been found upstream of the Park near both the Shoshone and Bighorn rivers. Distribution of this species in these drainages still is limited enough to justify control efforts. The Park has initiated a cooperative program of control with the Bureau of Reclamation, Ducks Unlimited, two county weed and pest control offices, and the Wyoming Game and Fish Department. An aerial survey was conducted in 1995 to document the distribution of the plant along the Bighorn and Shoshone rivers upstream of the Park. Herbicides were used for eradication. A public education program describing the characteristics of the plant and its potential for invasion began in 1995. A slide program for presentation in public schools, a billboard with information about characteristics of the plant for location along highways, and a brochure are major components of the education effort.

Leafy spurge and Russian knapweed are two species listed as invasive weedy species in the State of Wyoming with some potential to invade riparian and aquatic areas. They are the target of active control programs by weed and pest control offices because of their high potential to invade agricultural land. Leafy spurge has not been found in the Park, but staff constantly monitor for it in the course of other activities. Russian knapweed is present in the Park and is removed from areas adjacent to farmland, along roads, and in other selected areas whenever it is detected. It has established monoculture stands in some locations in the Park, e.g., along Crooked Creek. The Park has released a nematode, native to Russia *(Subanguina picridis),* to attempt control of the knapweed. Success with this effort in the Park is limited, primarily because the nematode is slow in expanding its range beyond the point of introduction.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY

The Park will continue to remove tamarisk, Russian olive, and other problem plants when they are identified within the natural zones and other locations of the Park and when success appears achievable. Such areas include sites far removed from populations of these plants and their seed sources. Sites will be monitored yearly to locate individual plants while they are still small so they can be removed by hand pulling. An approved chemical herbicide will be available in the event an extensive infestation occurs or if large trees or shrubs are located that require cutting and stump treatment. The Park will also continue to be involved in regional noxious-weed control programs.

An exotic plant management plan will be developed for the entire Park and address control of invasive terrestrial, riparian, wetland, and aquatic plants. The plan will define objectives of the program, set priorities for research and treatment, and establish thresholds for treatment for each problem species identified. A monitoring program will be a key component and will utilize the Park's geographic information system. The plan also will address the cost and practicality of removing non-indigenous plants, particularly tamarisk and Russian olive from the cottonwood riparian woodlands of the Park. Even if the cost is high, these woodlands are such a valuable resource that the National Park Service may find the cost justified.

Costs associated with the recommended project reflect personnel requirements for identifying infestations and removing plants. Also included are personnel costs for development of an exotic plant management plan. It is assumed that the plan will be authored by current Park staff, and costs of formatting and printing the plan will be small. Additional costs are associated with chemical herbicides needed for treatment of large infestations in the event they are identified. The recommendations developed for the exotic plant management plan will likely affect project costs.

BUDGET AND FTES:

FUNDED

	Source	Activity	Fund Type	Budget ($1000s)	FTEs
1995	PKBASE-OT INT			2.00	0.0
	PKBASE-NR ADM			1.00	0.0
1996	PKBASE-OT INT			2.00	0.0
	PKBASE-NR ADM			1.00	0.0
			Total:	6.00	

UNFUNDED

	Source	Activity	Fund Type	Budget ($1000s)	1- lEs
Year 1:				3.10	0.2
Year 2:				1.10	0.1
Year 3				1.10	0.1
Year 4:				1.10	0.1

(OPTIONAL) ALTERNATIVE ACTIONS / SOLUTIONS AND IMPACTS

No Action: The Park will not attempt to remove non-indigenous plants from natural zones or other key areas in the Park. Once populations of these plants become established, it will be difficult or impossible to eradicate them. Native plants and plant communities probably will suffer from the presence of the non-indigenous species.

LITERATURE CITED

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Compliance codes: EXCL Explanation:

516 DM6 App. 7.4 E(6) End of data.

Cooperate with State Agencies in Fisheries Management

Funding Status:	Funded: 18.00	Unfunded: 1.50
Servicewide Issues:	N19 CONSUMPT USE	
Cultural Resource Type:	N/A	
RMAP Program Codes:	W08	
10-238 Package Number:	10-238	

PROBLEM STATEMENT

Strong justification exists for the involvement of staff of Bighorn Canyon National Recreation Area in fisheries management issues for Bighorn Lake. Natural resources staff of the Park gradually have developed important relationships with the states of Wyoming and Montana for managing the recreational fishery at the lake. Continuation of that involvement, with defined responsibilities and funding sources, is proposed in this project statement.

Sport fishing, particularly in Bighorn Lake for walleye *(Stizostedion vitreum), is* a common visitor activity in the Park. Enabling legislation for the Park clearly allows for fishing and for the involvement of the National Park Service (NPS) in management decisions related to fishing within the lands administered by the NPS, although the states of Montana and Wyoming have regulatory authority over control, propagation, management, protection, and regulation of fish in the respective states (Wyoming Statutes Section 23; Administrative Rules of Montana Title 87). Management of lake levels, which is under the authority of the Bureau of Reclamation, influences the fitness of fish populations in the lake and the access to the lake by Park visitors. The recognized need for cooperative management has led to annual coordination meetings convened in the spring and attended primarily by representatives of state and Federal agencies and the Crow Tribe. The responsibility for hosting these meetings is rotated among the participants.

Bighorn Lake is an artificial impoundment and, as others like it throughout the western U.S., is heavily stocked with nonnative fish species. The artificial environment created by Yellowtail Dam bears little resemblance to the riverine system that existed prior to impoundment, and many fish species adapted to the former riverine environment do not thrive in the lake. The fish community currently in the lake consists of about 30 species, approximately half introduced and half native. Fisheries staff from Montana and Wyoming continue to stock several nonnative species to maintain the recreational fishery.

Park staff assist state fisheries biologists in a variety of ways. Using a standardized survey card agreed to by both states, Park rangers collect creel census data throughout the fishing season, including the ice-fishing season in the winter months. Summaries of these data are provided to both states. The design of the census is based on meeting the needs of the states for information on the fishery and the needs of the Park for information about the activities of Park visitors. It is difficult for Wyoming fisheries managers to census the lake because they are based in Cody, Wyoming about 97 km (60 mi) from Bighorn Lake. Similarly, Montana fisheries biologists are based in Billings, Montana, approximately 145 km (90 mi) from the lake. Park rangers are employed by the Park throughout the fishing season and regularly patrol the lake for a variety of reasons. In the course of carrying out their responsibilities, the rangers also question visitors about fishing activities. Park personnel also assist the states in other fish management activities as requested and as time is available, including gill netting, trapping, stocking, electrofishing for collection of eggs, fish marking, and sampling physical attributes of the habitat.

The Park continues to work with the states to implement a reciprocal licensing system for Bighorn Lake to avoid confusion when visitors cross the state line while fishing. A reciprocal system would allow anglers from either state to fish water of the neighboring state and simplify licensing for park visitors from outside states. The cost distribution for licensing for such an arrangement continues to be unresolved. A proposal for an agreement has been prepared for review, and the Park's involvement in the creel survey is a component of the proposal.

Fishing success in Bighorn Lake varies greatly between years. Fish managers still are in the early stages of understanding the processes regulating fish production, especially for walleye. Walleye spawning success probably is limited by high sediment loads at the southern end of the reservoir, but its reproductive success also appears to be low in the clear waters at the northern end of the lake. Funding to study population dynamics of this and other species is limited because both Wyoming and Montana assign relatively low priorities to Bighorn Lake in comparison to the other bodies of water they manage. The Park's participation in fisheries management activities greatly enhances the ability of state biologists to begin to address some of these questions.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY

Continue Cooperation with States: The Park will continue to play an active role in fisheries management decisions and assist the states with their management activities. Participation in the annual fisheries coordination meetings will continue as well as the creel survey conducted by Park rangers. The Park will continue to work with managers of both states to implement a reciprocal licensing system. The Park will assist state managers to conduct research to better define lake ecology and fish population dynamics. The Park will continue to stress the importance of conducting a thorough ecological assessment as part of any decision-making process regarding introductions of new fish species. These responsibilities will be integrated into the position descriptions of the appropriate natural resources management staff at the Park.

Some funding for this project already has been designated within the current Park budget. The dollar amount of the unfunded component is equivalent to the last dollar figure presented for 1998 funding. The unfunded FTE figure is a small fraction and is presented to acknowledge that some level of dedicated effort is needed to conduct this project, but the effort is largely included in the responsibilities of staff already assigned to the Park, although the effort is not specifically described in their position descriptions. If r1'E is identified to conduct the project statement Interagency Cooperation in Basin-wide Management of Water Resources, that FTE can also be used to accomplish this project.

BUDGET AND FTES: **FUNDED**

	Source	Activity Fund Type	Budget ($1000s)	FTEs
1995:	NON-NPS-O	MON	12.00	0.0
	PKBASE-NR	MIT	1.00	0.1
	PKBASE-NR	ADM	0.50	0.0
1996:	PKBASE-NR	MIT	1.00	0.0
	PKBASE-NR	ADM	0.50	0.0
1997:	PKBASE-NR	MIT	1.00	0.0
	PKBASE-NR	ADM	0.50	0.0
1998:	PKBASE-NR	MIT	1.00	0.0
	PKBASE-NR	ADM	0.50	0.0
		Total:	18.00	0.1

UNFUNDED

	Source	Activity Fund Type	Budget ($1000s)	IqEs
Year 1:			1.50	0.01
		Total:	1.50	

(OPTIONAL) ALTERNATIVE ACTIONS / SOLUTIONS AND IMPACTS

Discontinue Involvement in Fisheries Management: The Park will discontinue involvement in fisheries management activities. Representatives of the states of Wyoming and Montana will make decisions regarding fisheries and lake-level management with minimal involvement of the Park. Information on fish catch will not be collected unless the states provide funding to do so.

Compliance codes: EXCL
Explanation: 516 DMZ App 1.7
End of data.

Bacterial Monitoring at Swimming Beaches

Funding Status:	Funded: 0.00	Unfunded: 5.00
Servicewide Issues:	N11 WATER QUAL-EXT	
Cultural Resource Type:	N/A	
RMAP Program Codes:	E00	
10-238 Package Number:	10-238	

PROBLEM STATEMENT

Two swimming beaches are present in Bighorn Canyon National Recreation Area. Specific requirements for public health must be met in order to allow swimming at these beaches. The objective of this project statement is to provide funding to the Park to review existing protocol and to develop additional protocol as needed to bring the Park into compliance with public health requirements.

The Park offers swimming opportunities for visitors at Horseshoe Bend at the south end of the lake and at Ok-A-Beh at the north end of the lake. The Park designates the swimming beaches with signs, ropes, and floats as boat-exclusion areas. Lifeguard services are provided regularly at the beach at Horseshoe Bend during the summer season. Lake water samples are taken periodically during the swimming season at Horseshoe Bend and shipped to a water-quality laboratory in Powell, Wyoming for processing to determine density of total coliform bacteria. Samples are collected in the afternoon and refrigerated until they are transported to the laboratory for processing the next morning. The analysis is initiated the morning the samples arrive at the laboratory. Approximately 17 hours lapse from the time of collection until analysis.

The swimming site at Ok-A-Beh is considered to be of poor quality as a swim beach because of its proximity to a boat dock, rough shoreline topography, and rocky substrate. The site receives high use, especially by local residents, because better sites are not available. The Park provides a life-guard at Ok-A-Beh if funding is available to do so. Bacterial sampling is not conducted at the Ok-ABeh beach.

Under guidelines of the National Park Service (NPS), both swimming beaches in the Park are considered "designated swimming beaches" because the Park has "identified them with signs as available to the public for recreational swimming" (NPS-83 Public Health Guidelines). Beach monitoring for public health purposes is required for any designated beach. NPS Guidelines specify that state policies for swimming beach monitoring will be followed if they exist. The State of Montana through the Montana Depai latent of Health and Environmental Sciences, Health Services Division has explicit, stringent rules for swimming areas (Administrative Rules of Montana Title 16, Chapter 10, Subchapter 13 and Title 50, Chapter 53, MCA). The State of Wyoming does not, in which case NPS Guidelines should be followed. Because the requirements of Montana are equal to or exceed NPS guidelines, and to achieve similarity between the two major swimming beaches in the Park, the Montana requirements will be largely followed.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY

For the beach at Horseshoe Bend and the beach at Ok-A-Beh, the Park will conduct a sanitary survey at the start of each swimming season to determine that the beaches are free of domestic or industrial wastes and potential health or safety hazards. The bathing water will be of such chemical, physical and bacteriological quality so as not to endanger the health of the bathers during periods that the public bathing place is open for use, and a local public health officer will be involved in the inspections of each beach to evaluate compliance with this requirement at least once a year.

A key indicator of water quality relative to public health is the concentration of fecal coliform bacteria. Wyoming and Montana water-quality rules specify standards for these bacteria. Fecal coliform concentrations are not to exceed a geometric mean of 200 fecal coliform groups per 100 mm of water based on a minimum of not less than five samples obtained during separate 24-hour periods for any 20-day period, nor may more than 10 percent of total samples exceed 400 groups per 100 m. The Park will allow swimming at Horseshoe Bend and Ok-A-Beh only when water quality conforms to this standard. Three sampling stations will be established at each beach for monitoring of fecal coliform concentrations. A first set of samples each season will be collected two weeks before the beginning of the recreational season to allow sufficient time to sample again if the initial samples indicate the bacterial standard is exceeded (see above). Weekly sampling will then be conducted from the first through the last week of the recreational season. Sample collection will coincide with the times of greatest bather use of the beaches.

Standard methods for the examination of water and wastewater (American Public Health Association 1992) will be closely followed for sampling procedures and analyses. These methods specify that microbiological examination of a water sample will begin promptly after collection. If samples cannot be processed within one hour after collection, an iced cooler will be used for storage during transport to a laboratory. Six hours is the preferred maximum time between collection and examination, but up to 30 hours is allowed.

Notification, advisory, and closure procedures shall be developed by the Park if the bacterial standard is exceeded or other water-quality conditions indicate poor conditions for swimming. At a minimum, the bacterial density results will be reported to appropriate regional and state authorities, local news media will be used to publicize the closure, and the beach will be posted as closed.

One-time funding for this project statement is needed to develop the appropriate written protocols and to train staff in the implementation of the protocols. The cost of implementation of the monitoring will be incorporated in the Park's base budget.

BUDGET AND FTES:

FUNDED

Source	Activity	Fund Type	Budget ($1000s)	FTEs
		Total:	0.00	0.0

UNFUNDED

Source	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1			5.00	0.1
		Total:	5.00	0.1

(OPTIONAL) ALTERNATIVE ACTIONS / SOLUTIONS AND IMPACTS

No Action: The Park will continue to monitor total coliform bacteria at Horseshoe Bend swimming beach but not at the Ok-A-Beh beach. The Park will have little information to use to assess public health hazards at swimming beaches. The Park will not be in compliance with the bacterial standards for beaches of the National Park Service.

Sample Examination in Park: The Park will conduct the preferred alternative with modification to enable examination of the water samples in the Park using the membrane filter method. The Park will invest in sterile medium, petri dishes, two refrigerators, a water filtering device, gridded membrane filters, two vacuum pumps, equipment for sterilizing equipment and water, and two incubators. Appropriate space to house this equipment also will be set aside at the Park, and one or two members of the Park staff will be instructed in appropriate laboratory techniques. Because of the distance between the two swimming beaches and area offices in the Park, two laboratories will need to be established to process the samples. The cost of this alternative is estimated to be about $10,000 per laboratory for the first year to cover equipment and supplies as well as staff time. Costs for additional years would be primarily for sample collection and processing and are estimated to be $5,000 per laboratory per year.

LITERATURE CITED

American Public Health Association. 1992. Standard Methods for the Examination of Water and Wastewater. Eighteenth Edition. American Public Health Association, Washington, D.C. 1100 pp.

Compliance codes: NPS-83, Bacterial standards for beaches

Explanation:

End of data.

Contaminant Reconnaissance in Bighorn Lake

Funding Status:	Funded: 0.00	Unfunded: 45.00
Servicewide Issues:	N 11 WATER-QUAL-EXT	
Cultural Resource Type:	NA	
RMAP Program codes:	QOl	
10-238 Package Number:		

PROBLEM STATEMENT

The possibility of accumulations of toxic organic and inorganic compounds and heavy metals in sediments and biota as a result of natural features and land uses in the Bighorn River Basin is a concern to staff of Bighorn Canyon National Recreation Area. The objective of this project statement is to conduct a reconnaissance-level survey of several compounds and metals of concern to human health and aquatic biota. Results of this survey will determine the need for additional actions such as a detailed survey of the lake, the issuance of health advisories, or efforts to modify land-use practices that contribute nonpoint pollution.

Agriculture is a major industry in the vicinity of the Park, with sugar beets, corn, beans, and alfalfa common crops. A variety of pesticides and herbicides are used as part of local agricultural practices. Some of these compounds also are applied to lands that are part of the Park but are managed by the Wyoming Department of Fish and Game as part of the Yellowtail Wildlife Habitat Management Area. Runoff from these lands and agricultural lands outside the Park enter tributaries to Bighorn Lake from ditches and canals draining irrigated lands and as direct runoff. Some of this non-point pollution ends up in Bighorn Lake. Modem pesticides and herbicides do not tend to bioaccumulate in animal tissue like some of the older banned compounds such as DDT, DDE, toxaphene, and chlordane, although some of these older compounds may persist in biota or sediments and pose a hazard.

Agriculture is not the only possible source of toxic contaminants in the Bighorn River Basin. Weathering of landforms and erosion of soils in the drainage basin can bring polluting metals and compounds into the lake and tributary streams (Phillips et al. 1987). These processes can be accelerated by local land uses (Soil Conservation Service 1994). Municipalities and industries throughout the drainage basin are another obvious source of pollution. Municipalities with populations as high as 9,000 residents occur upstream of Bighorn Lake. Local industries are dispersed throughout the drainage basin and include oil refineries, oil fields, and processing plants for sugar beets. In a study in the 1980s of Tongue Point Reservoir about 160 km (100 mi) east of Bighorn Lake, about 93 percent of the mercury transported into the reservoir was in river water. Point sources included 1% mines, 9% sewage treatment plant, less than 1% ground water, 1% dry deposition, and 4.5% precipitation. Nonpoint sources, including weathering and erosion, were the source of most of the mercury.

Several limited studies have addressed the concentrations of some compounds in the Bighorn River Drainage. From 1984 through 1992, the U.S. Geological Survey sampled for several herbicides and herbicide by-products in the Bighorn River at the gaging station at Kane, Wyoming, and in the Shoshone River near Garland, Wyoming. Concentrations of the substances sampled were low. Limited studies have been conducted in Bighorn Lake to detect concentrations of polychlorinated biphenyls (PCBs) and concentrations and sources of some heavy metals. Sampling of sediments and water from Bighorn Lake for PCBs and mercury in 1992 yielded concentrations of both substances below detection levels of standard analysis techniques (Phillips and Bahls 1994). This study involved the collection of one sample of bottom sediment from Bighorn Lake at a mid-reservoir site. In the same study, concentrations of mercury in walleye *(Stizostedion vitreum)* were moderately high in Bighorn Lake, but PCBs were below detection levels. The sample size for this study was 12 walleye less than 38 cm (15 in) fork length, 4 walleye 45-53 cm (19-21 in) fork length, and 2 walleye 69-71 cm (27-28 in) fork length. Concentrations of mercury were low in the smallest size class (0.2 gg/g of muscle tissue), intermediate in the mid-size group (0.58 µg/g), and moderately high in the largest walleye (1.4 µg/g). The source of the mercury was not specifically addressed in the study, but the researchers believed the source to be a result of unique physical and chemical conditions that can occur in impoundments, rather than human-caused contamination. The Preventive Health Services Bureau of the Montana Department of Health and Environmental Sciences has issued a statewide advisory for fish consumption in 1995 because of high levels of mercury, and less commonly PCBs, found in Montana reservoirs, including Bighorn Lake (Montana Dept. Health & Env. Sci. 1995.)

A broad screening to further substantiate the presence of substances that may pose hazards to aquatic biota and humans is needed. Sample sizes in previous studies need to be expanded and sampling sites should be distributed in multiple locations in Bighorn Lake. Furthermore, many of the substances of concern often are not detected in surface waters, particularly filtered surface-water samples, because the substances attach to sediment particles. Even the contaminants that are soluble are often introduced and transported during storm events, which often are not represented in regular sampling programs. The proposed project is an initial survey for metals, organochlorine compounds, and PCBs; an array that includes the elements and compounds most likely to jeopardize human health and aquatic biota. Results from this initial survey will be used to assess the need for additional surveys or actions.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY

The objectives of this project are to 1) determine concentrations of heavy metals and organochlorine pesticides in game fish collected from Bighorn Lake, 2) determine concentrations of heavy metals and organochlorine pesticides in bottom sediments from Bighorn Lake, and 3) determine if heavy metals and organochlorine pesticides are present at concentrations that may pose a threat to piscivorous birds, piscivorous fish, and humans. This study will be conducted in cooperation with the Environmental Contaminants Specialist with the Ecological Services Field Office of the U.S. Fish and Wildlife Service in Cheyenne, Wyoming. Staff from this office developed the methodology described below. The Wyoming Ecological Services Field Office will be responsible for project management, including collecting, preparing, and shipping samples for analyses and for reporting project accomplishments and results. Staff of the Park and the Wyoming Game and Fish Department will assist with sample collecting.

A study team will collect sediment and game fish from five sites at Bighorn Lake. A composite sediment sample will be collected from each site using a ponar dredge. Sediments will be placed in 500-ml (0.1-gal) chemically clean glass jars and placed in an ice-filled cooler. Sediment samples will be frozen within eight hours of collection. One composite sample comprised of eight fish of the same species will be collected at each site using gill nets, hoop nets, or electrofishing. Ideally, five composite samples of a piscivorous fish such as walleye and five composite samples of a bottom-dwelling species such as channel catfish *(Ictalurus punctatus)* will be collected. White sucker *(Catostomus commersoni)* is an alternative for channel catfish. Collection of fish will be coordinated with fish surveys conducted at Bighorn Lake by the Wyoming Department of Fish and Game. Sediment and fish samples will be analyzed for trace elements and organochlorine pesticides. Data from this survey will be used to evaluate the need for additional surveys, long-term monitoring, or actions to limit the consumption of fish.

The budget for this project was developed in 1995 by the Ecological Services Office of the U.S. Fish and Wildlife Service in Cheyenne, Wyoming. These are the costs that would be incurred if the project were conducted entirely by that office and by a certified laboratory used by that office for sample analyses. The percentage of the total budget devoted to various components of the budget are: collection and shipment of samples (20%), data interpretation and reporting (30%), analytical costs (20%), and indirect costs (30%). The FTE indicated covers the Park staffing needed to coordinate the project with the office selected to conduct the work.

BUDGET AND FTES:

FUNDED

	Source	Activity	Fund	Type	Budget ($1000s)	FTEs
				Total:	0.00	0.0

UNFUNDED

	Source	Activity	Fund	Type	Budget ($1000s)	FTEs
Year 1:					45.00	0.1
				Total:	45.00	0.1

(OPTIONAL) ALTERNATIVE ACTIONS / SOLUTIONS AND IMPACTS

National Water-Quality Assessment Program: The Park will request that Bighorn Lake be integrated into the National Water-Quality Assessment Program (NAWQA) as the program is implemented in the Rocky Mountain Region. A study unit of NAWQA, a national assessment program conducted by the U.S. Geological Survey, will border or include Bighorn Lake. This program is designed to describe the status and trends in the quality of ground- and surface-water resources and to provide a sound understanding of the natural and human factors that affect the quality of these resources (Leahy et al. 1990). Development of sampling plans for this region is scheduled to begin in 1997 as part of the Yellowstone Basin Unit. Physical, chemical, and biological properties of ground water and surface water are part of the national program, including some organic and inorganic compounds in sediments and selected biota associated with use of herbicides and pesticides.

LITERATURE CITED

Leahy, P.P., J.S. Rosenshein, and D.S. Knopman. 1990. Implementation plan for the National Water-Quality Assessment Program. U.S. Geol. Surv. Open-File Rept. 90-17. 10 pp.

Montana Department of Health and Environmental Sciences. 1995. Montana fish consumption advisory. Preventive Health Serv. Bur., Dept. Health & Environ. Sci., Helena, MT. 4 pp.

Phillips, G., and L. Bahls. 1994. Lake water quality assessment and contaminant monitoring of fishes and sediments from Montana waters. Final Rept. to U.S. Environmental Protection Agency. MT Dept. Fish, Wildl. & Pks., Helena, MT. 21 pp.

Phillips, G.R., P.A. Medvick, D.R. Skaar, and D.E. Knight. 1987. Factors affecting the mobilization, transport, and bioavailability of mercury in reservoirs of the Upper Missouri River Basin. U.S. Dept. Int., Fish & Wildl. Serv., Fish and Wildl. Tech. Rep. 10. 64 pp.

Soil Conservation Service. 1994. Big Horn River Basin surface water quality study. Final Rept. and Recommendations, Wyoming Cooperative River Basin Study no. 4376. U.S. Dept. of Agric., Soil Conserv. Sew., Casper, WY. 29 pp.

Compliance codes: EXCL

Explanation: 516 DM2 App.2, 1.6

End of data.

Flow Characterization, Mapping, and Protection of Springs

Funding Status:	Funded: 0.00	Unfunded: 26.00
Servicewide Issues:	N11 WATER FLOW N20 BASELINE DATA	
Cultural Resource Type:	N/A	
RMAP Program Codes:	Q01 Q02	
10-238 Package Number:	10-238	

PROBLEM STATEMENT

Locations of the major springs in Bighorn Canyon National Recreation Area are known. Limited information about the location and characteristics of these springs is stored in the Park's geographic information system. In general, these springs are extremely important in the semi-arid region in which the Park occurs because they are a rare source of water for wildlife. They are also important supplies of water for human consumption. With the extensive land uses in the vicinity of the Park, there is a reasonable potential for anthropogenic activities that could alter spring hydrology. Small wetland areas are associated with each spring, and changes in the hydrology probably would result in changes to these wetlands. Acquisition of additional information to characterize and protect the springs is proposed in this project statement.

Most of the springs of the Park are extremely small, and many have been developed in various ways. Several are described here to provide a general perspective on their characteristics and the land uses that have the potential to influence them. Water rights to some of the springs recently were acquired by the National Park Service (NPS).

The Lockhart Springs are a series of approximately four small seeps along an access trail to the Lockhart Ranch in the southwestern portion of the Park. They are fenced to prevent use by cattle, but some cattle trespass occurs when cattle are herded through the area. Some of the fences are well maintained, whereas others have deteriorated and are in need of repair or replacement. The NPS has a water right to the springs named Lockhart #1 and Lockhart #2. One of these has a wooden structure over it, developed when the site was used as a "spring house" by the previous owner of the site.

Two or three small springs known as the Willow Springs are located east of the buildings of the historic Mason-Lovell Ranch at the southern end of the Park. Part of the main spring is fenced, but the fencing is in poor condition. The spring is used by cattle from an adjoining grazing allotment to the east of the spring managed by the Bureau of Land Management. Flow in the spring may also be affected by a local rancher's diversion since 1982 of Willow Creek to a watershed known as the Five Springs Basin. The rancher has senior rights to water in Willow Creek.

Two small, separate springs are in South B pasture of the Dryhead Grazing Allotment, approximately 0.4 km (0.25 mi) from north of the junction of Bad Pass Road with the access road to Barry's Landing. They are fenced for protection from cattle grazing.

Several other springs in and near the Park are used for water supplies for visitors and other Park needs. The water supply for facilities at Horseshoe Bend is Sykes Springs located about 3 km (2 mi) from Horseshoe Bend on private property, with use of the water by the NPS governed by a cooperafive agreement. The Ok-A-Beh facilities of the NPS at the north end of Bighorn Lake receive their water from a series of springs, also named Ok-A-Beh, along a hill in the immediate vicinity of the marina. A memorandum of agreement between the NPS and Crow Indian Tribe governs access to the water by the NPS. Flow from a spring known as Sorenson Spring at the Layout Creek Ranger Station is stored in a pond and piped out for livestock watering.

A comprehensive database describing locations of springs and their flow is lacking, although some recent flow information, collected during negotiations for water rights, exists for several of the springs. This flow information is based on visual estimates rather than actual measurements. Flow from most of these springs is of such a limited quantity that measurement with instrumentation would require some manipulation of the site to collect sufficient water to use a flow-measuring device.

Wetlands associated with Park springs also are poorly described. National Wetland Inventory Maps produced by the U.S. Fish and Wildlife Service are available for most of the Park at a scale of 1:24,000, but the small wetland communities surrounding the springs are probably not evident on these maps. The level of effort directed at detailed dassification and mapping of wetlands in the vicinity of the Park is variable, and some of the efforts are described here to provide a sense of the types of work being done in the vicinity of the Park.

Staff of the Worland District of the Bureau of Land Management have marked on quad maps the location of all riparian-wetland sites associated with streams on lands under their jurisdiction. These are non-Park lands. Information on the location and general characteristics of these sites is described in a data base containing over 50 fields called the Riparian Aquatic Information Data System. Some of the characteristics described include elevation, aspect, any exceptional fish and wildlife species, vegetation, suitability for designation as a Wild and Scenic River, state classification for water-quality management, classification of functioning condition, and descriptions of types of monitoring data available (pers. comm. B. Wilson, Hydrologist, Worland District, Bureau of Land Management, Feb. 1995). The staff of the Wyoming Natural Diversity Database of The Nature Conservancy have sampled and classified some wetlands and riparian habitats within the Bighorn River Basin associated with perennial and intermittent streams. Their classification work followed information provided in Bourgeron and Engelking (1994).

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY

Three springs located at different sites within the Park will be selected for monthly measurement of flow. These data will be used to establish a general sense for periods of minimum and maximum flow. Flow in all known springs will then be measured annually at periods of maximum and minimum flow for a five-year period to establish baseline information. If variability in discharge obscures detection of periods of maximum and minimum flow during the one-year period of observation, measurements at the start of the five-year period will be frequent enough to narrow this uncertainty. The frequency of sampling will be determined by the amount of variability observed, and thus, cannot be specified at this time. Additional surveys of flow will take place at five-year intervals. Sampling also will be conducted in years of extremely wet or dry weather conditions to document the effects of extreme precipitation situations on flow. Periodic statistical analyses will be conducted to evaluate if the monitoring protocol provides a reasonable representation of flow.

Wetlands surrounding the springs will be classified and mapped. The specific classification system to be adopted is not described here because classification systems for riparian-wetland sites continue to be refined. The Park will conduct a review of current procedures at the time the project is funded so that a system is adopted that conforms to current information. Notably, contacts will be made with representatives of local offices of the U.S. Forest Service, Bureau of Land Management, and Nature Conservancy to determine their classification systems and mapping methods.

The Park will install fencing around all natural springs that are not currently fenced and that have the potential to be damaged by cattle. Existing fencing around springs will be maintained. The Park will seek options for eliminating cattle in the vicinity of springs so that fencing can be removed eventually to allow free access to springs by wildlife. Cost information for fencing is provided in BICA-N-016.000 in the Park's Resources Management Plan. The other costs indicated cover the classification and mapping required for the first year, the equipment needed to conduct the flow measurements, and the effort needed to regularly visit the sites the first year and less regularly in ensuing years to collect flow information.

BUDGET AND FTES:

FUNDED

Source	Activity	Fund Type	Budget ($1000s)	FTEs
		Total:	0.00	0.0

UNFUNDED

Source	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:			20.00	0.1
Year 2:			2.00	0.1
Year 3:			2.00	0.1
Year 4:			2.00	0.1
		Total:	26.00	0.4

LITERATURE CITED

Bourgeron, P.S., and L.D. Engelking, editors. 1994. Preliminary vegetation classification of the western United States. Western Heritage Taskforce, The Nature Conservancy, Boulder, CO.

Compliance codes: EXCL

Explanation: 516 DM2 App. 2, 1.6

End of data.

PROJECT STATEMENT BICA-N-032.000

Last Update:

Initial Proposal: February 15, 1996

Water-Quality Inventory and Monitoring

Funding Status:	Funded: 0.00	Unfunded: 90.00
Servicewide Issues:	N11 WATER QUAL-EXT N20 BASELINE DATA	
Cultural Resource Type:	N/A	
RMAP Program Codes:	Q01	
10-238 Package Number:		

PROBLEM STATEMENT

This project statement addresses the collection of water-quality information in Bighorn Lake by Bighorn Canyon National Recreation Area. Many other project statements in this plan are related to this project statement, but specifically address only one or two variables. This project proposes a comprehensive and long-term approach, which should be conducted in unison with other issue-specific projects defined in related project statements.

Water resources of the Park are composed of many interrelated ground- and surface-water systems. The response of each of these systems to natural and human factors is evident in a corresponding set of hydrologic, chemical, and biological characteristics that reflect the effect of these factors on water quality (Leahy et al. 1990). Developing a description of current conditions of water quality, defining long-term trends in water quality, and discerning natural and human factors that affect observed condition and trends can be a challenge. Nonetheless, in order to provide public outdoor recreational use of the Park that is safe and aesthetically pleasing, Park staff must confront the challenge to a reasonable degree with a general water-quality monitoring program.

A major management objective for the Park is to provide for public outdoor recreational use in the states of Wyoming and Montana (Public Law 89-664). Because the Park is largely a reservoir (i.e., Bighorn Lake), water-based recreation is the predominant public use with over ten-thousand boaters using the lake annually in recent years (Files, Bighorn Canyon Natl. Rec. Area, Ft. Smith, MT). Fishing, boating, water skiing, swimming, and camping are major recreational activities. Clean water is essential for a safe and aesthetic recreational experience and for the existence of the native biota within the lake and along the lakeshore.

Water-quality issues in Bighorn Lake are numerous (Table 1). Some of the issues are inherent in the operation of a reservoir in a region containing highly erodible landforms. Other issues are the result of land uses and developments, which largely have accompanied the construction of major water impoundments on the Bighorn River and other tributaries of the Missouri River in the semi-arid West. Many of the issues are interrelated with features of both natural and cultural systems, and discernment of specific causes often is impractical or impossible. In recognition of this, a Park water-quality monitoring program should focus on health and safety concerns, parameters for which standards exist, and acquisition of information to support management activities such as management of fisheries and blue-green algae. Attempts to describe conditions, trends, and cause-effect relationships within the Park have been fairly limited.

Table 1. Documented water-quality issues in Bighorn Lake.

sedimentation	nutrient enrichment	pesticides from croplands
oil or gas spills	oil drilling residues	sewage effluent
dead animals	algal blooms	supersaturated dissolved gases
salts from runoff waters	mercury bioaccumulation	

Soltero (1971) conducted a limnological survey of the reservoir within the first decade after impoundment. Although characteristics of reservoirs can change with time (Thornton et al. 1990), many of Soltero's results probably are applicable to current lake conditions. Calcium, sodium, sulfate, and bicarbonate were the most common constituents of the dissolved solids in the lake, which is predictable given the surrounding geological landforms and soils. The landforms and soils are highly erodible and contribute to the high sediment levels in the lake, especially at the southern end where the Shoshone and Bighorn rivers enter the reservoir. Concentrations of nutrients were high, including nitrogen and phosphorus compounds. *Aphanizomenon*, a blue-green algae typical of eutrophic lakes, comprised about 70 percent of the total phytoplankton bio-volume during late summer and early fall.

The U.S. Geological Survey (USGS) operates a gaging station at the southern end of the Park just upstream of Bighorn Lake and, in recent years, has regularly collected data on discharge, temperature, and conductivity of waters entering the lake. Extensive records dating back to 1930 exist for this site, and periodically the survey has collected information on 30 physical, chemical, and biological variables at this site. These records are available through the Water Resources Center at the University of Wyoming and the STORET database system operated by the Environmental Protection Agency (EPA). Some of these data, coupled with other information from gaging stations in the Bighorn River Basin, were used recently by an interagency group to evaluate surface water quality issues in the Bighorn River downstream from Boysen Reservoir (Soil Conserv. Serv. 1994). The focus of the study was riverine rather than reservoir systems, and measurements in Bighorn Lake were not part of the database used. No impairments were identified from non-point sources that reached or exceeded limits for human health and safety set by the EPA, although sediment loads were identified as a major water-quality problem in the system. Furthermore, agricultural chemical pesticides were detected in the system during periods of use on croplands, but were found at low levels in relation to the standards of the EPA. Phosphate concentrations were sufficiently high to cause eutrophication problems in the riverine system, which corresponds well with the eutrophication evident in the southern portion of Bighorn Lake (Soltero 1971, Env. Prot. Agency 1977, Lee and Jones 1981, Phillips and Bahls 1994).

Limited studies have been conducted in Bighorn Lake to determine concentrations of PCBs and concentrations and sources of selected heavy metals. Sampling of sediments and water from Bighorn Lake for PCBs and mercury in 1992 yielded concentrations of both substances below detection levels of standard analytical techniques (Phillips and Bahls 1994). In the same study, mercury concentrations in walleye *(Stizostedion vitreum)* were moderately high in Bighorn Lake, but PCBs were below detection levels. The source of the mercury was not specifically addressed in this study, but the researchers believed the source to be a result of the unique physical and chemical condition that can occur in impoundments, rather than human-caused contamination. This conclusion was supported by other studies on the Tongue River Reservoir in southeastern Montana about 120 km (75 mi) from the Park (Phillips et al. 1987). About 93 percent of the mercury transported into the Tongue River Reservoir was in river water. Point sources included 1 percent mines, 9 percent sewage treatment plant, less than 1 percent ground water,l percent dry deposition, and 4.5 percent precipitation. Nonpoint sources, including weathering and erosion, accounted for most of the mercury, emphasizing the importance of land management to control erosion and leaching (Phillips et al. 1987). The Preventive Health Services Bureau of the Montana Department of Health and Environmental Sciences issued a statewide advisory in 1995 for fish consumption because of high levels of mercury, and less commonly PCBs, found in Montana reservoirs (Montana Dept. Health & Env. Sci. 1995.)

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY

The objective of the recommended project is to link the water-quality monitoring efforts of the Park with the efforts currently underway through the National Water-Quality Assessment Program (NAWQA) being conducted by the USGS. A study unit of NAWQA, the Yellowstone Basin, will border or include Bighorn Lake (Leahy et al. 1990). Development of sampling plans for the Yellowstone Basin Unit is scheduled to begin in 1997. Many of the water-quality issues of concern to the Park and protocols for monitoring for specific variables will be addressed by this program. The costs of the Park addressing these issues and protocols on its own is prohibitive at this time. It also is most practical for the Park to attempt to integrate into regional interagency programs rather than embark on separate efforts. This is particularly true because of the regional nature of the influences on the Park and because of the network of agencies involved in management of water resources throughout the Bighorn River Drainage.

The USGS proposed NAWQA in 1985 with the following objectives: (1) provide a nationally consistent description of current water-quality conditions for a large part of the water resources in the United States; (2) define long-term trends (or lack of trends) in water quality; and (3) identify, describe, and explain, to the extent possible, the major natural and human factors that affect observed water-quality conditions and trends (Leahy et al. 1990). The program consists of two major elements — study-unit investigations and regional and national syntheses of study-unit investigation results. Study-unit investigations, the basic building blocks of the program, are designed to address study unit and local water-quality issues and to provide the framework on which regional and national water quality assessment can be made. Major activities to be performed include the compilation of available water-quality information, sampling and analysis of water quality for a wide array of physical, chemical, and biological properties, and the interpretation and reporting of results.

Coordination is an integral component of NAWQA to help ensure that the water-quality information produced by the program is relevant to regional and local interests. Once a project chief is identified for a study unit, a liaison committee is formed comprised of non-USGS members who represent a balance of technical and management interests. Represented organizations can include Federal, state, interstate, and local agencies, Indian Nations, and universities. Specific activities of each committee include exchanging information about water-quality issues of regional and local interest, identifying sources of data and information, discussing adjustment to program design, assisting in the design of project products, and reviewing and commenting on planning documents and project reports. Opportunities sometimes are available to cost share in order to get a sampling site in a specific location.

Specific activities the Park will conduct to maximize opportunities for participation in NAWQA include:

1. Initiate correspondence with the NAWQA Regional Office in Denver, Colorado describing the array of water quality concerns in the Park and stating an interest in being an active partner in the program in the Yellowstone Basin Study Unit.
2. Specifically dedicate staff time and travel funds for participation in meetings of the Yellowstone Basin study-unit liaison committee meeting starting in 1997.
3. Establish a working relationship with limnological research scientists at Wyoming or Montana universities, with the intent of involving them in cost-shared study efforts. Use the expertise of these scientists to develop a proposal for liaison with the NAWQA Program.
4. Submit a Water Resources proposal requesting funding for cost-sharing participation in NAWQA starting in 1997.
5. Involve the National Park Service NAWQA coordinator in the Park's liaison efforts.
6. Assuming the Park is integrated into the NAWQA Program, use the result of sampling to develop a long-term program for monitoring key water-quality variables for status and trend analyses.

The budget figures presented here reflect the need for the National Park Service to show a serious interest in cost-sharing in water-quality monitoring efforts by NAWQA. It is anticipated that the first year of funding will be devoted to travel for participation in meetings of the Yellowstone Basin study-unit liaison and to establish a working relationship with limnological research scientists at Wyoming or Montana universities. A cooperative agreement with one or more of these scientists to support their participation on behalf of the Park may be required. Funding needs identified for years 2 through 4 is based on the assumption that the Park will become an active partner in the NAWQA program in the Yellowstone Basin and will need funds and F YE for collection and analysis of water samples from Bighorn Lake.

BUDGET AND FTES:

FUNDED

Source	Activity	Fund Type	Budget($1000s)	FTES
			Total 0.00	0.00

UNFUNDED

Source	Activity	Fund Type	Budget($1000s)	FTES
Year 1			10.00	0.0
Year 2			30.00	0.1
Year 3			30.00	0.1
Year 4			30.00	0.1
		Total	90.00	0.4

(OPTIONAL) ALTERNATIVE ACTIONS / SOLUTIONS AND IMPACTS

No Action: The Park will not have current information on water quality of Bighorn Lake. Similarly, the Park will not have a program for attempting to detect long-term changes in key water-quality characteristics. The Park will have little ability to accurately answer questions from Park visitors about water quality, nor to advise visitors of possible hazards imposed by conditions of poor water quality.

Cooperative Agreement with University: The Park may be unsuccessful in forming a liaison with the NAWQA Program that includes Bighorn Lake in sampling activities. If so, the Park will adopt NAWQA protocols and establish a cooperative agreement with a university to conduct sampling comparable to the NAWQA efforts. Using the same objectives (adopted to a specific site) and protocols, and conducting the sampling in the same time frame as the NAWQA effort will maximize the Park's ability to compare results from Bighorn Lake with results from other locations. The Park will use the results of this effort to develop a long-term water-quality monitoring program. The National Park Service NAWQA coordinator will be involved in the Park's efforts.

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Soltero, R.A. 1971. Limnological studies on Bighorn Lake (Yellowtail Dam) and its tributaries. Ph.D. Thesis. MT State Univ., Bozeman. 272 pp + appendices.

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Compliance codes: EXCL

Explanation: 516 DM2 App. 1.7

End of data.

PROJECT STATEMENT BICA-N-012.000

Last Update: Priority: Medium

Initial Proposal: February 15, 1996 Page Number: 1

Stabilization and Restoration of Crooked Creek

Funding Status:	Funded: 17.20	Unfunded: 0.00
Servicewide Issues:	N11 WATER QUAL-EXT	
Cultural Resource Type:	N/A	
RMAP Program Codes:	E00	
10-238 Package Number:	10-238	

PROBLEM STATEMENT

Crooked Creek is a first-order stream of the Bighorn Drainage that flows into Bighorn Lake about 5 km (3 mi) south of the Montana-Wyoming border. The stream is considered a significant resource in Bighorn Canyon National Recreation Area because it is the only stream within the Park that has a major segment flowing completely within the Park's boundary. Only the extreme lower reaches of most other streams are contained within the Park, just before they discharge into Bighorn Lake. Although the quality of the stream is compromised by water withdrawals and grazing upstream of the Park boundary, coupled with poor historic land-use practices even for the segment flowing within the Park, the Park is interested in maximizing the benefits of Crooked Creek for fish and wildlife. The portion of the creek in the Park also is valuable for environmental education due to its natural history and accessibility from the south end of the Park. This project statement addresses restoration and protection of the creek to maximize these benefits.

Crooked Creek originates in the Pryor Mountains of Montana. It flows south through Montana for most of its length, and crosses into Wyoming a few miles from where it enters Bighorn Lake. Drainage area and approximate discharge are 300 km^2 (116 mi^l) and 0.3 m^3sec^{-1} (10 cfs), respectively (Environmental Protection Agency *1977).* Based on the size of the stream and qualities of its drainage basin, it can be presumed that historically the stream was perennial. Although the headwaters of the stream are in Custer National Forest, upstream of the Park, it crosses private land and lands managed by the Bureau of Land Management for a total of over 16 km (10 mi) where water is withdrawn from the stream for irrigation and grazing occurs by domestic livestock and wild horses. In recent years, the Park's portion of the stream occasionally has ceased flowing completely for short periods during spring and summer when irrigation withdrawls peak. A 1983 Wyoming District Count ruling (Civil No. 4993) denied "reserved water rights" for the portion of the Park in Wyoming, including Crooked Creek.

Crooked Creek's current condition reflects past land uses which have resulted in a downcut channel through deep alluvial soils to a depth of nearly 6 vertical m (20 ft) in several places. As a result of the lowered stream bed, the creek no longer supports typical riparian vegetation. Instead, xeric shrubs adapted to semi-arid conditions now occupy the terraces that were once a floodplain for major portions of the stream's length. Organisms normally associated with a healthy stream environment are either absent or present only as a thin riparian strip immediately adjacent to the incised channel. Down-cutting appears to have slowed in recent years, with protection of the streambank from domestic livestock, coupled with the fact that the channel has reached bedrock in some places. At best, the process of down-cutting is now static. The creek also has flooded several times in recent years, scouring the channel and removing streamside vegetation and beaver dams that had managed to become established.

Crooked Creek has been evaluated by two professionals with expertise in stream hydrology and vegetation, Dr. Quinten Skinner from the University of Wyoming and Charles Taylor from the U.S. Soil Conservation Service (currently Natural Resources Conservation Service). Both generally agreed that the stream channel already resides at bedrock and, therefore, cannot be further incised. Protection of the stream from disturbance, encouragement of beaver so that their dams can trap sediment, and considerable time to allow the stream channel and floodplain to rebuild are necessary to restore the system.

Park staff have begun to implement several actions for stream restoration. Beaver activity is encouraged by aggressive enforcement of a no-trapping regulation. Although beaver are desirable because their dams retain sediment and assist with channel aggradation, beaver also have the potential to kill the few mature cottonwood trees *(Populus deltoides)* that persist along the streambank and also to retard the recruitment of willow *(Salix)* and young cottonwood along the stream. Large cotton-wood trees along the stream bank are crucial for shade and for holding soil in place. Some level of recruitment of cottonwoods and willow also is needed to replace the mature trees as they die. Therefore, beaver guards constructed of hardware cloth have been installed on several large cottonwood trees to keep beaver from killing them. Additionally, some young willow and cottonwood trees are selected each year for protection with sheaths of hardware cloth. The black greasewood *(Sarcobatus vermiculatus)* community, an upland community that parallels the stream, currently is protected from fire even though it is an artifact of the lowered table and incised morphology of the stream. A concern is that loss of the greasewood community would open the area to invasion by Russian knapweed *(Centaurea repens)*, which occurs along the outer perimeter of the greasewood stand and is a highly invasive non-indigenous species. Fencing is in place to prevent use by cattle, and in some locations outside the Pryor Mountain Wild Horse Range, to prevent use by wild horses. The site is used as an environmental study area for school groups because it is accessible, and it provides a good field location for demonstrating ecological relationships and discussing consequences of certain land-use practices on natural systems.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY

The Park will continue current management activities to stabilize and restore Crooked Creek. This commitment includes the following activities:

1. Maintain beaver guards made out of hardware cloth sheaths on large cottonwood trees along the creek.
2. Encourage the presence of beaver by aggressively enforcing the no-trapping regulations.
3. Protect the black greasewood community until there is a reasonable potential for re-establishment of a native riparian community.
4. Annually select seedlings of willow and cottonwood for protection from browsing animals by sheathing the seedlings in hardware cloth.
5. Maintain fences to prevent trespass by cattle, and on Park lands outside the Pryor Mountain Wild Horse Range, also maintain fences to prevent trespass by wild horses.
6. Periodically evaluate the need for and usefulness of installing rock gabions for the extreme lower reaches of the stream near the lake where down cutting of the channel is less severe than at upstream locations. Installation in severely downcut reaches probably would not hold under flood conditions.
7. Use the Crooked Creek site as an environmental study area for school groups.

Funds for this project currently exist in the Park's base budget. The primary reason for including the project statement in this plan is to acknowledge the need for continued funding and to identify the general costs if a change in priorities should necessitate funding sources other than the Park's base budget.

BUDGET AND FTES:

FUNDED

	Source	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:	PKBASE-OT	INT		0.30	0.0
	PKBASE-NR	MIT		3.00	0.1
	PKBASE-NR	MON		1.00	0.1
			Subtotal	4.30	0.2
Year 2:	PKBASE-OT	1NT		0.30	0.0
	PKBASE-NR	MIT		3.00	0.1
	PKBASE-NR	MON		1.00	0.1
			Subtotal	4.30	0.2
Year 3:	PKBASE-OT	INT		0.30	0.0
	PKBASE-NR	MIT		3.00	0.1
	PKBASE-NR	MON		1.00	0.1
			Subtotal	4.30	0.2
Year 4:	PKBASE-OT	INT		0.30	0.0
	PKBASE-NR MIT			3.00	0.1
	PKBASE-NR MON			1.00	0.1
			Subtotal	4.30	0.2
			Total:	17.20	0.8

UNFUNDED

Source	Activity	Fund Type	Budget ($1000s)	FTEs
		Total:	0.00	0.0

(OPTIONAL) ALTERNATIVE ACTIONS/SOLUTIONS AND IMPACTS Discontinue Current Management Program: The Park would discontinue efforts to protect the stream from livestock, wild horses, and beaver as a means to accelerate the natural process of creek restoration. Beaver would frequently pass through the area and cut cottonwood and willow seedlings. The few old trees remaining along the creek would eventually die or be cut by beavers. Their replacement by young trees would be slow to occur or maybe would not occur under present browsing pressures by native, feral, and domesticated animals. The chances that a mature, native riparian community would develop along the creek would be poor.

LITERATURE CITED

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Compliance codes: EXCL Explanation:

516 DM2 App 7.4 B(11) End of data.

Last Update:
Initial Proposal: February 15, 1996

Priority: med
Medium Page Number: 1

Monitoring of Blue-green Algae at Swimming Beaches

Funding Status: Funded: 0.00 Unfunded: 5.00

Servicewide Issues: N11 WATER QUAL-EXT

Cultural Resource Type: N/A

RMAP Program Codes: E00

10-238 Package Number: 10-238

PROBLEM STATEMENT

Blooms of blue-green algae (Cyanophyceae) are a continuing summer-time problem in Bighorn Lake. The algal blooms present aesthetically undesirable conditions and have the potential to cause human health problems. The National Park Service should provide adequate warnings to visitors of possible health effects associated with exposure to algal blooms and develop a system for documenting the incidence of health problems associated with exposure to blue-green algae in the lake.

Blue-green algae are a group of cosmopolitan, primarily freshwater algae (Lee 1980). Although many of the members of this group occur in lakes at low or moderate levels of abundance, many species have the notorious capacity to reach bloom proportions in eutrophic systems, usually in late summer and early fall. Most freshwater blooms in eutrophic lakes consist of the genera *Microcystis, Anabaena, Aphanizomenon, Gleotrichia, Lyngbya, or Oscillatoria* (Lee 1980), and several species within these genera occur in Bighorn Lake (Soltero 1971). Given that the trophic quality of Bighorn Lake ranges from mesotrophic near the dam to eutrophic in the upper pool (EPA 1977), it is not surprising that Bighorn Lake is subject to extensive blooms of blue-green algae, as are many reservoirs in the Missouri River reservoir systems (Carmichael 1992). The blooms in Bighorn Lake tend to appear in July, persist through summer, and diminish by the end of October (Soltero 1971; B. Byrne, Big-horn Canyon Natl. Rec. Area, pers. comm., Oct. 1995). In particularly, *Aphanizomenon flos-aquae* can become extremely abundant during this time frame (Soltero 1971). Blooms in the lake can be extensive in surface area. In the summer of 1995 for example, individual mats of algae covered several hundred square meters in some locations, particularly embayments in the lake, including some in the northern end of the reservoir near Yellowtail Dam. Either eutrophic conditions existed near the dam as well as in the southern reaches of the reservoir in 1995, or winds moved extensive mats of algae from southern reaches to extreme northern reaches. Location of the blooms and major points of lake access and camping sites often coincide. Maximum concentration of chlorophyll *a* in the reservoir correspond with blooms of this species and ranges from 35 to 77 mg/m^3 (Soltero 1971).

Many blue-green algae are toxic to vertebrates. Blooms of toxic species are reportedly the reason for the death of some livestock, pets, and wildlife in the Midwest (Fawks et al. 1994) Globally high losses of livestock have been documented (Lee 1980). Blue-green algae are taken into the digestive system when an animal drinks water, the algae die in the digestive tract, and the toxins are released (Lee 1980). The toxins can also be released in the water during decomposition of the algae. In additional to causing deaths of animals, the toxins in moderate quantities in drinking water can cause diarrhea in humans (Aziz 1974). Reports of skin disorders associated with contact with blue-green algae are rare, although one bloom of a species of *Lyngbya,* which has not been recorded in Bighorn Lake, was associated with severe dermatitis on the skin of swimmers in Hawaii, including inflammation, swelling of mucous membranes of the eyes and nose, and redness and pus on the skin (Moikeha and Chu 1971, Mynderse et al. 1977).

There are two incidents that provide speculative evidence of toxic levels of blue-green algae in Bighorn Lake. During the summer of 1993, a pet dog became sick and died shortly after accompanying a family on a visit to Horseshoe Bend at the south end of the lake. The dog had played in the water, an extensive algal bloom was present, and the dog had eaten a crayfish covered with blue-green algae along the shoreline. In the summer of 1995, two children swimming at Frozen Leg when a bloom was present developed skin sores that persisted for several weeks. Frozen Leg is an embayment toward the north end of the lake. A self-contained pit toilet at the site was checked for leakage to rule out the possibility that septic contamination was related to the infection. The toilet vault was not found to be leaking. It remains unresolved whether the skin sores reflected a severe dermatitis as a result of contact with a blue-green alga, a bacterial infection associated with poor water quality, or some other situation.

The best way to prevent blooms of blue-green algae is to reduce the input of excessive amounts of nitrate, phosphate, and organic matter in the water bodies concerned (Lee 1980). If this is impossible, treatment with copper sulfate to give concentration in the water of about 9.2 mg/L is effective in preventing the development of blooms without causing damage to other species of plants or fish. If none of these actions is feasible, humans, pets, and wildlife should reduce their contact with surface water and consumption of such water during periods of blooms.

Phosphorus is the element most likely controlling phytoplankton growth in Bighorn Lake in summer months, with phosphorus fertilization of the lake derived from non-point sources (e.g., runoff from crop, range, and forest lands), as well as identifiable sources such as discharge points from municipal and industrial wastes. Recent estimates of phosphorus loading are not available, although levels are presumed to be high. Phosphorus loading in Bighorn Lake in 1974 was estimated to be 20.42 $g/m^2/yr$. An even higher level of 33.40 $g/m^2/yr$ was present in 1968 based on phosphorus and flow data reported by Wright and Soltero (1973). These levels far exceed those levels needed to create eutrophic conditions (Vollenweider and Dillon 1974). Extensive control of point sources and non-point sources in the Bighorn Basin would be necessary for a reduction in the potential for algal blooms in Bighorn Lake. Although this is a reasonable long-term goal, the need for the National Park Service to provide for reasonably safe conditions in the lake for visitors requires immediate action. Thus the best near-term approach to the problem is to advise visitors to reduce their contact with the water during periods of blooms.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY

Post Warnings and Systematically Compile Case Records: The Park will alert visitors to the presence and toxic effects of blue-green algae by posting written information at major access points to the lake. Visitors will be advised against swimming within algal blooms and against direct or indirect ingestion of water containing algae. They will also be advised to limit the exposure of any pets to waters infected with blue-green algae. Park rangers will ask visitors to report any incidents of suspected illness associated with contact of blue-green algae or consumption of water with dense algal colonies. Records will be kept of any reported incidents, and efforts will be made to correlate exposure with any reported symptoms. Nutrient monitoring will be given added emphasis under the project "Water-Quality Inventory and Monitoring", which is also included in this plan.

The primary costs associated with this project are to develop the necessary signing and brochures describing the possible hazards to human health. A small level of support and FTE also will be necessary to document actual and possible cases of health problems associated with contact with blue-green algae in Bighorn Lake and to maintain signs and other information media.

BUDGET AND FTES:

FUNDED

	Source	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1	PKBASE-OT	MIT		10.00	0.4
Year 2:	PKBASE-OT	MIT		10.00	0.4
Year 3:	PKBASE-OT	MIT		10.00	0.4
Year 4:	PKBASE-OT	MIT		10.00	0.4
			Total:	40.00	1.6

UNFUNDED

	Source	Activity	Fund Type	Budget ($1000s)	F 1Es
Year 1:				5.00	0.5
Year 2:				0.50	0.1
Year 3:				0.50	0.1
Year 4:				0.50	0.1
			Total:	6.50	0.8

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Compliance codes: EXCL

Explanation: 516 DM2 App.2, 1.6

End of data.

Last Update: Priority: Med.-Low
Initial Proposal: February 15, 1996 Page Number: 1

Qualitative Survey of Selected Aquatic Invertebrates

Funding Status:	Funded: 0.00	Unfunded: 20.00
Servicewide Issues:	N20 BASELINE DATA	
Cultural Resource Type:	N/A	
RMAP Program Codes:	Q01	
10-238 Package Number:	10-238	

PROBLEM STATEMENT

The only study in Bighorn National Recreation Area that has specifically addressed aquatic invertebrates is a survey of zooplankton conducted by Horpestad (1977) during the summers of 1968-70 soon after impoundment. Twenty-six taxa of zooplankton were identified in the reservoir at that time: 10 cladocerans, 3 copepods, and 13 rotifers. The cladoceran, *Daphnia galeata mendota* numerically was the most abundant species and contributed more to the total standing crop of zooplankton than any other taxon. This survey probably is outdated because of successional changes in the reservoir (Kimmel and Groeger 1986) and because fish, some of which prey on zooplankton, have been extensively stocked. Benthic animal communities, which include aquatic insects, crustaceans, univalve (snails) and bivalve mollusks (clams and mussels), aquatic worms, and several other groups, remain poorly described in the lake. The benthic community is presumed to be limited in species richness and abundance of individuals in most taxonomic groups because of the extensive accumulation of sediments in the lake, particularly at the southern end.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY

The Park will conduct a qualitative survey of the benthic macro-invertebrate fauna of Bighorn Lake. It probably will be conducted through a cooperative agreement with a National Biological Service cooperative research unit or center. The objective of the survey will be to determine the taxa present to the lowest taxonomic level practical and to describe in general terms the habitats occupied by the taxa. Relative abundance of common taxa in various habitats also will be described.

The habitats to be surveyed will include the littoral and profundal zones of the lake shore and the bottom of the lake. Distribution of the sampling locations will encompass eastern and western shores of the lake and northern, southern, and middle locations within the lake. Some of the bays, such as Horseshoe Bend, will be included. A minimum of three samples will be collected at each location. Methods of collecting samples will vary depending on location. The bottom of the lake and deep locations along the shoreline will be sampled with a Ponar dredge. In places, a diver equipped with SCUBA equipment and a sweep net will collect samples from rocky substrates down to depths of about 15 m (50 ft). Insects traps will be used along the shoreline to obtain adult insects as they emerge. Opportunistic collections will be made along portions of the shore by hand-picking from rocky substrates and using a fine-mesh dip net.

All samples will be sorted, counted, and recorded according to major taxonomic groups. A simple habitat classification system will be developed during the process of collecting the samples, and the habitats occupied by the various taxa will be described using this system to facilitate future sampling. Specimens will be archived according to regulations of the National Park Service.

BUDGET AND FTES:

FUNDED

Source	Activity Fund Type Budget ($1000s)	FTEs
	Total: 0.00	0.0

UNFUNDED

Source	Activity Fund Type Budget ($1000s)	N'1'Es
Year 1:	10.00	
Year 2:	10.00	
	Total: 20.00	0.0

LITERATURE CITED

Horpestad, A.A. 1977. Changes in zooplankton species composition in newly filled Bighorn Lake, Montana and Wyoming. Ph.D. Thesis. MT State Univ., Bozeman. 55 pp.

Kimmel, B.L., and A. W. Groeger. 1986. Limnological and ecological changes associated with reservoir aging. Pages 103-109 in G.E. Hall and M.J. Van Den Avyle, editors. Reservoir Fisheries Management: Strategies for the 80's. Reservoir Committee, Southern Div., Am. Fish. Soc., Bethesda, MD.

Compliance codes: EXCL

Explanation: 516 DM2 App. 1.6

End of data.

Protection of Wetland Habitats

Funding Status:	Funded: 0.00	Unfunded: 20.00
Servicewide Issues:	N 13 WATER RIGHTS	
Cultural Resource Type:	N/A	
RMAP Program codes:	Q02 W01	
10-238 Package Number:		

PROBLEM STATEMENT

The Yellowtail Wildlife Habitat Management Area in Wyoming includes over 7,600 ha (19,000 ac) of wildlife habitat. Nearly 4,860 ha (12,000 ac) of this total area are within Bighorn Canyon National Recreation Area. The Yellowtail area is managed by the Wyoming Game and Fish Department through cooperative agreement with the National Park Service, Bureau of Land Management, and Bureau of Reclamation. Among the activities in the area is the creation of wetland wildlife habitat in the form of several large shallow impoundments.

The Wyoming Game and Fish Department has advocated the use of water rights for existing and proposed wetland reservoir projects within the Yellowtail area. The Park also is interested in using water rights to develop and protect wildlife habitat. The Park applied for and received in 1988 a Wyoming state-appropriated water-right permit for a "fishing preserve" at Railroad Pond in the Yellowtail area. The Park would like to pursue a similar approach to protect other pond and wet-land features on Park Lands within the Yellowtail area. Potential sites for protection include Kane Ponds; Cemetery Pond; Ponds 6 1/2, 7, 9, and 10; and old river meanders along the Bighorn River near the site of the Mason-Lovell Ranch.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY

This project has four components: 1) determine which features should be maintained and protected as wetland habitats; 2) determine the priority order for accomplishing protection of individual features based on significance of habitat provided, construction requirements, construction costs, and any other pertinent considerations; 3) coordinate efforts to secure water rights protection for pond and wetland features; and 4) develop individual pond and wetland features in a manner consistent with the results of the planning phases. Construction requirements and costs mentioned in the preceding list refer to any construction projects deemed necessary to maintain or improve the operation of the ponds currently in existence. Repairs to some dikes or water-control devices may be needed now or in the future to effectively manage some of the ponds. Park natural resources management staff have the expertise to complete the first component. Park staff primarily would be responsible for completing the second component as well, but would need some technical engineering assistance to identify associated construction requirements and costs. This assistance may be available from the Denver Service Center of the National Park Service or through contract with a private consulting firm, and the Bureau of Reclamation may be able to provide the needed expertise. The third component would be handled by the Water Rights Branch of the National Park Service. The following budget numbers reflect planning phase elements only. Construction costs would need to be estimated as a component of the project planning phase.

Last Update:
Initial Proposal: February 15, 1996

Priority: Low
Page Number: 2

BUDGET AND FTES:

FUNDED

Source	Activity	Fund Type	Budget ($1000s)	FTEs
		Total:	0.00	0.0

UNFUNDED

Source	Activity	FundType	Budget ($1000s)	FTEs
Year 1:			10.00	0.25
Year 2:			10.00	0.25
		Total:	20.00	0.5

Compliance codes: EA

Explanation: End of data.

Driftwood Management

Funding Status:	Funded: 40.00	Unfunded: 6.50
Servicewide Issues:	N11 WATER QUAL-EXT	
Cultural Resource Type:	N/A	
RMAP Program Codes:	E00	
10-238 Package Number:	10-238	

PROBLEM STATEMENT

Driftwood is a prominent feature of Bighorn Lake and poses hazards to the safety and property of visitors. Bighorn Canyon National Recreation Area has tried a variety of techniques to manage driftwood accumulations. Because driftwood is extremely difficult to remove and sources of driftwood primarily are outside the control of the National Park Service, the proposed strategy is to inform visitors of the hazards associated with driftwood and actively control only those accumulations that limit boat launching at developed boat launches.

Logs, trees, and other forms of woody debris enter the lake from the Bighorn and Shoshone rivers and their tributaries and add to the accumulation of woody debris already present in the reservoir. Much of this debris is perched on the lakeshore when lake water levels are low and then is deposited back into the lake as water levels rise when the reservoir fills each year. Although this driftwood probably has numerous biological benefits especially when it is submerged (Kimmel et al. 1990, O'Brien 1990), various methods have been used to remove portions of the wood because it poses hazards to boaters and to the operation of Yellowtail Dam. The Bureau of Reclamation manages driftwood removal near the dam with a crane system and the Park manages removal at several boat ramps on the reservoir (see below). Accumulations can be extensive enough to block lake access from the two boat ramps at the south end of the lake — Horseshoe Bend and Barry's Landing. High densities of driftwood coincide with the spring and summer recreational seasons.

The Park's information on losses to visitors because of encounters with driftwood is poor. All Park visitors are required to report any incidents involving accidents, collision, or other casualty to authorized Park staff within 24 hours (Title 36 CFR 3.4b), but rarely do visitors comply. In a typical recent year, about ten thousand boats use the lake, with the majority of that use concentrated during the period of June through September (Files, Bighorn Canyon Nat. Rec. Area, Ft. Smith, MT). Only a few incidents of property damage, primarily broken propellers, are reported to the Park as a result of collisions with driftwood, although many more incidents are presumed to occur. The marina at Ok-A-Beh rents seven boats to the public, and has replaced over 20 propellers in a single season on these boats when lake levels are high and large amounts of driftwood float in the lake (J. Joyce, Ok-A-Beh Marina Manager, pers. comm., Jun. 1995). Comparable levels of damage seem to occur in the south end of the reservoir. Occasionally damage is more serious than loss of a propeller, such as damage to an outdrive or hull (B. Byrne, Bighorn Canyon Natl. Rec. Area, pers. comm., Jun. 1995).

The Park has implemented various management tactics for driftwood control. In the mid 1980s, Park crews located concentrations of driftwood on the lake and along the shoreline, loaded the wood onto barges, stacked it at designated sites along the lakeshore, and burned it. This effort was labor intensive and was repeated through the entire spring and summer season. It was eventually discontinued due to lack of funding. From 1971-1975, the Park used a floating log boom to attempt to prevent driftwood from moving south to north through the lake. The boom was assembled near the "south narrows", south of Horseshoe Bend, and was aligned across the channel at an angle calculated to guide and trap driftwood into a cove. Logs accumulating in the cove were kept there as the lake level dropped and, when they were stranded on the beach in the winter, were gathered and burned. At times, the structure captured 0.8-1.2 ha (2-3 ac) of driftwood every 3-5 days. With such accumulations, winds from the south and southwest forced driftwood under the log boom and back into the lake, where it was free to float northward beyond the structure. The log boom solved the collection problem, but the effort needed to repeatedly remove the accumulations were too costly. Since 1976, the Park has relocated the log boom to create a protected, enclosed area around the immediate vicinity of the Horseshoe Bend boat launch. Wood still needs to be removed periodically from all boat launches. Driftwood that is removed either at Horseshoe Bend or Barry's Landing is pushed onto the shoreline using a bulldozer in winter when the ground and shoreline are frozen. The public is allowed to cut firewood from the piles, and then the piles are burned on site. This practice probably eliminates less than 10 percent of the total accumulation of driftwood in the reservoir (T. Peters, Bighorn Canyon Natl. Rec. Area, Lovell, WY, pers. comm., May 1994).

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY

The primary management approach will be to inform the public of the presence and dangers of driftwood in the lake through extensive signing at boat launches and the visitor centers. The signs will explain that floating and submerged driftwood are a common feature of reservoirs, and that the public should travel with caution on the lake to avoid property damage and bodily injury. Park brochures and announcements in newspapers will carry the same message.

The Park will continue with the current program of driftwood management at boat launches. A log boom will be used to exclude driftwood from an area enclosed, except for a small opening for incoming and outgoing boats, in the immediate vicinity of the Horseshoe Bend Marina. Driftwood will be removed periodically from the boat launches at Horseshoe Bend, Barry's Landing, and Ok-A-Beh if boat launching becomes difficult due to accumulations. Driftwood that is taken from the launches will be transported from the various sites if practical or stored along the shoreline until it can be or pushed high onto the shoreline using a bulldozer in winter when the ground and shore-line are frozen. The Park will use some of the driftwood to heat the Horseshoe Bend Ranger Station and the Layout Creek Ranger Station, and for campfire programs. Some wood will be left at the boat ramps for use by campers. The public also will be allowed to cut firewood from the piles, and the remaining driftwood will be burned periodically on site.

The Park currently supports driftwood control efforts with annual base funding of $10,000 and 0.4 FTEs. An additional $5,000 is needed to development signs and brochures describing the presence and hazards of driftwood in the lake. A small level of support will than be necessary to maintain these signs.

BUDGET AND FTES:

FUNDED

	Source	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1	PKBASE-OT	MIT		10.00	0.4
Year 2:	PKBASE-OT	MIT		10.00	0.4
Year 3:	PKBASE-OT	MIT		10.00	0.4
Year 4:	PKBASE-OT	MIT		10.00	0.4
			Total:	40.00	1.6

UNFUNDED

	Source	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:				5.00	0.0
Year 2:				0.50	0.0
Year 3:				0.50	0.0
Year 4:				0.50	0.0
			Total:	6.50	0.0

(OPTIONAL) ALTERNATIVE ACTIONS / SOLUTIONS AND IMPACTS

High Lake Level: The Park will request that the Bureau of Reclamation briefly raise the level of Bighorn Lake to or near the lake's maximum floodpool to attempt to strand driftwood high on the shores of the reservoir. The risk of this alternative is that driftwood that is currently out of reach of lake levels may become suspended in the lake, in addition to the supplies already present. This alternative also poses threats to property owners upstream of Bighorn Lake, whose property could be flooded as lake levels rise.

Hand Removal: Park staff will patrol the shoreline of the lake in boats at regular intervals and remove by hand any driftwood found on the shoreline and the boat ramps. Removal efforts will be intensified when lake levels are low to maximize the benefits of this program. The wood will be used by the Park and by visitors, as described under the preferred alternative, and anything left will be burned at designated sites along the lakeshore. Floating and submerged logs will continue to pose hazards to boaters. Problems with air quality may develop due to burning practices.

Improved Log-Boom System: The Park will reinstall the floating log boom at a point in the south end of the lake where driftwood can be effectively intercepted and where a hard surface can be developed on both sides where the log boom intersects the shore. The surfaces will be durable enough to allow the operation of a bulldozer. Wood trapped by the boom will be pushed onshore using the bulldozer far enough to be out of the reach of high water levels until the wood can be transported away from the lake or burned. The Park has one bulldozer for this operation, but will require the rent or purchase of a second one to accomplish the task. Removal efforts will probably be intensive for several years to remove the accumulations currently in the lake, and then should drop to a less intensive, but ongoing maintenance effort.

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Compliance codes: EXCL

Explanation: End of data.

Last Update:
Initial Proposal: February 15, 1996

Priority: low
Page Number: 4

Perpetuate Riparian Vegitation Dynamics, Bighorn River Upstream of Bighorn Lake

Funding Status:	Funded: 0.00	Unfunded: 40.00
Servicewide Issues:	N 11 WATER-QUAL-EXT N	
	13 WATER RIGHTS	
Cultural Resource Type:	NA	
RMAP Program codes:	E00 V01	
10-238 Package Number:		

PROBLEM STATEMENT

The composition and distribution of riparian vegetation along the banks of the Bighorn and Shoshone rivers have changed dramatically during the last 65 years (Akashi 1988, Bighorn Canyon National Recreation Areas files). Most notably, cottonwood *(Populus deltoides)* woodlands have decreased in distribution and abundance, and shrublands have become prevalent, particularly shrublands dominated by tamarisk *(Tamarix chinensis),* an exotic, and sumac *(Rhus trilobata), a* native. These woodlands are extremely valuable because they are Federally owned and readily accessible for research, which is not characteristic of most riparian woodlands in the Rocky Mountain region, and because they are one of the most extensive tracts of cottonwood-dominated riparian woodlands in the Rocky Mountain Region (D. Knight, Univ. WY, Laramie, pers. comm., May 1995). Although the species may differ slightly, comparable changes have occurred at other locations in the western United States, with a cumulative loss of mature cottonwood woodlands (Rood and Mahoney 1990, Bradley et al. 1991, Johnson 1994). The onset of these changes correlates well with the development and operation of dams on major rivers. Operation of these dams generally has dampened the magnitude of flood events, altered the frequency and timing of flooding, and changed patterns of sediment deposition within floodplains. These changes often cause reductions in channel length, sinuosity, and surface area of the riverine system, with ensuing consequences for riparian vegetation. The objective of this project is to propose to begin the process of acquiring the needed information to initiate changes in the flow regimes of the Bighorn River in order to enhance the establishment and survival of cottonwood woodlands in the floodplain between Boysen Dam and Bighorn Lake.

A study of the state and dynamics of riparian vegetation was conducted along the Bighorn River at the southern end of Bighorn Canyon National Recreation Area in 1985 and 1986 by Akashi (1988). Study sites were located in Wyoming along a 10-km (6 mi) reach of the Bighorn River just south of the Wyoming-Montana border. Boysen Dam and Reservoir, with a storage capacity of about 11.7 $x10^8$ m^3 (952,432 ac-ft), is located about 153 km (95 mi) upstream of the area studied. The average elevation of the upper pool of the large reservoir created by Yellowtail Dam, called Bighorn Lake, extends to the downstream boundary of the area studied (Bur. of Reclamation 1994). Akashi (1988) focused on classifying and mapping the riparian vegetation now present and comparing it to what was present before dam construction using pre-dam and current aerial photography and field plots. She examined relationships between vegetation and physical environments, described changes in riverine characteristics from 1938 to 1986, and examined evidence of fire to estimate intervals between burns. Many of the generalizations and recommendations contained in this project statement are based on her results, with more recent references added as appropriate.

The tree component of woodlands along the Bighorn River in the vicinity of the Park is almost exclusively cottonwood. In 1986, cottonwood woodlands occupied about 37 percent of the area studied by Akashi (1988). They occurred fairly evenly distributed along the floodplain, ranging in age from about 15 years to about 142 years. Middle-aged woodlands were the most prevalent type. Young woodlands tended to occur close to point bars along the current river channel, and older woodlands tended to occur away from the point bars. Four other major classes of riparian vegetation were present: shrublands, meadows, marsh, and agricultural land. Shrublands covered about half of the total area of the floodplain studied, with three types especially common: (1) tamarisk, (2) greasewood *(Sarcobatus),* and (3) tamarisk-willow *(Salix).* Tamarisk is an exotic shrub that probably invaded the area in the late 1950's, became relatively common on sandbars and low terraces by the early 1960's, and invaded many of the native shrublands and woodlands on the middle and higher terraces of the floodplain by the late 1960's. Although tamarisk seeds are light and well-equipped for aerial dispersal, large floods in the 1960's probably facilitated the rapid and wide distribution of the exotic.

A comparison of plant communities present in 1986 with communities present before the completion of Boysen Dam in 1952 indicates that woodlands now are less common and shrublands more common. Individual areas occupied by woodlands also have changed from large, continuous stands to small, discrete stands. There has been little change in this situation from 1986 to the present (T. Peters, Bighorn Canyon Natl. Rec. Area, Lovell, WY, pers. comm., Mar. 1995), although some cottonwood seedlings germinated and established on sandbars in the vicinity of Kane, WY several years after an unusually high discharge of 314 $m^3 sec^{-1}$ (11,100 cfs) in mid-June 1991on the Bighorn River (J. Cagney, Bur. Land Manage., Craig, CO, pers. comm., Jun. 1995). The loss of wood-lands appears to be driven by a drastic reduction in the recruitment of young woodland species plus a decrease in the survival of cottonwood trees in the middle-to-old-age classes. Recruitment of young cottonwoods into the riparian zone seems to be reduced because of an apparent failure of cottonwood seedlings to find suitable substrate and moisture conditions for regeneration. Disturbance by fire and conversion of woodlands to cropland has contributed to the fragmentation and loss of woodlands.

Because of the dominance of cottonwoods, woodland persistence through time is directly linked to the requirements of this species. Germination of cottonwood seeds and development of seedlings require bare and relatively coarse-textured soils with a constant supply of moisture and full sun-light (Read 1958). These conditions for cottonwood seed germination and seedling growth along the Bighorn River often occur on point and lateral bars and along islands within the channel. These are the only places where Akashi (1988) found abundant first-year cottonwood seedlings during the summer of 1985. The presence of sandbars in riverine systems are strongly influenced by fluctuations in river discharge and sediment loads carried by the river. The actual relationship between sediment loads, sandbar formation, and discharge can be very complicated. Sediment loads in-crease with increasing discharge, but sandbars do not necessarily disappear during high flows and form during declining stages. At a given discharge, the spatial distribution of hydraulic forces is not uniform in streams, so sediment is eroded from some areas and deposited in others. Much of this erosion and deposition occurs during high flows, but bars are further modified during falling stages (Keller and Melhorn 1973). Timing of cottonwood seed dispersal and changes in river discharge are important for successful cottonwood regeneration (Scott et al. 1993). Under unregulated flow conditions, peak flows coincide with the release of cottonwood seeds in the spring. Seeds carried by high flows in June are deposited on sandbars as water levels begin to decline. As water levels continue to drop toward mid-summer, seeds germinate and their roots grow and extend deep in the sandbar deposits. Low discharge floods tend to wash away seeds and seedlings on low slopes of the sandbars, which results in a band of cottonwood seedlings more or less parallel to the channel meander. A sapling grove develops and matures if a band of seedlings on a sandbar escapes scouring flows of the river or other forms of disturbance over sufficiently long time-frames.

The flow of the Bighorn River upstream of the cottonwood woodlands has been altered largely by Boysen Dam and Reservoir. Several small dams, including a small concrete dam completed in 1908 and also known as Boysen Dam, influenced the flow before the construction of the new and much larger Boysen Dam in 1952. Before dam operation, discharge of the Bighorn River was low from October through December and reached a minimum in January. Discharge increased gradually from mid-February toward April, then rapidly rose in May to reach a maximum in June. Discharge then rapidly dropped during July and continued to decline to a low level in October. The difference between maximum and minimum discharges was about 209 $m^3 sec^{-1}$ (7,400 cfs), and the maximum instantaneous discharge could reach nearly 425 $m^3 sec^{1}$(15,000 cfs) during June.

Discharge has remained fairly constant from October through April since construction of the new Boysen Dam. Discharge gradually increases in May toward a maximum in June of about 136 $m^3 sec^{-1}$ (4,800 cfs), then drops gradually through July to a minimum in late summer of about 41 $m^3 sec^{-1}$ (1,450 cfs). The peak discharge still occurs during June, but the difference between maximum and minimum discharge is only about 95 $m^3 sec^{-1}$ (3,350 cfs), less than half the difference before construction of the dam. The maximum instantaneous discharge during June also is nearly half of the discharge before dam replacement. These generalizations are based on discharge summaries in Akashi (1988), but current discharge records provide comparable trends (Table 1). Additionally, the amount of sediments carried by the stream has changed. Sediment discharge dropped rapidly and has remained at low levels for the system, about 10,545 metric tons (11,600 tons) per day, since completion of the dam. Average sediment discharge prior to dam construction was about three times this amount.

Sandbars develop downstream of Boysen Dam under current patterns of reservoir management, but the sandbars do not appear to be high enough and large enough to provide adequate bare seedbeds where cottonwood seeds are deposited. In the mid-1980s, all cottonwood tree bands found by Akashi (1988) were older than 15 years, indicating that the necessary sandbar habitat for seedling establishment was absent since around 1970. Everitt (1968) reported that accretion of sandbars to about 1.5 m (5 ft) above low river level is necessary for successful establishment of cottonwood seedlings. In 1986, sandbars occurred mostly at elevations lower than 1.2 m (4 ft) above low flows measured in September. Some cottonwood seedlings may germinate successfully on terraces already occupied by shrubs or young cottonwood trees, but they tend to die out because of competition. Reduced cottonwood reproduction rates have also been reported on various other floodplains (Fenner et al. 1985; Johnson et al. 1976; Ohmart et al. *1977;* Crouch 1979a,b; Bradley and Smith 1986; Engel-Wilson and Ohmart 1978), commonly as a result of modified river flows.

Table 1. Discharge information for the Bighorn River measured at Kane, WY from October 1992 to September 1993 (USGS Water Data Report). Units are cubic ft per sec.

Month	Mean	Maximum	Minimum
Oct	1,281	1,450	1,080
Nov	1,179	1,380	1,070
Dec	1,027	1,120	910
Jan	1,099	1,190	950
Feb	1,033	1,130	926
Mar	1,286	1,800	1,120
Apr	1,004	1,240	757
May	4,136	7,580	946
Jun	5,754	7,060	4,160
Jul	3,747	10,900	1,740
Aug	1,575	2,260	1,190
Sep	1,532	1,780	1,230

Instantaneous peak flow for period: 12,900 cfs on July 4, 1993.

In addition to problems with regeneration, cottonwood woodlands have been affected by the removal of mature trees. Along the Bighorn River in the vicinity of the Park, cottonwoods 30-54 years of age are considered to be middle aged, and only a small portion of the canopy generally is alive in woodlands where trees are greater than 80 years old (Akashi 1988). For the last 50 years, fire appears to be the predominant disturbance eliminating old cottonwood trees in this area. Woodland replacement by cropland, shifting of channels, and wildlife (e.g., beaver activity) also have caused some mortality of mature trees. These disturbances often create conditions conducive to the establishment of tamarix. Unless mass reproduction of cottonwood occurs in the next half century, the woodlands probably will become scarce in the floodplain of the Bighorn River and eventually will disappear. Tamarix-dominated shrublands will likely become even more pervasive than they are now.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY

The Park will begin efforts to explore the possibility of requesting the Bureau of Reclamation for periodic artificial flooding by large releases of reservoir water as suggested by Bradley and Smith (1986) and Rood and Mahoney (1990) to improve the rate of cottonwood regeneration. This effort will require research to better understand the discharge and sediment patterns needed in the Bighorn River System for cottonwood germination and survival. Specifically, the frequency of flood events, the seasonal timing of the flooding, and the shape of the hydrograph needed for cottonwood germination and survival needs to be well defined in order to justify the request. Potential methods for mitigating the impacts of dams on downstream forests tend to include downstream flow schedules that (1) retain occasional spring flooding, (2) taper off rather than abruptly drop downstream flow, and (3) provide adequate flows throughout the summer. Similar efforts to understand the implications of dam operations and artificial flood flows are being conducted on the Green River in Dinosaur National Monument and the Colorado River in Grand Canyon.

In addition to cottonwood success, changes in the flooding regime may have benefits for other water resources. Experimental flow events of high magnitude and short duration (flushing flows) have already been requested from the Bureau of Reclamation by the Wyoming Department of Fish and Game in the Bighorn River upstream of Bighom Lake. These flows are being conducted to assess the need for a flushing flow to enhance the natural recruitment of rainbow trout *(Oncorhynchus mykiss)* and brown trout *(Salmo trutta)*, and to determine the magnitude, duration, and timing of such flow releases from Boysen Reservoir to scour pools, clean spawning gravel, maintain side channels, and flush fine sediment from the Bighorn River (Wiley 1994). Enhanced flooding also may help in reducing fire frequency on the floodplain by removing some of the accumulated litter (Akashi 1988). High flows are important in creating and maintaining geomorphic features such as side channels, back channels, sandbars, chutes, and pools that serve as essential habitat for native fish species. These off-channel features increase habitat diversity and likely serve as important feeding and nursery areas (Funk and Robinson 1974). Still waters in these areas pro-mote the accumulation of organic matter, which in turn, is important for macroinvertebrate production, which in turn is a food resource for many fish species. Furthermore, high flows in late May and June have been shown to stimulate spawning migrations of shovelnose sturgeon (Berg 1981). Efforts are now underway to reintroduce this species to the Bighorn Drainage upstream of Bighorn Lake (M. Welker, WY Fish & Game, Cody, pers. comm., Mar. 1995). In general, maintenance of some pattern of high flows within the Bighorn River between Boysen and Yellowtail dams would provide benefits to a wide array of terrestrial and aquatic resources.

Use of flooding for cottonwood regeneration has several drawbacks. The size of many sandbars today in the Bighorn floodplain may still be inadequate for seedbeds even when periodically flooded. Furthermore, periodic flooding could favor the expansion of tamarisk. Therefore, any change in flooding regime must be accompanied by a monitoring program to evaluate changes in the distribution and abundance of cottonwood and tamarisk. Although extremely difficult and costly, some tamarisk control may be required. Efforts to do so should be selective and realistic. Tamarisk removal can only be done on shrub-sized individuals, however if millions of seedlings and saplings are established, which can happen in one year, control with herbicides or cutting is impractical (D. Cooper, Colorado St. Univ., pers. comm., Apr. 1995).

One of the biggest drawbacks to use of flooding for cottonwood regeneration is the potential for flood damage to developed property in the floodplain between Boysen Dam and Bighorn Lake. Extensive planning, extensive public discussion and some mitigation for damage will be needed in order to proceed with this alternative.

Consideration will be given to the planting of cottonwood seedlings and shoot cuttings in selected portions of the floodplain (Ohmart et al. 1977, Anderson et al. 1984). A team consisting of a botanist, hydrologist, and soil scientist will provide advice on the areas to be planted. Irrigation will be conducted as needed for initial stand establishment. Livestock grazing within the recreation area on point bars and areas planted will be eliminated so young trees are not damaged by cattle. Fencing may also be required to prevent loss of seedlings due to browsing by native ungulates.

A large fire in the floodplain woodlands of the Bighorn River would drastically impact the cottonwood trees. There is at least a moderate potential for such an event because of the abundance of dead woody and herbaceous debris in the floodplain coupled with the practice of burning by farmers to clean irrigation ditches. The Park will develop fuel breaks to reduce the possibility of fire damage as part of a fire management plan. Cost estimates for this project assume that the National Park Service will work with research staff at a university or another organization with appropriate technical expertise to conduct the research to define the discharge and sediment patterns needed for cottonwood germination and survival. Costs of this initial assessment have been distributed over a four-year period. These costs are presented with the caution that the initial assessment may well determine that defining discharge and sediment patterns will require a larger inquiry than the effort supported by funding in this project statement.

BUDGET AND FTES:

FUNDED

Source	Activity Fund Type Budget ($1000s)	1, 1Es
	Total: 0.00	0.0

UNFUNDED

Source	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:			10.00	0.1
Year 2:			10.00	0.1
Year 3:			10.00	0.1
Year 4:			10.00	0.1
		Total:	40.00	0.4

(OPTIONAL) ALTERNATIVE ACTIONS / SOLUTIONS AND IMPACTS

No action: The general trend of a decrease in woodland area and an increase in shrublands will continue. The young and middle-aged stands of cottonwood now present will shift to middle-aged to old stands in the next 10-20 years, and to old and very old stands in the next half century. Old trees will be eliminated from the woodlands due to natural mortality. At the same time, disturbances such as bank erosion, beaver activity, and fire will destroy some portion of the woodlands. Fire frequency may actually increase because of accelerated litter accumulation if litter is not washed away by flooding or covered with sediments under regulated flow conditions.

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Compliance codes: EXCL

Explanation: 516 DM2 App.2, 1.6

End of data.

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Appendix 1. Selected surface water-quality standards for State of Wyoming waters classified as Class 2 based on Chapter 1, water quality rules and regulations last revised November, 1990.

ITEM	SPECIFICATION
Toxic materials	None in concentrations or combinations that constitute pollution, except those designed to kill or eliminate problem-causing aquatic life (e.g., mosquito larvae or plant growth in irrigation ditches) and fish toxicants by Wyoming Game and Fish Department
Settleable solids	None in quantities that could result in significant aesthetic degradation, significant degradation of habitat for aquatic life or adversely affect public water supplies, agricultural or industrial water use, plant life or wildlife.
Floating and suspended solids	None in quantities that could result in significant aesthetic degradation, significant degradation of habitat for aquatic life, or adversely affect public water supplies, agricultural or industrial water use, plant life or wildlife.
Taste, odor and color	None attributable to or influenced by the activities of man that pro-duce taste, odor and color or that would alone or in combination impart off-flavor to fish flesh, alter natural color of the water, impart color to skin, clothing, vessels or structure, produce detectable odor, or result in concentrations that negatively affect odor or taste of public water supplies.
Dead animals and solid waste	Not allowed to be placed or allowed to remain in surface water or to be placed or allowed to remain in any location that would contami-nate or threaten to contaminate surface water. Except as authorized through "404 permit", same standards apply to solid waste.
pH	Range of 6.5-9.0
Dissolved oxygen	Range from 3.0 to 9.5 mg/l depending on number of measurements incorporated in calculation of average and life-history needs of aquatic organisms present.
Turbidity	Substance discharge attributable to or influenced by human activities shall not results in a turbidity increase of more than 10 nephelometric turbidity units.
Temperature	Effluents attributable to or influenced by human activities shall not be discharged in amounts which change natural water temperatures to levels deemed harmful to existing aquatic life.
Fecal coliform bacteria	Fecal coliform concentration based on a minimum of five samples during any 30-day period must not exceed a geometric mean of 200 groups per 100 ml, nor may more than 10 percent of total samples exceed 400 groups per 100 ml.
Total dissolved gases	Less than 110 percent of saturation value for gases at the existing atmospheric and hydrostatic pressures for locations below man-made dams
Salinity	No standards except for Colorado River Drainage.

Appendix 2. Selected surface water-quality standards for State of Montana waters classified as B-1 based on Title 16, Chapter 20, Sub-chapter 6 and last revised in 1993.

ITEM	SPECIFICATION
Toxic or deleterious materials	May not exceed maximum contaminant levels specified in U.S. Environmental Protection Agency National Primary Drinking Water Regulations or the U.S. Environmental Protection Agency National Secondary Drinking Water Regulations. Also may not exceed "Gold Book levels".
Sediments, settleable solids, oils, or floating solids	None above naturally occurring concentrations which will or are likely to create a nuisance to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.
Color	No increase in true color of more than five units above naturally occurring color.
pH	Induced variation within the range of 6.5-9.0 must be less than 0.5 pH units. Natural pH outside this range must be maintained without change.
Dissolved oxygen	Not less than 7.0 mg/1 from October 1 through June 1 nor below 6.0 mg/l from June 2 through September 30.
Turbidity	Naturally allowable increase above naturally occurring turbidity is 10 nephelometric turbidity units. Limited exceptions permitted for short-term construction and hydraulic projects.
Temperature	A 1°F maximum increase above naturally occurring temperatures allowed within the range of 32°F to 66°E Within naturally occur-ring range of 66°F to 66.5°F, no discharge is allowed that causes the temperature to exceed 67°F. Where the naturally occurring water temperature is 66.5 °F or greater, the maximum allowable increase in water temperature is 0.5°F. A 2°F-per-hour maximum decrease below naturally occurring water temperature is allowed when the water temperature is above 55°F, and a 2°F maximum decrease below naturally occurring water temperature is allowed within the range of 55°F to 32°F.
Fecal coliform bacteria	Based on a minimum of five samples obtained during separate 24-hour periods during any consecutive 30-day period, must not exceed a geometric mean of 200 groups per 100 ml, nor may more than 10 percent of total samples exceed 400 groups per 100 ml.