COVER SHEET

Title: Salt Lake City Area Integrated Projects Electric Power Marketing Final Environmental Impact Statement, DOE/EIS-0150

Cooperating Agencies: U.S. Fish and Wildlife Service, the National Park Service, and the Bureau of Reclamation

Lead Agency: Western Area Power Administration, U.S. Department of Energy

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ABSTRACT

The Colorado River Storage Project Customer Service Office of the Western Area Power Administration (Western) markets electricity produced at hydroelectric facilities operated by the Bureau of Reclamation. The facilities are known collectively as the Salt Lake City Area Integrated Projects (SLCA/IP) and include dams equipped for power generation on the Colorado, Green, Gunnison, and Rio Grande rivers and on Plateau Creek in Arizona, Colorado, Utah, Wyoming, and New Mexico. Of these facilities, only the Glen Canyon Unit, the Flaming Gorge Unit, and the Aspinall Unit (which includes Blue Mesa, Morrow Point, and Crystal dams) are influenced by Western power scheduling and transmission decisions. The environmental impact statement (EIS) alternatives, called commitment-level alternatives, reflect combinations of capacity and energy that would feasibly and reasonably fulfill Western's firm power marketing responsibilities, needs, and statutory obligations. The viability of these alternatives relates directly to the combination of generation capability of the SLCA/IP with energy purchases and interchange. The economic and natural resource assessments in this EIS include an analysis of commitment-level alternatives. Impacts of the no-action alternative are also assessed. Supply options, which include combinations of electrical power purchases and hydropower operational scenarios reflecting different operations of the dams, are also assessed. The EIS evaluates the impacts of these scenarios relative to socioeconomics, air resources, water resources, ecological resources, cultural resources, land use, recreation, and visual resources. Western has identified commitment-level alternative 1, the Post-1989 commitment level, as its preferred alternative. The impact evaluations indicate that this commitment level is also the environmentally preferred alternative.

1 INTRODUCTION

1.1 NEED FOR AGENCY ACTION

The Western Area Power Administration (Western) needs to determine the level of long-term firm capacity and energy commitment from the Salt Lake City Area Integrated Projects (SLCA/IP) that Western will make available to its customers and that will form the basis for its SLCA/IP power marketing program.

1.2 PURPOSE OF AGENCY ACTION

The alternative commitment level selected by Western must be consistent with its statutory obligations and legal constraints. This necessity requires a weighing of economic, environmental, and other public considerations. Western's action will have to achieve a balanced mix of purposes as follows:

- Provide the greatest practicable amount of long-term firm capacity and energy.
- Provide for the meeting of firming requirements as practicable by purchases of capacity and energy.
- Provide long-term resource and contractual stability.
- Provide the greatest practical value of the power resource.
- Result in the lowest practicable associated adverse environmental impacts.
- Be responsive and adaptable to likely future operations of SLCA/IP facilities.
- Be responsive to decisions from the Bureau of Reclamation's (Reclamation's) Glen Canyon Dam Environmental Impact Statement (EIS) (Reclamation 1995) and the Energy Planning and Management Program (EPAMP) EIS (Western 1995).

1.3 DESCRIPTION OF THE PROPOSED ACTION

to sell and deliver capacity and energy generated by hydroelectric power plants built as part of certain Federal water projects. The SLCA/IP power plants include facilities in the states of Wyoming, Utah, Colorado, Arizona, and New Mexico. The facilities are located on the Colorado River and its tributaries and on the Rio Grande and its tributaries (Figure 1.1).

Power generated by the SLCA/IP facilities or purchased by Western from other sources is provided to Western's customers under contracts that establish the terms for how capacity (generation capacity) and energy (quantity of electrical energy) are to be sold. The contracts also specify amounts of capacity and energy that Western agrees to offer for long-term sale (greater than 12 months) to its customers. These amounts constitute Western's "commitment levels." The capacity and energy level is called "firm" when its availability is guaranteed to the customer.

Currently, Western's sale commitments from the SLCA/IP, including capacity and energy purchased from other sources, total approximately 1,300 megawatts (MW)[1] of long-term firm capacity and 5,700 gigawatt-hours (GWh)[2] of long-term firm energy. This commitment level was established in 1978 (1978 marketing program) for the period to 1989. As part of the development of its power marketing program for the period 1989 to 2004 (the Post-1989 marketing program), Western proposed to increase these commitment levels to 1,449 MW of capacity and 6,156 GWh of energy.

This EIS has been prepared in accordance with Section 102(2)C of the National Environmental Policy Act of 1969 (NEPA), as implemented in regulations promulgated by the Council on Environmental Quality (CEQ) (40 Code of Federal Regulations [CFR] Parts 1500-1508) and DOE NEPA implementing regulations (10 CFR Part 1021).

1.4 WESTERN RESPONSIBILITIES AND MISSION

The Western Area Power Administration was established within the DOE pursuant to the Department of Energy Organization Act of 1977 (42 U.S. Code [USC] §§ 7101 *et seq.*) (DOE Act). This legislation provided for the transfer of Federal power marketing and power transmission functions from the Secretary of the Interior through the Bureau of Reclamation to the Secretary of Energy, acting through Western's Administrator. Western performs these functions in 15 western states: Arizona, California, Colorado, Iowa, Kansas, Minnesota, Montana, Nebraska, Nevada, New Mexico, North Dakota, South Dakota, Texas, Utah, and Wyoming. Western conducts its functions in conformance with certain laws, primarily the DOE Act, Section 5 of the Flood Control Act of 1944 (16 USC § 825s), Section 9(c) of the Reclamation Project Act of 1939 [43 USC § 485h(c)], and, in this case, the Colorado River Storage Project (CRSP) Act (43 USC §§ 620-620o). While Western took over the power marketing activities, Reclamation retained irrigation, water supply, and dam-operation functions at Federal water projects constructed by Reclamation.

FIGURE 1.1

Western's Colorado River Storage Project Customer Service Office (CRSP-CSO) markets power from the CRSP and the Collbran, Rio Grande, and Provo River Projects. The CRSP power plants are those authorized by the Colorado River Storage Project Act; specifically included are power plants at Glen Canyon Dam (the Glen Canyon Unit) on the Colorado River just below the Utah-Arizona border; at Flaming Gorge Dam (the Flaming Gorge Unit) on the Green River just below the Wyoming-Utah border; at Fontenelle Dam on the Green River; and at the Blue Mesa, Morrow Point, and Crystal dams (Aspinall Unit) on the Gunnison River in Colorado (Figure 1.1). On October 1, 1987, the CRSP hydropower facilities, the Collbran Project (Upper and Lower Molina dams), and the Rio Grande Project (Elephant Butte Dam) were integrated as the SLCA/IP for marketing and rate-making purposes. The Provo River Project has been operationally integrated in the CRSP since 1963. The hydroelectric facilities of the SLCA/IP are operated by Reclamation. Within the limits on dam operations set by Reclamation, Western coordinates water releases with Reclamation for hydropower generation and markets the capacity and energy so produced.

Western's power marketing responsibility begins at the switchyard of Federal hydroelectric power facilities and includes the Federal transmission system to interconnected utility systems. In marketing power in excess of project-use needs, Western sells both long-term and short-term firm power. This power is first offered for sale to what are known as "preference customers." This designation originates from the Reclamation Project Act of 1939, which requires Western to give preference in the sale of Federal power to municipalities, nonprofit corporations or agencies, cooperatives, and other nonprofit organizations financed under the Rural Electrification Act of 1936 (17 USC - 901 *et seq*.).

Western sells power to nonpreference customers, such as investor-owned utilities, only if the available supply exceeds the demands of interested and eligible preference customers, or if so required by unique legislation. The Reclamation Project Act of 1939 permitted revenues from the sale of electricity generated at the Federal facilities to be used to repay the appropriate share of the costs incurred in developing the hydroelectric facilities and some of the investment in irrigation. About 90% of all revenues received from these projects are from power sales.

1.5 RECENT HISTORY OF MARKETING CRITERIA DEVELOPMENT

The SLCA/IP power marketing criteria specify terms and conditions for the long-term firm capacity and energy sales contracts. In 1980, Western began examining its marketing criteria for long-term capacity and energy from the SLCA/IP because the existing long-term firm contracts were to expire in 1989. Through this process, Western developed the proposed "Post-1989 Criteria." Western prepared an environmental assessment (EA) for implementation of the Post-1989 Criteria, and on January 8, 1986, a Finding of No Significant Impact (FONSI) was approved by DOE. On December 20, 1988, the National Wildlife Federation (NWF) and others filed suit against Western regarding the adequacy of Western's 1986 EA and FONSI (*National Wildlife Federation, et al. vs. Western Area Power Administration, et al.*, Docket No. 88-C-1175-J, U.S. District Court, Central District of Utah).

Western developed their Post-1989 Criteria to supersede the existing "General Power Marketing Criteria" for the CRSP (1978 Criteria) and those governing sales of Collbran and Rio Grande resources. The Post-1989 Criteria included the terms by which Western would allocate long-term firm capacity and energy from the SLCA/IP during the period October 1, 1989, through September 30, 2004. Western determined that it would prepare an EIS on the Post-1989 Criteria to end the litigation and to respond to public concerns about the operation of Glen Canyon Dam. On September 29, 1989, the court entered an order allowing Western to implement the Post-1989 contracts, providing that the aggregate commitment level of firm capacity and energy would remain essentially the same as the 1978 levels until Western had completed an EIS. The court was concerned that an increase in commitment, which was a principal feature of the Post-1989 Criteria, might result in changed operation of the SLCA/IP power plants and changes in downstream environmental impacts. Thus, while the court's September 29, 1989, order permitted the Post-1989 contracts to become effective, neither the Post-1989 commitment level nor any alternative commitment level could be implemented until Western completed an EIS. Accordingly, current levels of commitment are based on 1978 levels with minor adjustments established by Western and the court. This EIS is intended to meet the requirement of the court order for an EIS that includes an assessment of downstream impacts of power generation at SLCA/IP facilities.

1.6 RELATIONSHIP OF THIS EIS TO OTHER ACTIONS

In determining the scope of this EIS, Western has taken into consideration other environmental assessments, environmental impact statements, and environmental surveys or studies related to the SLCA/IP prepared by Western and other Federal agencies. Western has integrated, to the fullest extent possible, these other assessments, EISs, analyses, and studies into this Electric Power Marketing EIS. These other instruments and programs include the Energy Planning and Management Program (EPAMP) EIS (Western 1995), the Glen Canyon Dam EIS (Reclamation 1995), the Recovery Implementation Program for Endangered Species in the Upper Colorado River Basin applicable to Flaming Gorge Dam and the Aspinall Unit, and the NEPA compliance document for the Gunnison River contract.

1.6.1 EPAMP EIS

Western prepared an EIS (Western 1995) on its proposed EPAMP which will replace its current conservation and renewable energy program with a two-part program that will determine the percentage of long-term allocations of Western's hydroelectric resources to be extended to its customers at the end of their existing contract terms (called the "power marketing initiative") and require preparation of long-term integrated energy resource management plans (called the Integrated Resource Plan [IRP] provision) by Western's long-term firm power customers. Western will evaluate the application of the power marketing initiative to the SLCA/IP after this Electric Power Marketing EIS is completed, and will prepare any additional required NEPA documentation before implementing the power marketing initiative. In the EPAMP EIS, Western determined that the implementation of the IRP program would have no adverse environmental consequences and more environmental benefits than the current conservation and renewable energy program. The EPAMP EIS provides sufficient NEPA documentation to apply the IRP provision to all of Western's long term firm power customers.

1.6.2 Glen Canyon Dam EIS

Reclamation has prepared the Operation of Glen Canyon Dam EIS (Glen Canyon EIS) (Reclamation 1995) to examine the impacts of current operations on downstream resources and the specific operational options for Glen Canyon Dam that could be implemented to minimize (consistent with law) adverse impacts on the downstream environment, cultural resources, and Native American interests in Glen and Grand canyons. Western, a cooperating agency in preparation of that document, has not repeated the analysis performed in the Glen Canyon EIS for this Electric Power Marketing EIS but has instead incorporated appropriate analyses and conclusions of that EIS into this document.

1.6.3 Biological Opinion on Operation of the Glen Canyon Dam

Concurrent with preparing the Glen Canyon EIS, Reclamation consulted with the U.S. Fish and Wildlife Service (USFWS) on the effects of operation of Glen Canyon Dam on endangered species. This process, conducted pursuant to the Endangered Species Act of 1973 (15 USC 1531 et seq.), led to the publication of a final Biological Opinion on Glen Canyon Dam operations (USFWS 1994a). This Biological Opinion was considered by Reclamation in preparing the Glen Canyon EIS (Reclamation 1995).

In their Biological Opinion, the USFWS determined that the modified low fluctuating flow alternative for Glen Canyon Dam (the preferred alternative in the Glen Dam EIS) would be likely to jeopardize the continued existence of the humpback chub and razorback sucker and would be likely to destroy or adversely modify designated critical habitat (USFWS 1994a). The USFWS, however, determined that this alternative was not likely to jeopardize the continued existence of the bald eagle, Kanab ambersnail, or peregrine falcon. The Biological Opinion supported maintenance of biological diversity associated with the historic hydrograph and the dependent ecosystem components including other native fishes.

The reasonable and prudent alternative to be implemented by Reclamation that was presented in the Biological Opinion included (1) examination of the effects of high steady flows in the spring and low steady flows in the summer and fall in low water years, and operations according to the modified low fluctuating flow alternative in moderate and high release years; (2) evaluation of the effects of a selective withdrawal structure; (3) deter-mination of the response of native fishes to various temperature and flow regimes; (4) protection of the humpback chub spawning population and habitat in the Little Colorado River; (5) development of recommendations that would help ensure the continued existence of the razorback sucker; and (6) development of a program to establish a second spawning aggregation of humpback chub downstream of Glen Canyon Dam.

1.6.4 Biological Opinion on Operation of the Flaming Gorge Dam

On February 27, 1980, the USFWS requested consultation with Reclamation regarding projects under construction and regarding the continued operation of all existing Reclamation projects in the Upper Colorado River Basin (USFWS 1992b). Reclamation agreed with the request, and formal consultations on the operation of Flaming Gorge Dam were initiated on March 27, 1980. Western became a party to this consultation on August 9, 1991, with Reclamation remaining the lead agency. Coincident with its request to Reclamation, the USFWS issued a Biological Opinion on February 27, 1980, for the Strawberry Aqueduct and Collection System (Strawberry System). The Strawberry System Biological Opinion determined that depletions from the Duchesne and Green rivers would likely jeopardize the continued existence of the Colorado squawfish and the humpback chub. The reasonable and prudent alternative for the Strawberry System was that the Flaming Gorge Dam and reservoir would compensate for those depletions and would be operated for the benefit of the endangered fish.

Jeopardy opinions were also issued in the late 1970s and early 1980s for the Upalco, Jensen, and Uinta projects of the Central Utah Project, and the reasonable and prudent alternative for each of these projects was again the operation of Flaming Gorge Dam to provide flows for endangered fish (USFWS 1992b). Biological opinions for the Narrows Project (March 25, 1992) and the Price-San Rafael Salinity Control Project (February 4, 1992) are also linked to the Flaming Gorge Biological Opinion. Because of the absence of sufficient data, the Biological Opinion for the operation of Flaming Gorge Dam was delayed until studies were completed and sufficient scientific data were collected to recommend specific flows. Flows within the operational criteria of the dam were evaluated from 1979 to 1984, while a number of summer flow regimes were evaluated from 1985 to 1991.

The Final Biological Opinion for operation of Flaming Gorge Dam was issued by the USFWS on November 25, 1992 (USFWS 1992b), and dam operations have been constrained to comply with the reasonable and prudent alternative identified in that opinion. The Biological Opinion issued by the USFWS is consistent with the provisions of the Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin. The purpose of the program is to recover the endangered fish while allowing water development to proceed in the Upper Colorado River Basin consistent with the Endangered Species Act (USFWS 1992b). The program identifies refining the operation of Flaming Gorge Dam as one of the principal habitat management strategies for recovering endangered fish in the Green River. The operations stipulated by the Biological Opinion are reflected in the three seasonally adjusted operational scenarios for Flaming Gorge Dam that are being analyzed in this EIS.

1.6.5 Gunnison River NEPA Documentation

Reclamation, the National Park Service (NPS), the Bureau of Land Management (BLM), and the Colorado Water Conservation Board are initiating formal studies to provide a long-term water supply from the Aspinall Unit to the Black Canyon of the Gunnison National Monument through a water-delivery contract. Being considered is release of water stored in Blue Mesa Reservoir to the Monument in a manner that more closely resembles "natural hydrology." The proposed change would result in higher springtime water releases from the reservoir. Reclamation, NPS, and BLM have announced their intent to prepare an EIS on the proposed water-delivery contract (57 Fed. Reg. 19,437, May 6, 1992). Reclamation recently announced that it may not need to prepare an EIS, but may prepare another NEPA document. That document will examine the environmental impacts of executing this contract. The analyses and results of the Gunnison River NEPA evaluation will not be available for incorporation into this Electric Power Marketing EIS.

Before Gunnison River NEPA documentation is completed, the seasonal pattern recommended by the USFWS for study of endangered fish in the Gunnison River (Harris 1992) and the draft contract to deliver water to the Black Canyon of the Gunnison National Monument would be used to determine releases from the Aspinall Unit. These research flows would be in place until 1997 and thus would be relevant to the interim period between issuance of the ROD for this Electric Power Marketing EIS and the Gunnison River NEPA documentation. These research flows form the basis of the seasonally adjusted release patterns of the hydropower operational scenarios for the Aspinall Unit evaluated in this EIS.

1.6.6 Biological Opinion on Operation of the Aspinall Unit

The Recovery Implementation Program for Endangered Species in the Upper Colorado River Basin includes a number of recovery activities in the Gunnison River, including a five-year research plan that was initiated in 1992 to evaluate the effects of the operation of the Aspinall Unit on endangered fish and their habitats. Following completion of that research, the USFWS will issue a Biological Opinion on operations at the Aspinall Unit. Upon receipt of the Biological Opinion, Reclamation will take necessary actions to incorporate the results into Aspinall Unit operations. The USFWS may also prepare a Biological Opinion on the proposed water contract for the Black Canyon of the Gunnison National Monument or may combine the two Biological Opinions on the Aspinall Unit.

Although certain constraints may be imposed on the operation of the Aspinall Unit once the proposed water contract is in place or the Biological Opinion is issued, Western cannot at this time anticipate the levels of capacity and energy that may result. Western will participate with Reclamation in the Gunnison River EIS concerning an analysis of power impacts and in any other NEPA process necessary in conjunction with the Biological Opinion. The operation of Crystal is constrained by operational limits set by Reclamation. Crystal Dam is a reregulation dam, which steadies the hourly fluctuations of the upstream power plants. Crystal's operation is not influenced by Western's power sales. Because of this situation and the environmental activities listed herein, environmental impacts below Crystal Dam (the farthest downstream facility in the Aspinall Unit) are not evaluated in this Electric Power Marketing EIS. However, a probable level of capacity and energy available from the Aspinall Unit is included in the evaluation.

1.7 PUBLIC INVOLVEMENT

Public involvement for this EIS began with the publication of a Federal Register notice in April 1990 (Western 1990). That notice announced Western s intent to prepare an EIS. Western held seven scoping meetings in Arizona, Utah, Colorado, and New Mexico and received more than 21,000 written comments during the formal scoping period. In response to this significant public response, Western developed a newsletter and mailing list to keep the public informed about the EIS process and the need for review and comment.

After receiving comments from the public, Western developed a scoping report to assist it in characterizing and understanding the scoping comments. From this report, Western developed a statement of scope. At this same time, Western developed the purpose and need statement for this EIS. Western described both the statement of scope and the purpose and need in a public newsletter requesting review and comment. Subsequent to this, Western developed draft commitment-level alternatives and hydropower operational scenarios for the three facilities under consideration. These alternatives and operational scenarios were submitted to the public for review and comment. On the basis of the comments received, Western published final alternatives and operational scenarios in advance of the draft EIS.

The draft EIS was made available to the public for review on March 28, 1994, with publication of a Notice of Availability in the Federal Register (Western 1994a) and the mailing of the draft EIS to about 360 individuals or organizations. At the same time, the project newsletter *EIS Update* (Western 1994b) announcing both the availability of the draft EIS and the schedule for public informational hearings was sent to approximately 2,100 individuals. An additional 30 copies of the draft EIS were mailed to individuals at their request. The draft EIS and all supporting documents were made available for public review in reading rooms in Flagstaff, Page, and Phoenix, Arizona; Denver, Loveland, and Montrose, Colorado; Albuquerque, New Mexico; Salt Lake City and Vernal, Utah; and in Washington, D.C. The locations of these reading rooms were identified in the Notice of Availability.

Comments on the draft EIS were received from the public either in written, mailed-in form or at public hearings held in April 1994 in Denver, Salt Lake City, Flagstaff, and Phoenix. The public comment period closed on June 30, 1994. During that period, a total of 41 comment documents were received (including hearing transcripts); 444 individual comments were categorized from these documents. Comments on the draft EIS and the corresponding responses are presented in Appendix E.

In addition to the above public involvement, Western visited directly with coordinating agencies, cooperating agencies, environmental groups, and customer groups before finalizing the statement of scope, the commitment-level alternatives, and the hydropower operational scenarios. The cooperating agencies for this EIS are the Bureau of Reclamation, the National Park Service, and the U.S. Fish and Wildlife Service. The coordinating agencies are the states of Utah, Wyoming, New Mexico, Colorado, and Arizona.

1.8 CONTENT OF THIS EIS

Chapter 1 of this EIS defines the proposed action and describes the purpose and need for the action. Chapter 2 describes the commitment-level alternatives and briefly explains how those alternatives were selected. Also included in Chapter 2 is a description of the hydropower operational scenarios that provide marketable power from each of the SLCA/IP facilities. Since commitments also include power purchases and exchanges, such purchases and exchanges are also discussed in order to describe the relationship between power marketing and hydropower operational scenarios. Chapter 2 also compares the impacts of the various alternative commitment levels, including effects of hydropower operations.

Chapter 3 describes the affected environment of the SLCA/IP and the regional environment that may be affected by power marketing and hydropower generation. The descriptions include socioeconomic factors; air, water, ecological, and cultural resources; land use patterns; recreational features; and visual resources.

Environmental consequences of the commitment-level alternatives are analyzed in Chapter 4, Section 4.1. Section 4.2 evaluates the consequences of the various hydropower operational scenarios for the Glen Canyon and Flaming Gorge dams and the Aspinall Unit. Section 4.3 summarizes the projected impacts of the commitment-level alternatives and hydropower operational scenarios, and Section 4.4 outlines possible mitigation and monitoring measures.

Chapter 5 describes the cumulative impacts of commitment-level alternatives and hydropower operational scenarios. Chapter 6 describes unavoidable adverse impacts, and Chapter 7 describes irreversible and irretrievable commitments of resources. Relationships between short-term uses and long-term productivity are identified in Chapter 8. Environmental statutes, regulations, executive orders, and permit requirements are listed in Chapter 9, and consultation and coordination activities are described in Chapter 10. This EIS also contains a list of references (Chapter 11), a list of preparers (Chapter 12), a list of acronyms (Chapter 13), a glossary (Chapter 14), an index (Chapter 15), and a list of recipients (Chapter 16). Supporting data for several resources are presented in Appendixes A-D; public comments on the draft EIS and Western responses are provided in Appendix E.

[1] One megawatt equals 1,000,000 watts.

[2] One gigawatt-hour equals 1,000,000,000 watt-hours.

2 ALTERNATIVES, INCLUDING NO ACTION

Chapter 2 identifies and compares Western's power marketing commitment-level alternatives, including the no-action alternative, and describes the hydropower operational scenarios evaluated in this EIS for Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit. The bases for selecting the commitment-level alternatives are discussed in Section 2.2.1, and the alternatives selected are described in Section 2.2.2. The potential environmental impacts of these alternatives are summarized in a comparative format in Section 2.2.3.

The hydropower operational scenarios are addressed in Section 2.2. Section 2.2.1 describes the relationships between commitment-level alternatives and the operation of hydropower facilities. Section 2.2.2 discusses hydropower operations, purchases, and exchanges; Section 2.2.3 describes the hydropower operational scenarios selected for analysis for each facility. The impacts of these scenarios are compared in Section 2.2.4.

2.1 COMMITMENT-LEVEL ALTERNATIVES

Western needs to establish the level of its commitment for sales of long-term firm electrical capacity and energy generated by the SLCA/IP. As indicated in Chapter 1, these commitments are included in contracts establishing the terms for how capacity and energy are to be sold by Western.

Capacity is equivalent to the instantaneous output of a generator, usually stated in units of megawatts (MW)[1] or kilowatts (kW).[2] Generators are rated for their maximum capacity under specific conditions; this capacity is usually referred to as "nameplate generating capacity." Energy is the amount of power generated over a period of time and is stated in megawatt-hours (MWh)[3] or gigawatt-hours (GWh).[4] A level of commitment for sales specifies amounts of long-term firm capacity and energy.

The commitment-level alternatives, including the no-action alternative, evaluated in this EIS are defined on the basis of a specified level of both capacity and energy. This level of capacity and energy comes from two sources: hydroelectric power generated by SLCA/IP facilities and purchases from other sources. Western may purchase capacity and energy from any entity offering them for sale. The commitment-level alternatives cover a broad range of capacity and energy levels that Western could make available to its customers. The following section describes how these possible commitment levels were selected for evaluation in this EIS.

2.1.1 Selection of Commitment-Level Alternatives

The selection of commitment-level alternatives was based on the combinations of capacity and energy that would feasibly and reasonably fulfill Western's firm power marketing responsibilities and statutory obligations. The generation capability of the SLCA/IP is only one part of the basis for determining the amount of power available for long-term firm contracts. The other part consists of energy purchases and interchanges. Interchanges are agreements that Western has with other utilities to trade generation resources from different locales to increase total system efficiency or avoid transmission limits that would occur without such agreements. Purchases and interchange are key elements in Western's power marketing activities. Without purchases and interchange, Western might have to reduce its long-term firm commitments to about one-third of historical levels. Western would have to market on the basis of highly variable hydrological conditions and could not make long-term firm commitments to power deliveries in excess of that available under worst possible, highly improbable, drought conditions. In fact, it would be impractical for Western to make any long-term firm commitments that maximize the value of the hydropower resource without purchase flexibility.

The amount of SLCA/IP capacity and energy available for Western to market is determined after other needs are met, including the dam and power plant operators' station service requirements and dedicated uses for Bureau of Reclamation projects such as irrigation, maintenance requirements, and Western's reserves and system losses. The amount of marketable capacity and energy that can be generated by SLCA/IP power plants varies from year to year, depending on hydrological conditions (e.g., water flows), reservoir storage requirements, and downstream flow requirements.

Variations in hydrological conditions and other factors result in a risk that the SLCA/IP power plants would not be able to generate sufficient capacity and energy to meet Western's long-term firm commitments. For this reason, the amount of marketable long-term firm capacity and energy committed under each alternative is directly related to the level of risk Western assumes on behalf of its customers over the life of the contract. The risk Western assumes is essentially one of not having sufficient hydroelectric generation to meet contract commitments. However, Western's extensive transmission system allows it to make purchases over a wide region, and contracts ensure that purchase costs will be paid by the customers.

The amount of SLCA/IP capacity and energy that Western offers as long-term firm commitments is influenced by such factors as (1) the amount of installed hydroelectric capacity in the system; (2) restrictions on minimum and maximum water releases by each facility; (3) limitations on operations to protect or enhance natural, cultural, and recreational resources; (4) anticipated water conditions and water depletions; (5) resultant reservoir operations; (6) the amount of power needed by facility operators, such as Reclamation; (7) dedicated project uses; and (8) the electrical energy market and the availability of regional electrical resources. Because many of these factors are uncertain and highly variable over time, Western, with assistance from Reclamation, forecasts probable future conditions for a given period and sets its level of long-term firm capacity and energy commitments according to these predictions and sound business principles. These forecasts include both upper and lower limits of capacity and energy.

Limits to Power Production: As a starting point to establish the boundaries of reasonable levels of projected power considered in this EIS, Western assumed that the maximum installed capacity for the SLCA/IP would be approximately 1,800 MW. Installed capacity might change over the life of hydropower facilities because unit modifications can be made as technology advances. Installed capacity is greater than marketable capacity because water is available to operate at the maximum limit (installed capacity) only for limited periods.

Prior to 1977, before Western was established as a power marketing agency, Reclamation had based its long-term firm power commitments on a conservative adverse risk assumption; that is, the minimum level of power that could be expected to be available in some future period, even in the poorest water years. Western continued this practice until the development of the Post-1989 Criteria, when Western modified this historical risk assumption by considering a "10% risk" assumption as reasonable. This means that in approximately 1 year out of 10, the water levels behind the system dams would not be sufficient to produce the capacity needed to support the Post-1989 commitment level. This 10% risk approach was applied to a projection of future available power for the SLCA/IP for the period 1989 through 1999. That projection was based on an assumption of maximum flexibility in daily releases. In other words, within the minimum and maximum flows set by Reclamation (the dam operator) before 1989, no restriction would be set on daily fluctuations at each hydropower facility. This assumption of 10% risk coupled with full operational flexibility resulted in the *upper boundary* of marketable firm capacity of 1,450 MW.

To determine a *lower limit* of power operations, Western considered restricted release rates potentially affecting the Glen Canyon Dam, the principal hydropower resource of the SLCA/IP. Future additional constraints that may be placed on operations at the Flaming Gorge and Aspinall Unit facilities were also considered. Under assumptions of (1) future constant (nonfluctuating) releases at all SLCA/IP facilities and (2) continued worst-year water conditions for future years, the maximum level of marketable capacity after all adjustments would be approximately 550 MW. This value was identified as the assumed lower boundary of marketable firm capacity for the purpose of selecting commitment-level alternatives. This level provides minimum flexibility and essentially no risk.

Limits to Energy Production: Before 1977, Reclamation based long-term firm energy commitments on annual average energy generated by its facilities. To identify the *upper boundary* of long-term firm energy commitments for selection of alternatives for this EIS, Western assumed a 54% risk (average energy plus 400 GWh). This level of risk would equate to about 6,200 GWh annually (adjusted for losses and project uses), which corresponds to the limit on available transmission system capacity. For the *lower boundary*, assumptions of no risk and no purchases would result in a minimum energy commitment of approximately 3,300 GWh for the worst hydrologic year.

Figure 2.1 schematically illustrates the upper and lower boundaries of capacity and energy. The left side of the diagram indicates the lower, no risk, low flexibility boundary of marketable firm capacity (550 MW). The right side of the diagram is the upper, 10% risk, high flexibility boundary of marketable firm capacity (1,450 MW). The bottom of the diagram is the lower boundary of marketable firm energy (3,300 GWh), and the top is the upper boundary of marketable firm energy (6,200 GWh). Any point within the diagram represents a combination of marketable long-term firm capacity and long-term firm energy. Western could choose to market any combination of capacity and energy within the diagram.

Figure 2.1 also explains the desirability of the different commitment-level alternatives to Western's customers. The ratio of energy to capacity is called the load factor. The higher the amount of energy per unit of capacity, the higher is the load factor. Each of the diagonal lines in Figure 2.1 represents combinations of capacity and energy that yield the same load factor. Moving from the lower right corner to the upper left corner of the diagram, the load factor increases from 25% to 100%. When the load factor is low, the customer has more flexibility regarding when it takes delivery of the amount of energy it has committed to purchase. Thus, with a low load factor, energy can be used just to serve the additional load that arises during peak demand periods. In addition, the customer has more flexibility over the decision of whether to substitute less expensive energy for energy that could be produced by more expensive technologies. As the load factor increases, the customer must take energy on a more regular basis to ensure it takes the total amount of energy that it has committed to purchase (and Western has committed to deliver). Because the customer has less control over when it takes delivery of this energy, the usefulness of the energy declines. In this case, a customer may find itself in the position of having to purchase energy from Western in periods (e.g., off-peak) when that energy really is not needed or economical.

FIGURE 2.1

The area within Figure 2.1 defines all reasonable amounts of marketable firm commitments for capacity and energy. Points within this diagram represent combinations of either high or low capacity with either high or low energy. (These points represent alternatives, which are described below.) The values at the four corners of this diagram were selected as commitment-level alternatives. These values represent the reasonable bounds of capacity and energy given current resources. Alternatives 1, 2, 4, and 5 represent high capacity and high energy, high capacity and low energy, low capacity and low energy, and low capacity and high energy, respectively. Two moderate capacity and moderate energy alternatives (3 and 6) are also shown in Figure 2.1 These six alternatives (commitment levels 1-6) and the no-action alternative (the 1978 commitment level) have been carried forward for analysis in this EIS.

A *minimum schedule requirement* is also a component of each alternative. The minimum schedule requirement is the minimum quantity of capacity that a contract customer must accept on an hourly basis. This is an important component of each alternative and changes with each combination of capacity and energy. A high minimum schedule requirement (e.g., 35%) would negate the flexibility of the low load factor alternatives by requiring that so much energy be used around the clock that very little energy is left to schedule when it is needed. Therefore, alternatives with low load factors also have low minimum schedule requirements.

2.1.2 Description of Commitment-Level Alternatives

This section describes the commitment-level alternatives assessed in this EIS, including the no-action alternative. The features of these alternatives are summarized in Table 2.1.

TABLE 2.1 Electric Power Marketing EIS Commitment-Level Alternatives

Alternative	Capacity Commitment (MW)	Energy Commitment (GWh)	Load Factor (%)	Minimum Schedule Requirement (%)	Description
No action	1,291	5,700	50	35	Moderate capacity and high energy (the 1978 marketing program commitment level)
1 (preferred alternative)	1,449	6,156	48.5a	35	High capacity and high energy (the Post-1989 commitment level)
2	1,450	3,300	26	10	High capacity and low energy
3	1,225	4,000	37	15	Moderate capacity and moderate energy
4	550	3,300	68	52	Low capacity and low energy
5	625	5,475	100	100	Low capacity and high energy
6	1,000	4,750	54	33	Moderate capacity and moderate energy

[a] This load factor differs slightly from that published in the Post-1989 Marketing Criteria (50.2%) because of a difference between calculating this number annually versus seasonally.

2.1.2.1 No-Action Commitment-Level Alternative: the 1978 Commitment Level

If Western were to take no action to change the level of its long-term firm capacity and energy sales, commitments would remain at the 1978 power marketing program levels for the CRSP, Collbran, and Rio Grande projects. The 1978 program contains commitments for 1,291 MW of long-term firm capacity and 5,700 GWh of long-term firm energy (Figure 2.1). This alternative has a load factor of 50% and a minimum schedule requirement of 35%.[5]

2.1.2.2 Commitment-Level Alternative 1: the Post-1989 Commitment Level (Preferred Alternative)

Commitment-level alternative 1, or the Post-1989 commitment level, is associated with the proposed 1989 marketing plan and is the preferred alternative. This commitment level is for 1,449 MW of long-term firm capacity and 6,156 GWh of long-term firm energy. The energy offered under this alternative represents the highest energy commitment among all alternatives (about 8% higher than the no-action alternative). This commitment level has a load factor of nearly 50%. In addition, it imposes a minimum schedule requirement of 35% on long-term firm customers.

2.1.2.3 Commitment-Level Alternative 2: High Capacity-Low Energy

Commitment-level alternative 2 is a commitment to a high level of long-term firm capacity (1,450 MW) but a low level of long-term firm energy (3,300 GWh). This commitment level has the lowest load factor (26%) and lowest minimum schedule requirement (10%) of all the alternatives. This type of commitment would enable customers to take the highest percentage of their commitment during the on-peak hours, when power is most valuable. Although customers would gain value by purchasing a low load-factor resource, the value of this alternative would be diminished by the low energy commitment.

2.1.2.4 Commitment-Level Alternatives 3 and 6: Moderate Capacity-Moderate Energy

Commitment-level alternative 3 is a commitment to a moderate level of long-term firm capacity (1,225 MW) and a moderate level of long-term firm energy (4,000 GWh), as shown in Figure 2.1. This commitment results in a load factor of 37% and a minimum schedule requirement of 15%, the second lowest load factor and minimum schedule requirement of all the alternatives.

Commitment-level alternative 6 also is a commitment to a moderate level of long-term firm capacity (1,000 MW) and a moderate level of long-term firm energy (4,750 GWh). This alternative represents the midpoint of the ranges of capacity and energy, as illustrated in Figure 2.1. This commitment level has a load factor of 54%, which is mid-range between a high-load and a low-load resource, and a minimum schedule requirement of 33%.

2.1.2.5 Commitment-Level Alternative 4: Low Capacity-Low Energy

Commitment-level alternative 4 is the lowest commitment for long-term firm capacity (550 MW) and long-term firm energy (3,300 MWh), as shown in Figure 2.1. It is based on an assumption of continued adverse water conditions. This commitment level has a load factor of 68%, the third highest of all alternatives. The minimum schedule requirement of 52% is the second highest of all alternatives. Commitment-level alternative 4 offers the lowest long-term firm commitment of capacity and energy at a high load factor.

2.1.2.6 Commitment-Level Alternative 5: Low Capacity-High Energy

Commitment-level alternative 5 is characterized by a low level for long-term firm capacity (625 MW) and a high level for long-term firm energy (5,475 MWh). The load factor and minimum schedule requirement for this alternative are both 100%, indicative of a base-loaded resource. Under this alternative, the customer would have to take energy at the stated capacity at all times in order to meet its purchase commitment. This situation would not allow the customer flexibility to vary the energy it takes to meet varying load requirements throughout the day or over the period of a week or a month.

2.1.2.7 Common Elements of Commitment-Level Alternatives

A number of elements would be common to all commitment-level alternatives and would occur to minimize the impact of any commitment-level alternative. These common elements include:

- *Phase-in of commitment-level changes:* Implementation of this action depends on the extent to which Western could phase in any commitment-level change (increase or decrease) over time. In the case of an increase, Western would add allocations of power as it acquired new resources through uprates, new construction of generating facilities, purchases, and other means.
- *Establishment of financial exception criteria for the operations of Glen Canyon and Flaming Gorge Dams:* Emergency exception criteria, which allow normal operating parameters to be exceeded under emergency conditions, are part of both the Glen Canyon Dam EIS alternatives and the Flaming Gorge operational scenarios. At times, spot-market prices for electrical energy purchased by Western are exorbitantly high. If normal operating parameters were allowed to be exceeded during these temporary conditions, Western would be able to avoid a large portion of its purchased power expenses. Additional operational exception criteria for financial reasons would not change the operation of these facilities significantly, but could mitigate the loss of marketable capacity for any restrictions in power plant operation. Exceeding normal operating parameters could have

adverse impacts on ecological and recreational resources and resource values. Full consideration would be given to such impacts before intentional exceedance of any normal operating parameters.

- *Possible use of the Collbran, Seedskedee, and Rio Grande Projects to meet peak load requirements:* Western currently has no influence on the operation of the hydropower facilities at the Collbran Project (Upper and Lower Molina dams), the Seedskedee Project (Fontenelle Dam), and the Rio Grande Project (Elephant Butte Dam). Western, in evaluating options to meet alternative electrical power peaking requirements of the SLCA/IP system, would investigate modified use of these facilities. Anticipated use of these facilities for this purpose would be within current operating limits and operational constraints. Western and Reclamation are currently conducting feasibility testing of potential modifications to the generating resource at the Collbran Project. Western may also explore the potential peaking resource at the Rio Grande and Seedskedee projects. In so doing, it would comply with NEPA pursuant to 10 CFR 1021.

2.1.3 Comparison of Impacts of Commitment-Level Alternatives

The analyses conducted for this EIS indicate that for each environmental resource or attribute, the impact of each commitment-level alternative is related to the hydropower operational scenarios implemented.[6] This situation is especially true for impacts to water, ecological, cultural, and visual resources, land use, and recreation; impacts to these resources would be almost exclusively a result of the hydropower operations employed. Impacts of hydropower operational scenarios are presented in Section 2.2.4.

The impact of commitment-level alternatives on socioeconomics would depend on the specific mix of hydroelectric generation, purchases, and exchanges that constitutes the power marketed by Western. Therefore, to evaluate the impacts of commitment-level alternatives, three different supply options were defined that specified hydropower operational scenarios at Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit and the purchases that would be needed to meet the commitments of long-term firm power specific to each alternative. These supply options were chosen because they cover the full range of dam operations possible at the three facilities and represent the maximum, median, and minimum levels of impact to wholesale power costs. They were defined as follows:

- *Supply Option A:* Continuation of historical operations (high fluctuation) at Glen Canyon Dam, year-round high fluctuation at Flaming Gorge Dam, and seasonally adjusted high fluctuation at the Aspinall Unit combined with all necessary power purchases.
- *Supply Option B:* Low fluctuation at Glen Canyon Dam, year- round high fluctuation at Flaming Gorge Dam, and seasonally adjusted high fluctuation at the Aspinall Unit combined with all necessary power purchases.
- *Supply Option C:* Seasonally adjusted steady flows at Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit combined with all necessary power purchases.

The affected environment for socioeconomics is depicted in Figure 2.2 (information on the method used to define the affected area can be found in Section 3.1.1 and Appendix A). The results of the regional economic analysis suggest that the different commitment-level alternatives could have a slight impact on certain socioeconomic variables, in each of the nine subregions and in the two high-reliance counties included in the analysis. However, the range of predicted impacts on regional economic variables across the various commitment-level alternatives is extremely small. As indicated in Table 2.2, the estimated impacts on each of these variables are slight for any of the alternatives considered. Impacts on agricultural production, as measured by changes in net income of the agricultural sector in each of the affected states, and on conservation and renewable energy programs, measured in terms of impacts on consumption efficiency and load management, would also be slight.

FIGURE 2.2

TABLE 2.2 Relative Impacts of the Commitment-Level Alternatives a

Commitment-Level Alternative	Financial Viability	Retail Rates	Regional Impacts/ Agricultural Production	Air Resources	Water, Ecological, Cultural, Recreation, Land Use, and Visual Resources
No action (1978 Marketing Criteria)	No impact under supply option A; slight adverse impact under supply option B; moderate adverse impact under supply option C.	No impact under supply option A; slight adverse impact under supply option B; moderate adverse impact under supply option C.	No impacts in any of the nine subregions or in the two high- reliance counties; no impacts on agri cultural production.	No impact on air quality under supply option A; slight benefit under supply options B and C from decreases in SO2 and TSP emissions. No impact on noise.	Impacts dependent on hydropower operations (see Tables 2.6, 2.7, and 2.8).
Commitment-level alternative 1 (preferred alternative)	No impact under any supply option.	Slight adverse impact under all supply options.	No impacts in any of the nine subregions; slight impacts in the two high-reliance counties; slight adverse impact on agricultural production.	Similar to above.	Same as above.
Commitment-level alternative 2	Slight adverse impact under supply options A and B; moderate adverse impact under supply option C.	Slight adverse impact under supply options A and B; moderate adverse impact under supply option C.	Same as above.	Slight benefit to air quality under all supply options from decreases in SO2 and TSP emissions. No impact on noise.	Same as above.
Commitment-level alternative 3	Same as above.	Slight adverse impact under supply options A and B; moderate adverse impact under supply option C.	Same as above.	Similar to above.	Same as above.
Commitment-level alternative 4	Moderate adverse impact under all supply options.	Moderate adverse impact under all supply options.	Same as above.	Similar to above.	Same as above.
Commitment-level alternative 5	Same as above.	Same as above.	Same as above.	Slight adverse impact to air quality under supply option A from increases in SO2 and TSP emissions; slight benefit under supply options B and C from decreases in these emissions. No impact on noise.	Same as above.
Commitment-level	Slight adverse impact under	Slight adverse impact under	Same as above.	Similar to above.	Same as above.

alternative 6	supply options A and B; moderate adverse impact under supply option C.	supply options A and B; moderate adverse impact under supply option C.			

[a] The terms *slight, moderate,* and *large* are used to convey the importance of the impact. These relative terms were determined after the analysis of the impacts was completed and are based on professional judgment. For further descriptions of impacts, see Section 4.1.

The alternatives were also analyzed with respect to possible impacts on the financialcondition and retail rates of each of the utilities that receives an allocation of firm capacity and energy from Western's SLCA/IP (Table 2.2). In this case, it was determined that certain utilities could experience adverse impacts as a result of a change in Western's commitment levels. Under each of the commitment-level alternatives, the number of utilities with a coverage ratio (which measures the ratio of cash flow to interest expense or debt) of less than 2.0 would remain unchanged, but the number of utilities with a ratio of less than 1.1 could increase.[7] With respect to retail rates, the different commitment-level alternatives would result in slight to moderate impacts. Impacts would be largest under commitment-level alternative 4.

Under the worst case, the commitment-level alternatives would result in only slight adverse impacts to regional or local air quality or noise levels. Impacts to other resources, including water, ecological, cultural, recreation, land use, and visual resources, would be dependent on hydropower operations (Section 2.2.4).

2.1.4 Western's Preferred Alternative and the Environmentally Preferred Alternative

Commitment-level alternative 1 — the Post-1989 commitment level — was developed and chosen as Western's preferred alternative during an extended public process involving SLCA/IP customers and other interested parties. This alternative was also identified as the environmentally preferred alternative based on the results of the analyses in this EIS. The results of the impact assessments presented in Chapter 4 and summarized in Sections 2.1.3 and 2.2.4 indicate that most impacts to natural and cultural resources would result from hydropower operations rather than from commitments levels. This is because commitment levels are only weakly linked to hydropower operations (see Section 2.2.1). Furthermore, under this alternative, socioeconomic impacts, including financial viability, retail rates, and regional and agricultural economies, would be minimized.

2.2 HYDROPOWER OPERATIONAL SCENARIOS

2.2.1 Background

To meet the resource requirements for each commitment-level alternative, Western would use either the hydropower generated at each SLCA/IP facility or a combination of hydrogeneration and capacity and energy purchases and exchanges from outside sources. The statement of scope for this EIS (Western 1991) indicated that Western ". . . would analyze the effects of alternatives on the operation of the applicable hydro facilities."

A study was recently completed examining the influence of Western's power marketing program on the operation of these facilities. That study indicated that hydropower operations are weakly linked to long-term firm commitments for capacity and energy (Veselka et al. 1995b). However, in this EIS, Western makes no presumption regarding what effects the commitment-level alternatives have on the operation of the SLCA/IP hydropower facilities. Instead, in order to assess the complete range of potential impacts associated with hydropower generation, the full range of possible operations within the scope of Western's control is analyzed at each SLCA/IP facility.

Under all conditions, Western obtains a finite amount of energy from the operation of SLCA/IP facilities. The amounts of energy produced by these facilities basically depend on the amounts of water released from the dams, and the bounds of these releases are not set by Western. Monthly water volumes released through the CRSP facilities are established by Reclamation in consultation with the Colorado River Basin states according to legal require ments governing downstream water deliveries and the hydrological conditions of the river basin.[8] Within these monthly constraints and limitations on the daily operations of the facilities, water releases can be made in different ways. Water can be released as fast as possible for a short period of time or slowly over a long period of time. Because the value of energy is greatest when it is needed most, more water is released during the day to meet peak loads, and less water is released at night.

Western, in conjunction with Reclamation, has studied the operations of each of the SLCA/IP dams that generate hydropower to determine the amount of influence that Western exercises on each facility for hydroelectric generation. Certain facilities are operated for specific project purposes (usually irrigation) with no consideration of hydropower generation, other than as a by-product of the release of irrigation water. Neither Western nor its marketing programs influence the operation of these particular facilities: Provo River, Collbran, Fontenelle, Rio Grande, and the power plant at Crystal Dam (Figure 1.1). These facilities, which are operated for water services (such as irrigation) or other nonpower purposes, are not included in the hydropower operational scenarios described in this section. However, the capacity and energy available from these facilities were included in the commitment-level alternatives because they contribute to the total amount of capacity and energy available to fulfill Western's power marketing responsibilities.

For the remaining facilities of the CRSP (Glen Canyon, Flaming Gorge, Morrow Point, and Blue Mesa dams), Western has direct influence over their second-by-second, hourly, and daily operations within the minimum and maximum release rates, up- and down-ramp rates, and monthly release volumes set by Reclamation. Hydropower operational scenarios were developed for these facilities and are analyzed in this EIS to determine the full range of impacts associated with commitment-level alternatives. These hydropower operational scenarios, however, are not alternatives themselves.

2.2.2 Hydropower Operations, Purchases, and Exchanges

Simply stated, hydrogeneration plus purchases and exchanges must equal firm sales plus nonfirm sales. Western makes purchases and exchanges both in response to shortfalls in hydrogeneration and other operational constraints, such as transmission limitations, and in response to variations in the value of energy. This procedure is consistent with standard operating practices of electrical utilities.

Western's purchases and exchanges of capacity and energy vary with market conditions and changes in Reclamation's water release schedules and operational parameters of the dams. When Reclamation's monthly water releases are not sufficient to provide the capacity and energy needed for Western to meet its firm sales commitments, Western must purchase or exchange capacity and energy sufficient to meet its contractual obligations.

Purchases made by Western are usually short-term and may be made from any utility offering capacity and energy for sale. With Western's extensive transmission network across the Western states, purchases can be made from any number of generators. As market conditions change and regional weather patterns create unusual load demands, Western can compensate for reductions in the availability or value of the hydroelectric resource by buying or selling power around the system to capture the benefit of purchasing from others with surplus generation and selling to customers with deficit generation. Because these purchases are made on the open market, it is impossible to project from day-to-day or month-to-month which generation units would be dispatched to meet Western's firm loads and nonfirm sales commitments.

In addition to purchases, Western has entered into an agreement with the Salt River Project (SRP), referred to as the

SRP Exchange Agreement, to (1) make efficient use of Western's existing transmission system, (2) provide a mutual benefit through generation exchange, and (3) match regional loads with proximate resources and thus conserve energy by reducing line losses. Most (72%) of Western's SLCA/IP generating resources are located at Glen Canyon Dam in northern Arizona, while many of Western's loads are located in Utah, Colorado, and New Mexico. The Glen Canyon-Kayenta-Shiprock transmission line, used to link Glen Canyon with these major areas of load, has a capacity of only 400 MW. During times of peak loads, limits on the Glen Canyon-Kayenta-Shiprock line may restrict operating levels at many or all SLCA/IP hydroelectric dams. Western and SRP have an "exchange" arrangement in which generating capacity owned by SRP in Craig and Hayden, Colorado, and the Four Corners unit in New Mexico is exchanged for surplus generating capacity at Glen Canyon Dam under certain conditions. The power exchanges with SRP have enabled Western to service its loads northeast of Glen Canyon at times of peak loads on the Glen Canyon-Kayenta-Shiprock line.

Purchases and exchanges allow Western to diversify its generation risk, capitalize on short-term market differentials in supply and demand, and maximize the value of SLCA/IP resources. The overall effect of these purchases and exchanges is to provide Western flexibility over commitment levels given specific hydropower operational scenarios. This flexibility is illustrated by the effects of recent Reclamation interim flow restrictions at Glen Canyon Dam. This facility represents nearly 75% of SLCA/IP generation. Although operations have been severely restricted, Western has met its firm commitments with little interruption in supply by making purchases and exchanges.

Because of this flexibility, Western can meet load in excess of hydrogeneration. However, some commitment levels, when combined with certain hydropower operational scenarios, may not be desirable. For example, low commitment levels with hydropower operation scenarios that have high fluctuations may not be desirable because such a combination would have an economic cost without providing any environmental benefit. Western decisions regarding both commitment levels and hydropower operational scenarios will be based on all of the purposes stated for the EIS, in light of the environmental impacts. Ultimately, Western must determine both a commitment level and a means of supplying the commitment level, including operational scenarios at the hydropower facilities, within constraints and release volumes set by Reclamation.

2.2.3 Selection and Description of Hydropower Operational Scenarios

Only Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit require the development of operational scenarios for analysis in this EIS. For all facilities where operations are dictated by irrigation demands, municipal and industrial uses, flood control, or other nonpower purposes, operations are not described, and site-specific environmental analyses are not included because, although Western markets this power, Western does not affect dam operations or hydropower generation at those facilities.

For this EIS, Western developed hydropower operational scenarios for Flaming Gorge Dam and the Aspinall Unit but used the alternatives presented in the Glen Canyon Dam EIS as the operational scenarios for that facility. Since Reclamation, not Western, establishes operational limits (e.g., minimum and maximum releases, ramp rates) and monthly water release volumes for each facility, the EIS does not evaluate changes in these operational characteristics, and all operational scenarios for Flaming Gorge Dam and the Aspinall Unit are within power plant capacity. Within the constraints set by Reclamation, Western has the ability to determine hydropower generation by controlling the timing and magnitude of releases and, thus, the degree of flow fluctuation downstream. It is this degree of fluctuation in releases that is the focus of the evaluation of hydropower operational scenarios presented in the EIS. Specifically excluded from the analysis is an examination of changes in operations that are outside of Western's control, such as changes in monthly release volumes and modification of the dam structure. Also excluded is an evaluation of nonhydropower dam effects, such as the trapping of sediment and inundation of upstream environments. Thus, the focus of this EIS (power marketing) is not comparable to that of the Glen Canyon Dam EIS (dam operations). Although outside of the scope of this Power Marketing EIS, Western supports the evaluation of a wider range of releases (e.g., above power plant capacity releases such as habitat maintenance flows) and other aspects of dam operations in any future NEPA documents prepared by Reclamation on the operations of Flaming Gorge Dam or the Aspinall Unit.

2.2.3.1 Glen Canyon Dam

Nine modes of operation, which represent unique hydropower operational scenarios for Western's power marketing programs, have been identified in the Glen Canyon EIS (Reclamation 1995). These scenarios, which were evaluated as alternatives in the Glen Canyon Dam EIS, are described in Table 2.3; the modified low fluctuating flow alternative was identified by Reclamation as their preferred alternative in the EIS. When the Glen Canyon Dam EIS Record of Decision is issued, Western will have to maintain hydropower operations within the constraints specified by the alternative selected. These constraints will include such parameters as minimum flows, maximum flows, ramp rates, and allowable daily changes. The range of operations span maximum power plant capacity flows; (1,000 cubic feet per second [cfs] minimum flow to 33,200 cfs maximum flow); to year-round steady flows based on yearly prorated volumes with an allowable daily change of 2,000 cfs every 24 hours. Included within this range is continuation of historical[9] operations. A detailed explanation of the hydrology studies and release patterns derived from the EIS alternatives is provided in the Glen Canyon Dam EIS (Reclamation 1995). The release patterns and environmental impacts associated with those releases are based on results of the Glen Canyon Environmental Studies, the supporting literature, and related documentation found in the public record.

The Glen Canyon Dam EIS (Reclamation 1995) included elements common to all of the restricted fluctuation and steady flow operational scenarios. These actions are intended to reduce the impacts of dam operations and would be implemented by Reclamation as part of establishing future operations at that facility. Common elements included: (1) adaptive management of the facility to allow flexibility in changing future operations based on future monitoring and research findings and changes in resource conditions; (2) monitoring and protecting cultural resources within the Colorado River corridor of Glen and Grand canyons; (3) implementation of actions to reduce the frequency of unplanned floods below Glen Canyon Dam; (4) implementation of beach/habitat building flows to rebuild high elevation sand bars, deposit nutrients, restore backwater channels, and provide some of the dynamics of a natural system; (5) establishment of a new population of humpback chub within Grand Canyon; and (6) further study of a selective withdrawal structure to provide warmer release waters.

TABLE 2.3 Hydropower Operational Scenarios for Glen Canyon Dam

			Restricted Fluctuating Flows				Steady Flows		
	Continuation of Historical	Maximum Power Plant	High	Moderate	Modified Low[a]	Interim Low	Existing Monthly Volume	Seasonally Adjusted	Year-Round
Minimum releases[b] (cfs)	1,000 Labor Day-Easter 3,000 Easter-Labor Day[c]	1,000 Labor Day-Easter 3,000 Easter-Labor Day[c]	3,000, 5,000, 8,000, depending on monthly volume, firm load, and market conditions	5,000	8,000 between 7 a.m. and 7 p.m. 5,000 at night	8,000 between 7 a.m. and 7 p.m. 5,000 at night	8,000	8,000 Oct-Nov[d] 8,500 Dec 11,000 Jan-Mar 12,500 Apr 18,000 May-Jun 12,500 Jul 9,000 Aug-Sep	Yearly volume prorated[e]
Maximum	31,500	33,200	31,500	31,500[g]	25,000[g]	20,000	Monthly	18,000[g]	Yearly

releasesf (cfs)							volumes prorated		volume prorated[e]
Allowable daily change in flow (cfs/24 hours)	30,500 Labor Day-Easter 28,500 Easter-Labor Day	32,200 Labor Day-Easter 30,200 Easter-Labor Day	15,000 to 22,000	±45% of mean flow for the month not to exceed ±6,000	5,000,[h] 6,000, or 8,000	5,000,[h] 6,000, or 8,000	±1,000[i]	±1,000[i]	±1,000[i]
Allowable scheduled ramping (cfs/h)	Unrestricted	Unrestricted	Unrestricted up 5,000 or 4,000 down	4,000 up 2,500 down	4,000 up 1,500 down	2,500 up 1,500 down	2,000 cfs/d between months	2,000 cfs/d between months	2,000 cfs/d between months
Elements common to restricted fluctuating and steady flow alternatives	None	None	Adaptive management including long-term monitoring and research, monitoring and protection of cultural resources, flood frequency reduction measures, beach/habitat-building flows, new population of humpback chub, further study of selective withdrawal, emergency exception criteria						

[a] Identified by Reclamation as their preferred alternative (Reclamation 1995).

[b] In high volume release months, the allowable daily change would require higher minimum flows.

[c] Releases each weekday during recreation season (Easter to Labor Day) would average not less than 8,000 cfs for the period from 8 a.m. to midnight.

[d] Based on an 8.23 million acre-feet year; in higher release years, additional water would be added equally to each month, subject to an 18,000 cfs maximum.

[e] For an 8.23-million acre-feet year, steady flow would be about 11,400 cfs.

[f] Maximums represent normal or routine limits and may necessarily be exceeded during high-water years.

[g] May be exceeded during habitat-maintenance flows.

[h] Daily fluctuation limit of 5,000 cfs for monthly release volumes less than 600,000 acre-feet; 6,000 cfs for monthly release volumes of 600,000 to 800,000 acre-feet and 8,000-cfs for monthly volumes over 800,000 acre-feet.

[i] Adjustments would allow for small power system load changes.

Source: Adapted from Reclamation (1995).

2.2.3.2 Flaming Gorge Dam

Four operational scenarios for Flaming Gorge Dam were developed for this EIS (Table 2.4). All scenarios would feature releases within power plant capacity. Any releases above power plant capacity are outside of the scope of Western's control of operations. As described below, three of the scenarios comply with the Biological Opinion issued by the USFWS (1992b). Compliance with the opinion is described as follows:

1. A target flow at Jensen, Utah, is set between 1,100 and 1,800 cfs for summer and autumn, except that up to 2,400 cfs would be allowed after September 15 for wet years. The time periods covered are July 20-October 31 for a wet year, July 10-October 31 for a moderate year, and June 20-October 21 for a dry year.
2. Variations of flow at Jensen are limited to a total of 25% around the target flow for any 24-hour period. Variations above or below the target should be as close as possible.

3. Except due to the effects of storm runoff, the flow at Jensen should stay within the range of 1,100 to 1,800 cfs, or up to 2,400 cfs after September 15 for wet years.

Release patterns were developed for wet, moderate, and dry years (1983, 1987, and 1989, respectively) (see Section 3.3). Conditions in 1983 and 1989 represent extreme, worst- case conditions rather than typical wet and dry years. Release patterns for the four hydropower operational scenarios are presented in Appendix C. The principal difference in the hydropower operational scenarios is the hourly fluctuation characteristics of the release rate, as summarized below.

Scenario 1 — Year-Round High Fluctuating Flows: The ramping rates, maximum fluctuations, and maximum and minimum releases used to derive the representative release patterns are detailed in Appendix C. The minimum release is 800 cfs; the maximum release was assumed to be 4,700 cfs [10] with no limit on maximum daily fluctuations. Ramp-rate restrictions are 3,900 cfs/h (minimum flow to maximum generator capacity). This operational scenario would not comply with the Biological Opinion. It is representative of maximum power plant operations using monthly release volumes historically set by Reclamation and is considered here for comparative purposes. Consideration of this operational scenario enabled a determination of the environmental consequences of the seasonal and daily adjustment of releases required by the opinion.

TABLE 2.4 Hydropower Operational Scenarios for Flaming Gorge Dam [a]

Parameter	Year-Round High Fluctuating Flows	Seasonally Adjusted Flows[b]		
		High Fluctuating	Moderate Fluctuating	Steady
Minimum releases (cfs)	800	800 Oct-Jan 2,380 Feb-Mar 800 Apr-May 4,700 Jun 1-21 800 Jun 22-Jul 9 890 Jul 10-31 990 Aug 1,070 Sep	800 Oct 2,220 Nov-Jan 2,380 Feb-Mar 2,440 Apr 2,740 May 4,700 Jun 1-21 2,770 Jun 22-30 1,860 Jul 1-Jul 9 976 Jul 10-31 1,080 Aug 1,160 Sep	800 Oct 2,380 Nov-Mar 2,600 Apr 3,390 May 4,700 Jun 1-21 3,740 Jun 22-30 2,020 Jul 1-9 1,060 Jul 10-31 1,160 Aug 1,240 Sep
Maximum releases (cfs)	4,700	800 Oct 4,700 Nov-Jan 2,380 Feb-Mar 4,700 Apr-Jul 9 2,900 Jul 10-31 3,000 Aug 3,100 Sep	800 Oct 4,170 Nov-Jan 2,380 Feb-Mar 4,390 Apr 4,700 May-Jun 3,810 Jul 1-9 1,980 Jul 10-31 2,080 Aug 2,160 Sep	Same as minimum releases
Allowable daily change in flow (cfs/24 hours)	3,900	0 Oct 3,900 Nov-Jan 0 Feb-Mar 3,900 Apr-May 0 Jun 1-21	0 Oct 1,950 Nov-Jan 0 Feb-Mar 1,950 Apr-May 0 Jun 1-21	0

		3,900 Jun 22-Jul 9 2,010 Jul 10-Aug 2,030 Sep	1,950 Jun 22-Jul 9 1,000 Jul 10-Sep	
Allowable schedule dramping (cfs/h)	3,900	3,900	1,950	0

[a] For a moderate hydrological year.

[b] All seasonally adjusted hydropower operational scenarios comply with the Biological Opinion for operation of Flaming Gorge Dam (USFWS 1992b).

Scenario 2 — Seasonally Adjusted High Fluctuating Flows: Hourly releases would reach the maximum fluctuation feasible as limited by the Biological Opinion, water available for release, minimum release requirement, and power plant capacity. Volumes would be adjusted seasonally to meet requirements of the Biological Opinion.

Scenario 3 — Seasonally Adjusted Moderate Fluctuating Flows: Hourly releases would have fluctuations limited to 50% of the flow change identified under Scenario 2. Volumes would be adjusted seasonally to meet requirements of the Biological Opinion.

Scenario 4 — Seasonally Adjusted Steady Flows: Hourly releases would be constant during the day. Volumes would be adjusted seasonally to meet requirements of the Biological Opinion.

There is some uncertainty with regard to potential future operations at Flaming Gorge Dam and the operational scenarios were defined to capture the full range of likely future operations. Operations at Flaming Gorge Dam are currently being studied to determine the effects of different flow regimes on downstream resources. These studies are being funded, in part, by Western and are conceptually similar to the adaptive management proposed by Reclamation for Glen Canyon Dam. Operations could be modified in the future to reduce impacts on the basis of these studies or to restore flexibility at the Flaming Gorge hydropower facility where such changes would not significantly affect the environment. In addition, Western is a participant in the Recovery Implementation Program for Endangered Fishes in the Upper Colorado River Basin. The goal of this program is to fully recover endangered fish species in the basin. Western will continue to participate in this program and would modify operations accordingly to protect these species.

2.2.3.3 Aspinall Unit

The operations of the Aspinall Unit dams are being evaluated by Reclamation. Any NEPA documentation that is prepared will not be available for reference in this Electric Power Marketing EIS; however, Western has developed two operational scenarios for the Aspinall Unit (Table 2.5).

Scenario 1 — Seasonally Adjusted High Fluctuating Flows: This scenario would permit seasonally adjusted high fluctuating flows with daily fluctuations at Blue Mesa and Morrow Point dams, but only steady flows out of Crystal Dam.

Scenario 2 — Seasonally Adjusted Steady Flows: This scenario would provide for a steady water release through Blue Mesa, Morrow Point, and Crystal dams. The steady pattern would change monthly, depending on the monthly volume set by Reclamation.

TABLE 2.5 Hydropower Operational Scenarios for the Aspinall Unit a

Parameter	Seasonally Adjusted High	Seasonally Adjusted Steady Flows

	Fluctuating Flows					
	Blue Mesa	Morrow Point	Crystal	Blue Mesa	Morrow Point	Crystal
Minimum release (cfs)	1,750 Jun 0 Others	0 Oct-Mar 557 Apr 1,830 May 2,440 Jun 1,070 Jul 0 Aug-Sep	1,920 Oct 1,430 Nov 1,280 Dec 680 Jan-Mar 2,250 Apr 3,580 May 3,830 Jun 2,640 Jul 1,920 Aug-Sep	1,570 Oct 1,200 Nov 1,050 Dec 500 Jan-Mar 1,600 Apr 2,370 May 3,050 Jun 2,350 Jul 1,750 Aug-Sep	1,700 Oct 1,280 Nov 1,100 Dec 570 Jan-Mar 1,970 Apr 2,890 May 3,320 Jun 2,480 Jul 1,770 Aug 1,820 Sep	1,920 Oct 1,430 Nov 1,280 Dec 680 Jan-Mar 2,250 Apr 3,580 May 3,830 Jun 2,640 Jul 1,920 Aug-Sep
Maximum release (cfs)	3,700	5,300 Oct-Mar 2,680 Apr 3,420 May 3,770 Jun 3,190 Jul 5,300 Aug-Sep	Same as minimum releases	Same as minimum releases	Same as minimum releases	Same as minimum releases
Allowable daily change in flow (cfs/24 hours)	3,700 Oct-May 1,950 Jun 3,700 Jul-Sep	5,300 Oct-Mar 2,120 Apr 1,590 May 1,330 Jun 2,120 Jul 5,300 Aug-Sep	0	0	0	0
Allowable scheduled ramping (cfs/h)	3,700	5,300	0	0	0	0

[a] For a moderate hydrological year.

These scenarios are likely to bound any future operations established by Reclamation. It is possible, however, that the results of studies could result in some modification of releases from the Aspinall Unit. Only a seasonal shift in releases from the Unit different from the shift considered here would be outside the bounds of the scenarios considered here, since a full range of operational releases was considered and Western assumed no control of releases from Crystal Dam which regulates flows from the entire Aspinall Unit.

2.2.4 Comparison of Impacts of Hydropower Operational Scenarios

This section summarizes impacts on natural and cultural resources from hydropower operational scenarios for Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit. The location of the affected environments of these operational scenarios are depicted in Figure 2.3. These impacts are discussed in detail in Section 4.2. The natural and cultural resource impacts associated with Western's power marketing programs are direct results of hydroelectric operations rather than of the commitments of capacity and energy (i.e., commitment-level alternatives) specified in Western's contracts. These hydroelectric operations can be established independently of the level of commitment and are, thus, treated separately from the commitment-level alternatives in this EIS.

The operational scenarios examined for Glen Canyon and Flaming Gorge dams included scenarios that are similar to historical operations (e.g., continuation of historical operations and year-round high fluctuations, respectively). The current conditions of most resources downstream of the facilities have resulted, at least in part, from such operations, and, therefore, these operational scenarios would have little additional impact to most resources. Other operational scenarios examined would result in reduced flow fluctuations below the dams, which could benefit many downstream resources. None of the operational scenarios considered would materially affect noise, land use, or visual resources. Therefore, these resources are not discussed further in this section. For reasons discussed in Chapter 4, impacts to air resources are considered as part of the commitment-level alternative analysis.

2.2.4.1 Glen Canyon Dam

Table 2.6 summarizes impacts to water resources, ecological resources, cultural resources, and recreation in and along the Colorado River downstream of Glen Canyon Dam.[11] Since hydropower operations have little effect on the surface level of Lake Powell upstream of the dam (because of the large reservoir capacity), resources in the reservoir are not considered.

FIGURE 2.3

TABLE 2.6 Summary of Potential Impacts of Hydropower Operational Scenarios on Natural and Cultural Resources below Glen Canyon Dam a

Operational Scenario	Water Resources[b]	Ecological Resources[c]	Cultural Resources[d]	Recreation[e]
Continuation of historical operations	No change from current conditions.	Slight adverse impact to humpback chub; adverse impact to Kanab ambersnail; no change from current conditions for other resources.	No change from current conditions; some sites continue to be affected by fluctuation-induced erosion.	No change from current conditions.
Maximum power plant capacity	Slight adverse impact from increase in flow fluctuations.	Slight adverse impact to humpback chub and southwestern willow flycatcher; adverse impact to Kanab ambersnail; no impact to other resources.	Same as above.	Slight adverse impact to angling.
Restricted high	Slight benefit; slight increase	Slight adverse impact to humpback chub; adverse impact to Kanab ambersnail; slight	Same as above.	Slight benefit to angling and

fluctuating flows	in probability of net gain in riverbed sand.	benefit to aquatic and terrestrial resources.		white-water boating.
Moderate fluctuating flows	Moderate benefit; moderate increase in probability of net gain in riverbed sand.	Slight adverse impact to humpback chub; adverse impact to Kanab ambersnail; slight benefit to bald eagle, peregrine falcon, and southwestern willow flycatcher; slight benefit to aquatic resources; no impact to terrestrial resources.	Benefit because of reduced erosion rates.	Slight benefit to angling; moderate benefit to white-water boating.
Modified low fluctuating flows	Same as above.	Slight benefit to humpback chub, bald eagle, peregrine falcon, and southwestern willow flycatcher; adverse impact to Kanab ambersnail; slight to moderate benefit to aquatic resources; no impact to terrestrial resources.	Same as above.	Moderate to large benefit to white-water boating; moderate benefit to angling.
Interim low fluctuating flows	Same as above.	Same as above except moderate benefit to terrestrial resources.	Same as above.	Same as above.
Existing monthly volume steady flows	Same as above.	Slight benefit to humpback chub, bald eagle, peregrine falcon, and southwestern willow flycatcher; adverse impact to Kanab ambersnail; moderate benefit to aquatic resources; large benefit to terrestrial resources.	Same as above.	Large benefit to angling and white-water boating.
Seasonally adjusted steady flows	Same as above.	Slight to moderate benefit to humpback chub; no impact to terrestrial resources; same as above for other resources.	Same as above.	Large benefit to white- water boating; moderate benefit to angling.
Year-round steady flows	Same as above.	Slight benefit to humpback chub, bald eagle, and peregrine falcon; moderate benefit to southwestern willow flycatcher; adverse impact to Kanab ambersnail; moderate benefit to aquatic resources; large benefit to terrestrial resources.	Same as above.	Large benefit to angling and white-water boating.

[a] The impacts presented are relative to a baseline of existing conditions that have formed since placement and operation of the dam. No impacts to air resources, land use, or visual resources were identified. The terms *slight*, *moderate*, and *large* benefits and *adverse* impacts are used to convey the importance of the impact. These relative terms were not included in the Glen Canyon Dam EIS but have been added on the basis of a review of the findings presented in that EIS to provide consistency in treatment among facilities. For further descriptions of impacts, see Section 4.2.

[b] Effects of hydropower operational scenarios on water resources were considered benefits if they resulted in a more natural flow regime or sediment balance.

[c] Expected benefits of reduced flow fluctuations to native and endangered fishes may not occur if competing or predaceous non-native fishes increase in response to more stable flows.

[d] Archaeological, historical, and Native American resources.

[e] Angling and white-water boating.

Source: Adapted from Reclamation (1995).

The continuation of historical operations and maximum power plant capacity operational scenarios would have little additional impact on natural resources. These scenarios are similar to the operations that have occurred since the dam was completed in 1963, and existing water resources, ecological resources, and recreational activities have developed under these historical operations.

Because of their reduced fluctuations and maximum flows, all other operational scenarios would be beneficial for most resources relative to current conditions. Restricted high fluctuations would result in slight benefits to water resources, most ecological resources, and recreation; however, adverse impacts are expected to cultural resources. Moderate and low fluctuation operational scenarios would produce moderate benefits for water resources, cultural resources, and white-water boating. Steady flow scenarios would produce moderate to large benefits for these resources, as well as for aquatic ecology and angling. The seasonally adjusted steady flow scenario could benefit the humpback chub, but any benefit might require the proposed habitat-maintenance flows to flush accumulated sediments and encroaching vegetation from backwaters. All operational scenarios could have adverse impacts on the Kanab ambersnail.

2.2.4.2 Flaming Gorge Dam

Table 2.7 summarizes impacts to water resources, ecological resources, cultural resources, and recreation in and along the Green River downstream of Flaming Gorge Dam. Because hydropower operations have little effect on the surface level of Flaming Gorge Reservoir (because of the large reservoir capacity), resources in the reservoir are not considered.

The year-round high fluctuating flow operational scenario features slightly higher daily maximum flows and fluctuations than historical operations. This scenario could result in adverse impacts to native and endangered fish, trout, terrestrial resources, and cultural resources.

The seasonally adjusted operational scenarios feature shifts in monthly volumes to meet requirements of the USFWS Biological Opinion (USFWS 1992b). All of these scenarios exhibit a high sustained flow in May or June, reduced fluctuations and lower flows in summer and autumn, and steady flows when an ice cover is present on the river (February and March). These flow patterns are intended to protect endangered fish in the system and would benefit other resources as well. Some adverse impacts could result from seasonal adjustment, however. The spring peak flows would adversely affect anglers. In addition, the bald eagle and waterfowl could be adversely affected by steady flows in February and March. With steady flows, less open, ice-free water would be available for these species. Seasonal adjustment of flows could also result in reduced soil moisture in riparian areas during the summer and, in turn, produce slight to moderate adverse impacts to existing populations of the Ute ladies'-tresses. The more natural flow patterns of these scenarios, however, could result in the establishment of new populations of this species.

TABLE 2.7 Summary of Potential Impacts of Hydropower Operational Scenarios on Natural and Cultural Resources below Flaming Gorge Dam a

Operational Scenario	Water Resources[b]	Ecological Resources[c]	Cultural Resources[d]	Recreation[e]
Year-round high fluctuating flows	Slight adverse impact; increase in erosion	Slight to moderate adverse impacts to aquatic resources; slight adverse impacts to terrestrial resources.	Slight adverse impact because of increase in	Slight adverse impact to angling; conditions for white- water boating unchanged;

	rate.		erosion rate.	no impact on day floating.
Seasonally adjusted high fluctuating flows	Same as above.	Slight to moderate benefits to native fish and endangered fish; slight to moderate adverse impacts to trout; slight adverse impact to existing Ute ladies'- tresses but slight potential for establishment of new individuals; slight adverse impact to terrestrial resources; slight adverse impact to bald eagle.	Same as above.	Slight adverse impact to angling; moderate benefit to white-water boating; no impact on day floating.
Seasonally adjusted moderate fluctuating flows	Slight benefit; decrease in erosion rate.	Slight to moderate benefit to native fish and endangered fish; slight benefit to trout; slight adverse impact to bald eagle; slight to moderate adverse impact to existing Ute ladies'-tresses but greater potential for establishment of new individuals; slight adverse impact to terrestrial resources.	Slight benefit because of reduced erosion rate.	Slight adverse impact to angling; moderate benefit to white-water boating; no impact on day floating.
Seasonally adjusted steady flows	Same as above.	Moderate to large benefit to native fish and endangered fish; moderate benefit to trout; slight benefit to terrestrial resources; slight adverse impact to bald eagle; moderate adverse impact to existing Ute ladies'-tresses but greatest potential of establishment of new individuals; slight benefit to peregrine falcon.	Same as above.	Slight benefit to angling; moderate benefit to white-water boating; no impact on day floating.

[a] The impacts presented are relative to a baseline of existing conditions that have formed since placement and operation of the dam. No impacts to air resources, land use, or visual resources were identified. The terms *slight, moderate,* and *large* are used to convey the importance of the impact. These relative terms were determined after the analysis of the impacts was completed and are based on professional judgment. For further descriptions of impacts, see Section 4.2.

[b] Effects of hydropower operational scenarios on water resources were considered benefits if they resulted in a more natural flow regime or sediment balance.

[c] Expected benefits of reduced flow fluctuations to native and endangered fishes may not occur if competing or predaceous non-native fishes increase in response to more stable flows.

[d] Archaeological, historical, and Native American resources.

[e] Angling and white-water boating.

Seasonally adjusted high fluctuations would have slight to moderate benefits for native and endangered fish (e.g., humpback chub), but high fluctuations from November through January and in April and May could adversely affect trout. This scenario would produce large benefits for angling in mid-summer through autumn and moderate benefits for white-water boating during the spring peak. Slight adverse impacts to terrestrial ecology could occur because of the inundation of some riparian vegetation. Erosion rates would be similar to the year-round high fluctuation scenario, and thus cultural resources could be adversely affected.

Seasonally adjusted moderate fluctuations or steady flows could produce slight to large benefits for native and endangered fish, cultural resources, angling, and white-water boating. Only the steady flow scenario would benefit terrestrial resources, however, by allowing a moderate increase in riparian vegetation.

2.2.4.3 Aspinall Unit

Table 2.8 summarizes impacts to water resources, ecological resources, cultural resources, and recreation associated with the Aspinall Unit. Only slight impacts to resources in and around the reservoirs would result from the two operational scenarios under consideration. No hydropower-induced impacts would occur in the Gunnison River below the unit because Crystal Dam reregulates flows from the unit. Thus, flows in the Gunnison River would not be affected by the hydropower operational scenarios, and little difference exists in the impacts of the scenarios for this facility.

TABLE 2.8 Summary of Potential Impacts of Hydropower Operational Scenarios on Natural and Cultural Resources Associated with the Aspinall Unit a

Operational Scenario	Water Resources[b]	Ecological Resources	Cultural Resources[c]	Recreation[d]
Seasonally adjusted high fluctuating flows				
Blue Mesa Reservoir	Slight benefit; daily fluctuations same as historical but monthly release volumes change.	No impact to any resources.	No impact.	No impact.
Morrow Point Reservoir	Same as above.	Same as above.	Same as above.	Slight adverse impact to boaters
Crystal Dam Reservoir	Same as above.	No impacts to aquatic resources; slight benefit to terrestrial resources.	Same as above.	Same as above.
Seasonally adjusted steady flow				
Blue Mesa Reservoir	Slight benefit; daily fluctuations eliminated and monthly release volumes change.	No impact to aquatic or terrestrial resources; slight adverse impact to bald eagle.	No impact.	No impact.
Morrow Point Reservoir	Moderate benefit; daily fluctuations eliminated and monthly release volumes change.	Same as above.	Same as above.	Same as above.
Crystal Reservoir	Large benefit; daily fluctuations eliminated and monthly release volumes change.	No impact to aquatic resources; slight benefit to terrestrial resources; slight adverse impact to bald eagle.	Same as above.	Same as above.

[a] The impacts presented are relative to a baseline of existing conditions that have formed since placement and operations of the dams. No impacts to air resources, land use, or visual resources were identified. The terms *slight*, *moderate*, and *large* are used to convey the importance of the impact. These relative terms were determined after the analysis of the impacts was completed and are based on professional judgment. For further descriptions of impacts, see Section 4.2.

[b] Effects of hydropower operational scenarios on water resources were considered benefits if they resulted in a more natural flow regime or sediment balance.

[c] Archaeological, historical, and Native American resources.

[d] Angling and boating.

[1] One megawatt equals 1,000,000 watts.

[2] One kilowatt equals 1,000 watts.

[3] One megawatt-hour equals 1,000,000 watt-hours. A generator operating at a capacity of one megawatt for one hour would produce one megawatt-hour of energy. The same generator operating at a capacity of one megawatt for 10 hours would produce 10 megawatt-hours of energy.

[4] One gigawatt-hour equals 1,000 megawatt-hours.

[5] Minimum schedule requirements are associated with alternative combinations of capacity and energy to provide (1) sufficient load off-peak to match minimum release levels at all SLCA/IP facilities, (2) the ability for Western to purchase sufficient energy off-peak to satisfy energy commitments in an adverse water year, and (3) some remaining component of capacity and energy to be scheduled for the customer during on-peak periods. Unique minimum schedule requirements for each commitment-level alternative were determined through consistent application of this approach.

[6] These analyses assume that Western adjusts its firm power ratefor each commitment-level alternative so that required payments to the U.S. Treasury from theFederal projects are unaffected by choice of alternative.

[7] It is an industry-wide standard that the coverage ratio for utilities should be greater than 2.0.

[8] These legal requirements (sometimes collectively referred to as "the Law of the River") are stipulated in the following acts and compacts: the Colorado River Storage Project Act, the Colorado River Basin Project Act of 1968 (43 USC §§ 1501 *et seq*.), the Colorado River Compact (Dec. 21, 1928, Ch. 42, 45 Stat. 1057), Upper Colorado River Basin Compact Ch. 6, 1949, Ch. 48, 63 Stat. 31), the Boulder Canyon Project Act (43 USC §§ 617 *et seq*.) , the Boulder Canyon Project Adjustment Act (43 USC §§ 618 *et seq*.), as well as certain international boundary and water treaties.

[9] When used to describe flows or operational scenarios, the term *historical* refers to the period in time from construction of the dam to that time when operations recently were modified to protect downstream natural resources.

[10] The maximum possible release rate for Flaming Gorge Dam with uprated conditions could be in excess of 4,950 cfs for full reservoir conditions. However, such reservoir conditions would occur for limited periods.

[11] The assessment presented here for Glen Canyon Dam was based on the analysis presented in a separate EIS for that facility (Reclamation 1995). Relative levels of benefitor adverse impacts were added to provide consistency of treatment among facilities.

3 AFFECTED ENVIRONMENT

This chapter discusses the affected environment for each resource under consideration. For socioeconomics and air resources, the area served by the SLCA/IP is described because commitment-level alternatives would affect this broad geographical region. For other resources, including water resources, ecology, cultural resources, land use, recreation, and visual resources, the affected environment is the area associated with specific SLCA/IP hydroelectric facilities that provide most of the power marketed by Western - Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit (Crystal, Morrow Point, and Blue Mesa dams). Because there are larger differences between the impact of each commitment-level alternative on socioeconomics than on the natural environment, socioeconomic topics are addressed first in this chapter.

3.1 SOCIOECONOMICS

This discussion of the socioeconomic environment in the affected region focuses on key regional economic variables, including population, income, employment, and gross regional product; selected regional activities, including recreation, nonuse values, and agriculture; and existing rates for electricity and the financial condition of potentially affected utilities. However, before describing baseline conditions, it is necessary to first describe the socioeconomic "regions of influence" that have been defined for analytical purposes in this EIS.

3.1.1 Regions of Influence

The total area served by Western's CRSP-CSO includes portions of the states of Utah, Colorado, Wyoming, Nevada, Arizona, and New Mexico. As described in Chapter 2, the Western CRSP-CSO sells electricity to utilities in each of these states; however, not all electric utilities within these state boundaries receive power from Western. In addition, some of these utilities sell power to customers in states other than the six listed above.[1] As a consequence of these distinctions, the regions of influence for which impacts are assessed in this EIS were defined differently depending on the impact being analyzed. In the following sections, the definition of impact regions are specified for the analysis of utility finance and rates, regional economics, recreational economics, nonuse values, and irrigated agriculture. [2]

3.1.1.1 Utility Finance and Retail Rates

The region of influence for the power system's utility finance and rate impacts covers the entire six-state CRSP-CSO service area. The CRSP-CSO serves 183 customers that have the potential to be affected by changes in Western's marketing programs (i.e., changes in capacity and energy commitment levels). These customers include utilities of various sizes and types, and end-use facilities given preference customer status. For presentation in this EIS, the utilities were placed in a number of different categories based on level of reliance on Western power and type of ownership (municipals or cooperatives). These categories were designed to capture potential differences between utilities in urban and rural areas. Detail on these categorizations is provided in Section 3.1.3.

3.1.1.2 Regional Population, Employment, Income, and Output

The geographic region included in the analysis of regional population, employment, income, and output in this EIS consists of 195 counties in 12 states. The counties selected were identified as those most likely to experience effects as a result of a change in Western's commitment levels. This determination was based on the proportion of locally consumed power supplied by Western.

The 195 counties were divided into nine subregions by grouping counties with a common economic base. As shown in Figure 3.1, the groupings consist of six metropolitan subregions and three rural subregions. Each of the metropolitan subregions has a rather diversified economy, while each of the rural subregions is organized around a relatively homogenous economic base. The nine subregions include the Arizona Metropolitan, Colorado Metropolitan, Nevada Metropolitan, New Mexico Metropolitan, Utah Metropolitan, Wyoming Metropolitan, High Plains, Rocky Mountains, and Great Basin subregions. The individual counties included in each of the nine subregions are listed in Appendix A, Table A.2. Additional analysis was performed for two counties that contained utilities with high reliance on Western power and where a high proportion of power sold in the county comes from these utilities. These counties were chosen to examine an extreme case, since changes in retail electricity rates in these counties would be among the largest changes in all the counties receiving Western power. See Allison and Griffes (1995) for a discussion of how the nine subregions and the two high-reliance counties were selected.

Figure 3.1

3.1.1.3 Recreation

Each of the affected facilities - Glen Canyon, Flaming Gorge, and Aspinall Unit - attracts many recreationists each year. Although these recreational activities have little effect on the regional economies defined above, they do form a component of the local economy contiguous (adjacent) to the site.

The local economy associated with the Green River below Flaming Gorge Dam was defined to include the following counties: Uintah and Daggett in Utah, Sweetwater and Uinta in Wyoming, and Moffat and Rio Blanco in Colorado. This selection was based on the fact that together these counties include all of the cities and towns located reasonably close to the major recreation centers on the affected portion of the Green River. The local economy associated with recreation on the Colorado River below Glen Canyon Dam was defined to include Coconino and Mohave counties in Arizona (Reclamation 1995).

No economic analysis was conducted of recreation-related impacts for the affected environment associated with the Aspinall Unit. This decision was based on the determination that commitment-level alternatives and operational scenarios would not affect recreation use rates at the Aspinall Unit (Section 4.2.7).

3.1.1.4 Agriculture

About 49% of the irrigated acreage in agriculture in the study region is pump-irrigated and could be affected by Western's commitment levels through changes in electricity costs. Because the modeling approach used to estimate the regional economic impacts does not provide sufficient detail to estimate these types of impacts, current conditions regarding irrigated agriculture are described at the state level.

3.1.2 Socioeconomic Baseline

3.1.2.1 Economic Baseline

The socioeconomic baseline is defined as the conditions predicted to prevail under the Post-1989 Marketing Criteria for the years 1993 through 2008. [3] To adequately assess the possible effects of the different commitment-level alternatives, an array of variables was selected to describe the baseline socioeconomic conditions in the affected region and subregions. These variables include population and three key economic indicators: employment, real disposable income (i.e., total real income adjusted for taxes and transfer payments), and real gross regional product [4] (GRP). Estimated baseline values for these variables are provided in Table 3.1.

TABLE 3.1 Estimated Baseline Statistics: Population, Employment, Disposable Income, and Gross Regional Product

	Population (1,000)		Average Annual Change (%)	Employment (1,000)		Average Annual Change (%)
Subregion[a]	1993	2008		1993	2008	
1	3,264.3	4,597.1	+2.3	1,737.0	2,366.8	+2.1
2	2,398.7	2,890.4	+1.3	1,265.6	1,566.9	+1.4
3	778.2	1,072.8	+2.2	431.2	590.0	+2.1
4	683.7	936.1	+2.1	410.9	546.5	+1.9
5	1,440.6	1,698.2	+1.1	743.2	915.6	+1.4
6	58.5	64.6	+0.7	37.6	43.7	+1.0
7	835.1	817.5	-0.1	435.5	459.1	+0.4
8	1,026.2	1,114.6	+0.6	456.6	521.9	+0.9
9	1,325.3	1,380.0	+0.3	610.3	684.9	+0.8
Total	11,810.8	14,571.3	+1.4	6,127.8	7,695.5	+1.5
Gross Regional						
	(billions of 1994 $)		Average Annual Change (%)	(billions of 1994 $)		Average Annual Change (%)
Subregion[a]	1993	2008		1993	2008	
1	54.4	88.2	+3.3	71.0	108.9	+2.9
2	44.7	66.2	+2.6	51.2	74.4	+2.4
3	12.7	21.0	+3.4	17.2	24.9	+2.5
4	11.7	18.8	+3.2	17.3	25.3	+2.6
5	20.7	29.9	+2.4	31.4	44.7	+2.4
6	1.2	1.6	+2.2	2.8	3.6	+1.6
7	15.4	19.1	+1.5	21.3	25.8	+1.2
8	15.1	20.4	+2.1	20.7	26.4	+1.6

9	18.1	23.9	+1.8	27.1	33.5	+1.4
Total	194.0	289.1	+2.7	260.0	367.5	+2.3

[a] 1 = Arizona Metropolitan Subregion, 2 = Colorado Metropolitan Subregion, 3 = Nevada Metropolitan Subregion, 4 = New Mexico Metropolitan Subregion, 5 = Utah Metropolitan Subregion, 6 = Wyoming Metropolitan Subregion, 7 = High Plains Subregion, 8 = Rocky Mountains Subregion, and 9 = Great Basin Subregion.

Source: The data were estimated with the REMI modeling system, which is described in Appendix A (Section A.5).

As shown in Table 3.1, an estimated 11.8 million individuals resided in the affected region in 1993, about half of them in the Arizona and Colorado Metropolitan subregions. This relationship is predicted to remain relatively stable over the forecast period. Total population in the affected region is predicted to grow at an annual rate of approximately 1.4% - from 11.8 million to 14.6 million - between 1993 and 2008. Population growth is expected to be most rapid in the Arizona Metropolitan Subregion (with an average annual growth rate of about 2.3%), while the population in the High Plains Subregion is predicted to decline in both relative and absolute terms.

The number of individuals employed in the affected region is predicted to increase by an average of 1.5% per year, to just under 7.7 million workers in 2008 (Table 3.1). The Nevada Metropolitan Subregion is predicted to experience the highest average annual growth rate of 2.1%. In contrast, employment in the High Plains Subregion is predicted to grow at an annual rate of 0.4% over the same period.

Employment is most heavily concentrated in the wholesale and retail sectors and the business and public services sectors in each of the metropolitan subregions. In contrast, employment is more evenly distributed across sectors in each of the rural subregions; no sector accounts for more than 25% of total employment. By 2008, the share of total employment in the retail and wholesale sectors and the business and public services sectors in the six metropolitan subregions will range from 52% to 70%; no sector in the three rural subregions will account for more than 23% of total employment.

Real disposable income in the affected region is predicted to increase by an average of 2.7% per year, rising from $194 billion[5]in 1993 to just over $289 billion in 2008 (Table 3.1). The Arizona Metropolitan Subregion is predicted to experience the highest average annual growth rate, 3.3%. In contrast, real disposable income in the High Plains Subregion is predicted to grow at an annual rate of 1.5% over the same period. Once again, relative growth rates across subregions are consistent with the relative growth rates in population reported in Section 3.1.2.1.

For 1993, real GRP is estimated to be approximately $260 billion (Table 3.1). This figure is expected to rise to nearly $368 billion by 2008, which translates to an average annual growth rate of 2.3%. All of the nine subregions are expected to experience an increase in real GRP over the forecast period. The Arizona Metropolitan and New Mexico Metropolitan subregions are predicted to experience the highest growth rates, while the High Plains Subregion is predicted to experience the lowest.

Recreation-related expenditures contribute to the levels of income and employment in many local economies. In the case of Flaming Gorge Dam, approximately $24.8 million (in 1994 dollars), or 0.22% of the 1991 economic activity in the local economy identified in Section 3.1.1.3, was directly or indirectly attributable to expenditures associated with recreational activities (fishing, boating, hunting, etc.) on the Green River below Flaming Gorge Dam (Rose and Frias 1993). Similarly, recreation-related expenditures were responsible for an estimated $24 million (1994 dollars) in the local economic activity around Glen Canyon Dam (Reclamation 1995).

In addition to producing economic benefits to the local economy, recreation at each site brings in economic benefits to the recreationists who engage in activities there. These benefits, referred to as use values, are measured as the difference between participants' willingness to pay for the recreational experience and the actual costs incurred. On the basis of results of a study by Bishop et al. (1987) and estimated use rates (Section 3.7.2.1), the annual use value of trout fishing on the Green River below Flaming Gorge Dam was estimated at $4.0 million in 1991. Similarly, the annual use value of white-water rafting on the Green River between Flaming Gorge Dam and Jensen, Utah, was estimated at $0.1 million. (See Appendix A, Section A.6, for a more detailed discussion of the derivation of these estimates.) The annual use values of trout fishing and white-water rafting below Glen Canyon Dam were estimated at $1.3 million and $8.1 million, respectively.

Evidence is growing that many individuals also attach "nonuse" values to many resources. As the term suggests, a nonuse value measures the amount individuals would be willing to pay to maintain the condition of a particular resource, independent of any use values they attach to that resource (see Appendix A, Section A.6 for a discussion of this concept). A growing number of studies, including recent efforts by Loomis (1987) and Sanders et al. (1990), have attempted to estimate the nonuse value of specific resources. According to these studies and a review of a number of earlier studies (Fisher and Raucher 1984), nonuse values might be one-half to 73 times as large as the estimated recreational use value of the resource.[6] On the basis of this information and the use values presented above, a reasonable lower bound on the nonuse value associated with the environment below Flaming Gorge Dam would be $2.1 million. The estimated lower bound on the nonuse value associated with the environment below Glen Canyon Dam would be approximately $4.7 million. However, because of the unique characteristics of the natural environment at these two locations, the nonuse values could be considerably higher than the lower bounds noted above.

The agriculture, forestry, and fisheries sector in the affected region produced about $1.4 billion dollars of output and employed more than 65,000 persons in 1990 (Allison and Griffes 1995). By the year 2000, employment in this sector is expected to grow to over 83,000 persons. Only two other economic sectors in the six-state region (services and medical/educational) will see their share of total employment increase over this period.

Because of the arid climate of much of the affected region, agriculture is heavily dependent on irrigation. About 49% of total irrigated acreage in this six-state region is pump irrigated (compared with irrigation of 11% of total farm acreage in the United States as a whole). The data in Table 3.2 show that over 80% of the pumped irrigated acreage in the region is electrically irrigated.

Table 3.3 illustrates the variation in crop production activity by state and irrigation method. For most states, irrigated crop production exceeds dryland production. The notable exception is wheat production in Colorado, which is predominantly dryland.

3.1.2.2 Low-Income and Minority Baseline

Commitment-level alternatives and supply options could differentially affect the various income and population groups residing in the affected area. To address this concern, the analysis undertaken for the EIS considered the impact of the alternatives on low-income and minority populations. The six metropolitan and three rural subregions used as the basis for the estimation of socioeconomic impacts were used for the analysis.

Each of the subregions in the affected area contains households in a range of annual income groups. The number and percentage of households with annual household incomes of less than $30,000 in each of the nine subregions for the three years 1993, 2000, and 2008 is shown in Table 3.4. In 1993, the High Plains and Great Basin subregions both had more than 70% of households in this group, and the majority of the remaining subregions had between 50% and 65% of households in this income group. More information on the distribution of household income in each of the subregions can be found in Rose and Frias (1993).

TABLE 3.2 Irrigated Acreage in Six-State Region in 1987

State	Total Farm	Irrigated Acreage	Irrigated Acreage	Irrigated Acreage

	Acreage		Pumped	Electrically Powered
Arizona	865,817	859,654	465,613	388,748
Colorado	5,522,216	2,442,358	1,445,164	1,239,603
Nevada	526,067	524,067	229,064	206,565
New Mexico	989,214	606,344	481,100	271,231
Utah	1,076,886	829,732	294,992	231,816
Wyoming	1,717,027	1,132,266	228,039	186,829
Total	10,697,227	6,394,421	3,143,972	2,525,507

>Source: Bajwa et al. (1992).

TABLE 3.3 Agriculture Output for Selected Crops in 1984

Output (1,000 tons)								
Crop	Farming Method	Arizona	Colorado	Nevada	New Mexico	Utah	Wyoming	Total
Alfalfa	Dryland	0.0	254.3	0.0	150.2	153.1	213.0	770.6
	Irrigated	1,008.0	2,132.7	940.0	1,175.8	1,726.9	1,037.0	8,020.4
Barley	Dryland	0.0	8,604.9	0.0	0.0	339.2	2,388.6	11,332.7
	Irrigated	5,353.0	11,545.1	3,330.0	1,500.0	11,267.9	8,011.4	41,007.3
Corn	Dryland	222.1	0.0	0.0	446.8	0.0	776.7	1,445.5
	Irrigated	3,027.9	91,115.2	0.0	8,403.2	1,888.0	5,223.3	109,657.7
Cotton	Dryland	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Irrigated	1,185.1	0.0	0.0	99.4	0.0	0.0	1,284.5
Sorghum	Dryland	0.0	9,718.7	0.0	11,201.5	0.0	0.0	20,920.2
	Irrigated	1,360.0	6,191.3	0.0	4,198.5	0.0	0.0	11,749.8
Oats	Dryland	0.0	635.4	0.0	0.0	0.0	789.4	1,424.7
	Irrigated	0.0	2,096.7	0.0	0.0	871.0	2,430.6	5,398.3
Wheat	Dryland	0.0	100,910.6	0.0	7,032.1	5,482.5	7,293.7	120,718.9
	Irrigated	12,780.0	14,109.4	1,840.0	4,927.9	2,572.5	778.3	37,008.1
Total	Dryland	222.1	120,123.9	0.0	18,830.5	5,974.8	11,461.4	156,612.6
	Irrigated	24,714.0	127,19d0.3	6,110.0	20,304.9	18,326.2	17,480.6	214,126.1

Sources: Schaible et al. (1989a,b).

TABLE 3.4 Households with Annual Incomes of $30,000 or Less, by Subregion and Year

Subregion[a]	1993			2000			2008		
	<$30,000	Total	%	<$30,000	Total	%	<$30,000	Total	%
1	919,989	1,640,343	56.09	930,890	1,987,446	46.84	909,716	2,239,376	40.62
2	674,619	1,242,514	54.29	654,354	1,416,690	46.19	617,579	1,537,493	40.17
3	281,586	570,647	49.35	275,732	594,174	46.41	273,655	685,893	39.90
4	239,418	393,790	60.80	240,601	467,437	51.47	229,707	524,606	43.79
5	375,445	704,362	53.30	363,497	800,687	45.40	345,896	867,411	39.88
6	25,251	40,013	63.11	25,820	44,088	58.56	24,025	46,682	51.47
7	221,403	302,195	73.30	174,830	296,754	58.90	131,005	295,826	44.30
8	266,398	462,877	57.55	258,079	502,118	51.40	242,764	527,435	46.22
9	423,973	597,816	70.90	344,019	605,092	56.90	258,597	626,891	41.30

[a] 1 = Arizona Metropolitan Subregion, 2 = Colorado Metropolitan Subregion, 3 = Nevada Metropolitan Subregion, 4 = New Mexico Metropolitan Subregion, 5 = Utah Metropolitan Subregion, 6 = Wyoming Metropolitan Subregion, 7 = High Plains Subregion, 8 = Rocky Mountains Subregion, and 9 = Great Basin Subregion.

Source: The data were estimated with the IMPLAN modeling system, which is described in Appendix A (Section A.5).

Within the affected area, minorities made up 14.6% of the total population in 1990 (see Table 3.5). The minority population was concentrated primarily in the New Mexico metropolitan subregion with 22% of the total population, the Great Basin subregion (19.7%), the Nevada metropolitan subregion (18.7%), and the Rocky Mountain subregion (18.2%). Within the minority population group, the Hispanic (15.6%), American Indian (3.7%), and black (2.7%) populations were present in significant numbers. These three minority groups were distributed somewhat unevenly across the affected area, with Hispanics making up 38.4% of the population in the New Mexico metropolitan subregion, 24% in the Rocky Mountain subregion, and 20% in the High Plains subregion. Smaller concentrations of Hispanics occurred in the Arizona metropolitan (18.7%), Great Basin (11.6%), and Nevada metropolitan (11.2%) subregions. The American Indian population was concentrated primarily in the Great Basin (13.6%) and Rocky Mountain (9.5%) subregions, with smaller concentrations elsewhere in the affected area. The black population was more concentrated in the Nevada metropolitan subregion (9.5%), with smaller populations in the Arizona (3.4%) and Colorado metropolitan (3.2%) subregions.

3.1.3 Electric Power Marketing Baseline

Utilities that could be affected the most by changes in Western's commitment-level alternatives and dam operations include Western's preference customers and the systems that are directly interconnected with those customers. These utilities range in size from small municipalities to large investor-owned utilities that have service territories spanning several states. In general, the larger utilities tend to own their electricity-generating resources and transmission capabilities. Smaller systems have very limited or no generating resources and rely principally on purchases to meet load. Many of these systems have formed associations.[7]

For purposes of this analysis, utilities were grouped by level of reliance on Western power and by ownership type. The level of reliance on Western power consists of high and low categories. A utility was defined as having "high" reliance on Western power if more than 25% of its total system load is met by Western sources. If 25% or less of a utility's load is served by Western sources, it was categorized as having a "low" reliance level. Within each of the reliance categories, utilities were further disaggregated according to whether they are municipal or cooperatively owned.

Table 3.6 provides some detail on the categorization of the utility systems. The total load served by the low-reliance utility systems is slightly more than 2,650 MW. Municipals account for 680 MW of this total. Approximately 6% of their average energy is served by Western. Cooperatives serve the remaining 1,970 MW of load, with 12% of their energy served by Western. The high-reliance utilities serve approximately 750 MW of load.

TABLE 3.5 Distribution of Minorities by Subregion, 1990

Sub-regiona	Hispanicb	Black	American Indian	Asian & Pacific Islander	Other	Total Minority Population	Total Population
1	542,822 18.68%	98,700 3.40%	69,132 2.38%	48,760 1.68%	277,153 9.54%	493,745 16.99%	2,905,360
2	237,110	70,236	14,584	46,117	86,336	217,273	2,218,731
3	10.69% 82,904 11.18%	3.17% 70,738 9.54%	0.66% 6,416 0.87%	2.08% 26,043 3.51%	3.89% 35,604 4.80%	9.79% 138,801 18.72%	741,459
4	229,257 38.36%	13,910 2.33%	19,244 3.22%	8,327 1.39%	90,240 15.10%	131,721 22.04%	597,620
5	70,452 5.27%	10,838 0.81%	10,250 0.77%	29,556 2.21%	31,495 2.36%	82,139 6.15%	1,335,817
6	2,252 3.68%	458 0.75%	404 0.66%	280 0.46%	761 1.24%	1,903 3.11%	61,226
7	168,247	12,401	13,759	4,775	75,817	106,752	839,708
8	20.04% 238,407	1.48% 13,294	1.64% 94,232	0.57% 6,997	9.03% 66,188	12.71% 180,711	995,372
9	23.95% 158,588 11.60%	1.34% 9,252 0.68%	9.47% 186,250 13.62%	0.7% 9,806 0.72%	6.65% 64,534 4.72%	18.16% 269,842 19.73%	1,367,451

[a] 1 = Arizona Metropolitan Subregion, 2 = Colorado Metropolitan Subregion, 3 = Nevada Metropolitan Subregion, 4 = New Mexico Metropolitan Subregion, 5 = Utah Metropolitan Subregion, 6 = Wyoming Metropolitan Subregion, 7 = High Plains Metropolitan Subregion, 8 = Rocky Mountain Subregion, 9 = Great Basin Subregion.

[b] Persons of Hispanic origin may also be included in the totals for any population group.

Sources: U.S. Bureau of the Census (1991a-c).

TABLE 3.6 Power Marketing Utility Categories

Utility Category	Number of Utilities	Total Load (MW)	Average % Load Served by Western
Low reliance Municipals Cooperatives	22 56	680 1,968	6 12
High reliance Municipals Cooperatives	54 11	541 215	47 32
Total	143a	.	.

[a] This total of 143 utilities is less than the 183 customers served by the SLCA/IP resource. The additional 39 customers are nonutilities such as Federal installations, state universities, irrigation districts, and others.

Source: Bodmer et al. (1995).

Municipals account for 541 MW, with 47% of their energy being provided by Western. Cooperatives account for the remaining 215 MW. Approximately 32% of their load is served by Western.

Average retail rates for each of the utility categories are presented by state in Table 3.7. The values presented represent estimates of the rates that are forecasted to exist under baseline conditions for the years 1993, 2000, and 2008. To facilitate comparison over time, all values have been indexed to 1994 prices. As the data indicate, rates charged by the low-reliance utilities are predicted to remain fairly stable over the forecast period. The major exceptions include Nevada and Utah, where rates are predicted to increase by approximately 53%, and Colorado, where rates are predicted to fall by approximately 23% over the forecast period. In the case of the high-reliance utilities, rates charged by municipals are predicted to increase somewhat, while the rates charged by the cooperatives are generally predicted to decrease.

As was discussed in Chapter 2, the coverage ratio is a commonly used indicator of the financial viability of a utility. Table 3.8 provides data on the number of firms with coverage ratios of varying magnitudes. In this case, the disaggregation has been limited to whether a utility has a low or high degree of reliance on Western. According to the data in Table 3.8, almost half of Western's customers currently have coverage ratios of less than 2.0. About a quarter of the utilities in each category have coverage ratios of less than 1.2.

TABLE 3.7 Average Retail Rates by State and Utility Size - 1993, 2000, 2008

Utility Category	Average Retail Rate (1994 $/MWh)			
	Low Reliance		High Reliance	
	Municipals	Cooperatives	Municipals	Cooperatives
Arizona				
1993	106	69	43	90
2000	107	63	53	81
2008	105	73	60	73
Colorado				

1993	56	86	54	NA[a]
2000	63	76	64	NA
2008	57	66	71	NA
New Mexico				
1993	75	73	91	90
2000	68	74	97	81
2008	65	74	99	73
Nevada				
1993	NA	72	NA	NA
2000	NA	94	NA	NA
2008	NA	110	NA	NA
Utah				
1993	75	72	73	64
2000	72	94	76	87
2008	67	110	73	102
Wyoming				
1993	65	69	NA	NA
2000	72	67	NA	NA
2008	66	63	NA	NA

[a] Not applicable.

Source: Bodmer et al. (1995).

TABLE 3.8 Baseline Coverage Ratio (CR) by Reliance Level

Utility Category/ Coverage Ratio	Number of Utilities
Low Reliance CR < 1.1 1.1 < CR < 2.0 CR > 2.0	5 7 10
High Reliance CR < 1.1 1.1 < CR < 2.0 CR > 2.0	3 5 13

Total[a]	43

[a] The number of systems in this table differs from the number of systems shown on the rate impact table. For financial impact purposes, only independent financial entities were modeled. For example, Tri-State was modeled rather than its members because the principal financial impacts accrue to Tri-State as a generation and transmission cooperative.

Source: Bodmer et al. (1995).

3.2 AIR RESOURCES

3.2.1 Climate and Meteorology

The six-state study region includes Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming. The climate of this region is characterized by low precipitation, low humidity light winds, and highly variable (but generally warm) temperatures. All of these parameters vary greatly with topography and latitude. Summer thunderstorms with heavy downpours and strong winds contribute most of the total annual precipitation in the northern part of the region. Winter storms are important contributors to annual precipitation in the southern part of the region. A discussion of climate in the region is provided in Appendix B, Section B.1.1.

3.2.2 Air Quality

The six-state study region enjoys generally good air quality, with a large number of Class I areas where air quality degradation is stringently limited under the Prevention of Significant Deterioration regulations (Appendix B, Figure B.11). Many major population centers are located in the region, including Phoenix and Tucson, Arizona; Denver and Colorado Springs, Colorado; Albuquerque, New Mexico; Las Vegas, Nevada; and Salt Lake City, Utah. These population centers and some of their suburbs are designated as nonattainment areas with respect to one or more of the National Ambient Air Quality Standards (NAAQS) (40 CFR 50). All remaining areas of the region are designated as either in attainment or unclassified with respect to all criteria pollutants. A list of the NAAQS and State Ambient Air Quality Standards (SAAQS) for each of the six states in the study region is given in Appendix B, Table B.1; nonattainment areas within the six-state study region are listed in Table B.2, and their locations are shown in Figure B.2.

Nonattainment areas that are not associated with large population centers include (1) those for total suspended particulates (TSP) (Trona Industrial Park in Wyoming and the Grand Junction area in Colorado), where high levels of dusts are emitted from sources such as unpaved roads and road sanding in winter, and (2) those for sulfur dioxide (SO2) and/or TSP, which involve a number of small cities in Arizona with large power-generating facilities or mining operations. (These cities are all located in the southernmost part of the state except for Joseph City, which is located in the northeastern quadrant of the state.)

The electric utility sector is a major contributor to the overall human-produced air pollutant emissions within the six-state study region. The location, name, capacity, and type of major electric power plants within the study region are shown in Figure B.1. Annual emissions from the region's utilities of SO_2 and nitrogen oxides (NO_x), the precursor pollutants for acid deposition and visibility impairment, represented approximately 49 and 56%, respectively, of the region's total human-produced emissions of these pollutants in 1990. However, the utility sector contributed only small amounts of TSP and volatile organic compounds (VOCs) (Appendix B, Table B.3). Annual emissions of carbon dioxide (CO_2), a greenhouse gas, from the electric utility sector accounted for a significant portion (36%) of the region's total human-produced emissions in 1990, but represented only a small fraction (2%) of the emissions of the United States as a whole (Appendix B, Table B.4).

Ambient air quality data from the monitoring stations located within the study region for 1987-1990 show that, except for scattered industrial sites and the major cities of the region, the air quality in the basin is quite good (Arizona Office of Air Quality 1988-1991; Colorado Air Pollution Control Division 1988-1991; Clark County Air Pollution Control Division 1991; Nevada Bureau of Air Quality 1989; State of New Mexico Air Quality Board 1990, 1991; Utah Bureau of Air Quality 1991; Wyoming Air Quality Division 1988-1991). During this period, nitrogen dioxide (NO_2) and lead

(Pb) levels were substantially below the NAAQS throughout the region. Carbon monoxide (CO) levels remained fairly constant in the major cities of the region over the same period. Regionwide, ozone (O_3) concentrations slightly decreased, but SO_2 and PM concentrations slightly increased. Figures B.3 through B.9 in Appendix B show the location of all ambient air quality monitoring stations reporting to the six states in 1989 and indicate which stations reported ambient concentrations in exceedance of the applicable standards for that year.

Visibility impairment is caused by light scattering and absorption by particles (primarily fine particles), and, to a lesser extent, NO_2 present in the lower atmosphere. The largest single factor controlling the seasonal and long-term variations in visibility in the Colorado River Basin is the concentration of fine, airborne sulfate aerosols (Malm 1989). The region's four largest sources of fine sulfates identified by the National Park Service (NPS) for 1983-1985 were, in descending order, Southern California, Monterrey (Mexico), the coal-burning generating stations in the Four Corners [8] region, and the copper smelters in southeastern Arizona and in New Mexico (Malm et al. 1990). It is now widely recognized that carbonaceous particles such as soot also play an important role in impairment of visibility. However, the dominant source categories of carbonaceous particle emissions are on-road and off-road mobile sources and residential fuel combustion sources. Electric utilities are a very minor source of carbonaceous particles.

Regional visibility in the six-state study region is currently the best in the contiguous United States. The Four Corners region has a summer visibility of over 120 mi (Appendix B, Figure B.10). Except for Arizona, the remainder of the study region has summer visibility above 110 mi. In Arizona, the summer visibility decreases from 120 mi in the northeast corner to 60 mi in the southwest corner bordering California. Throughout the region, visibility varies greatly with the seasons. In winter, visibility is approximately 1.5 times better than in the summer. Long-term trends for the region indicate that, overall, visibility has decreased since the mid-1950s, with some recovery made during the 1970s and essentially no change in the 1980s (Malm 1989).

3.2.3 Acoustic Environment

The principal noise sources at Western's major hydroelectric generating plants (Glen Canyon, Flaming Gorge, and Blue Mesa, Morrow Point, and Crystal of the Aspinall Unit) include turbine generators, step-up transformers, and substation transformers. Because turbine generators and step-up transformers are located near canyon bottoms and because the turbine generators are also enclosed inside concrete plant buildings,[9] they contribute minimally to the environmental noise levels in areas beyond the canyon rims. Section B.1.3 contains a description of the acoustic environment in facility areas.

3.3 WATER RESOURCES

Important water resource parameters for Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit include flow, stage (water elevation), sediment, temperature, and floodplains. For each facility in this EIS, an affected environment was defined consistent with the anticipated impacts of the hydropower operational scenarios. The hydrological parameters of interest for Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit are discussed in Sections 3.3.1, 3.3.2, and 3.3.3, respectively. A brief description of the geology near each facility is provided for context.

3.3.1 Glen Canyon Dam

Glen Canyon Dam is part of the Colorado River Storage Project (CRSP) and serves the CRSP through storage and release of water from Lake Powell. Glen Canyon Dam is located on the Colorado River about 15.5 mi upstream of Lees Ferry, Arizona (Figure 3.2). The drainage area for the river is shown in Figure 3.3. The EIS for operation of Glen Canyon Dam (Reclamation 1995) includes a description of an affected environment that extends from Lake Powell to Lake Mead. Lake Powell, however, was not included in the affected environment for this Power Marketing EIS because hydropower operational scenarios would not affect it.

The Colorado River in northern Arizona is located on the Colorado Plateau in an area of nearly horizontal sedimentary rocks that generally are more than 5,000 ft above mean sea level (MSL). The Colorado River and its tributaries have eroded large quantities of material from the plateau. This erosion, in conjunction with other natural weathering processes and geologic uplift, have carved the Grand Canyon, which is more than 1 mi deep and ranges in width from about 600 ft at river level to 18 mi on the rim. In cutting the Grand Canyon, the Colorado River has exposed rocks of all known eras of geologic time, recording a span of nearly two billion years.

The rocks in the Grand Canyon can be classified in five distinctive groups or sequences. The upper, youngest rock sequence is of Cenozoic age. Older sediments record pre-Grand Canyon environments. Younger deposits of travertine and lava have been forming as the Grand Canyon is carved. The second sequence is of Mesozoic age and is exposed around the northern and eastern margins of the canyon. These rocks were deposited between 60 and 230 million years ago during the Age of the Dinosaurs. As the Mesozoic Era ended, disturbances began to raise both the Rocky Mountains and the Colorado Plateau. The third sequence of rocks in the Grand Canyon is of Paleozoic age and is exposed as horizontal sedimentary beds at river level upstream of the mouth of the Little Colorado River and throughout the canyon walls. These rocks were deposited between 270 and 545 million years ago. In this sequence, the harder sandstone and limestone layers form vertical cliffs, and the slopes between the cliffs are composed of softer shale beds. The fourth sequence of rock is exposed only in the eastern Grand Canyon, where layers of sediment and lava record events involved in formation of the North American west coast in late Precambrian time, 1,250 to 725 million years ago. The oldest sequence of rocks in the Grand Canyon is also of Precambrian age, which occurred 2,000 to 1,400 million years ago. It occurs as granite, gneiss, and schist that make up large portions of the Upper, Middle, and Lower Granite gorges. This sequence was deposited as lava flows, limestone, silt, and sand and metamorphosed to its present state as the region was "welded" onto the North American continent.

FIGURE 3.2

FIGURE 3.3

3.3.1.1 Flow and Stage

Before Glen Canyon Dam was constructed, flow in the Colorado River below the dam was unregulated and variable

(Figure 3.4); annual peak flows averaged 93,400 cubic feet per second (cfs) between 1921 and 1962. The lowest recorded flow of 700 cfs occurred in December 1924 (Carothers and Brown 1991). The average annual minimum flow was about 4,000 cfs. The average yearly flow in the Colorado River at Lees Ferry for the period 1922 through 1990 was about 11.3 million acre-feet (maf). Although the range in river flows varied widely on an annual and seasonal basis, daily fluctuations (difference between maximum and minimum daily flow) and hourly changes in flow were small before dam operations, except during flood events.

Upon completion of the dam in 1963, flow in the Colorado River below the dam became regulated and ranged from about 1,000 to 60,200 cfs between 1963 and 1980 (Figure 3.4) when Lake Powell filled (Reclamation 1990a). After Lake Powell filled in 1980, excess water storage capacity was eliminated, and spring releases of greater than 31,500 cfs became more frequent. From June 1983 to July 1986, higher than normal peak flows occurred because of wet weather. A peak flow of 92,600 cfs occurred on June 29, 1983.

Water from the dam can be released in three ways: normal power plant releases (up to 31,500 cfs); bypass water releases through the river outlet works (15,000 cfs capacity); and spillway releases (208,000 cfs capacity) (Reclamation 1995). The combined release capacity is 256,000 cfs but is never expected to exceed 180,000 cfs. Although the maximum combined release capacity of the eight turbines at Glen Canyon Dam is about 33,200 cfs, past releases have been limited to 31,500 cfs (Reclamation 1995). Release schedules for dam operations vary greatly on an annual basis, but a minimum yearly release of 8.23 maf is legally required, and when releases are to be greater, a storage equalization must be maintained between Lake Powell and Lake Mead to satisfy legal requirements.

Power demand and associated water releases are highest during the summer and winter months. For low-, moderate-, and high-release years, the monthly release for August corresponds to about 0.9, 1.3, and 1.7 maf, respectively (Reclamation 1995). Lowest monthly releases occur in the fall (October) and are about 0.6, 1.2, and 1.6 maf, respectively (Reclamation 1995). Maximum and minimum daily flows for selected low-, moderate-, and high-release years are plotted in Figure 3.5.

Hourly releases are set to achieve monthly release volumes, to maintain established release restrictions, and to complement the pattern of energy demand (Reclamation 1995).

FIGURE 3.4

FIGURE 3.5

Historically, minimum releases were generally 1,000 cfs during the winter (Labor Day through Easter) and 3,000 cfs in summer. Dam releases for power have ranged from the minimum release to a maximum value of 31,500 cfs. In general, releases were maximized during peak energy demand periods - Monday through Saturday between 7 a.m. and 11 p.m. The ranges of daily fluctuations for Glen Canyon Dam releases during 1966-1989 for months having the greatest range in daily flow (July, December, October, and April) are shown in Figure 3.6 (Reclamation 1995). Hourly release patterns for a typical day with high, moderate, and low fluctuations are shown in Figure 3.7.

Between Glen Canyon Dam and Lake Mead, the Colorado River drops about 1,900 ft in a series of pools and rapids, from an elevation of 3,100 to 1,200 ft (Reclamation 1995). More than 100 rapids account for most of this change in elevation. The average slope of the river (change in elevation per distance) is about 8 ft/mi (Reclamation 1995); in rapids, the slope may be 10 times steeper. In contrast, low-slope (0.5 ft/mi), low-velocity areas exist between rapids where water moves slowly across deep pools (Reclamation 1995). In both narrow and wide reaches, channel characteristics change in the vicinity of rapids that are formed at the mouths of steep tributaries. The channel is shallower, narrower, and steeper near the rapids than it is upstream or downstream. The channel bed in the vicinity of rapids is composed primarily of boulders.

The time for a 15,000-cfs discharge to travel from Lees Ferry to Lake Mead has been estimated at 104 hours (2.3 mph) (Reclamation 1995). Peak releases travel downstream as an identifiable wave. For fluctuating flows, wave peaks travel faster than wave troughs, eventually overrun them, and catch up with preceding wave peaks. This process causes a dampening of the amplitude of the release and an increase in the minimum flow (Reclamation 1995). Thus, farther downstream, fluctuations in flow and stage are less than at the dam.

3.3.1.2 Sediment

Sediment below Glen Canyon Dam includes suspended solids (sand and silt) in the Colorado River and its tributaries, as well as deposits on the river bottom and banks that include silt, sand, gravel, cobble, and boulders. For this EIS, the most important sediment is sand because the smaller silts move through the system to Lake Mead and are largely unaffected by dam operations whereas the larger sediments are only moved by large flood events. The most important section of the Colorado River in terms of hydropower impacts on sediment is found between the confluence of the Paria River and the Little Colorado River. Upstream of the Paria River, most fine riverbed and bank sediments have been removed by high-velocity water, although some large terraces of fine sediments still exist in this reach. Below the Little Colorado River, sediment and river flow are nearly in equilibrium, so there is no net erosion or aggradation of the riverbed and banks (Reclamation 1995).

Sediment deposits of concern and related physical processes are illustrated in Figures 3.8 and 3.9, respectively. Debris flows (moving rocks, sand, and clay containing less than 40% water by volume) move downstream in tributaries until the main channel of the Colorado River is reached. When the debris flows reach the main channel, they form a debris fan - a sloping mass of boulders, sand, silt, and clay formed at the mouth of a stream valley.

FIGURE 3.6

FIGURE 3.7

FIGURE 3.8

FIGURE 3.9

At the upstream edge of the debris fan (Figure 3.9), a sand deposit (separation bar) can be formed by current in the main channel. The projection of the debris fan into the main channel results in a zone of recirculating water, with well-defined eddy currents (currents of water moving against the main current in the river channel with a circular motion) just beyond the point of separation. Downstream of the recirculation zone, the current reattaches to the river bank at the reattachment point (Figure 3.9) and forms another sand deposit (reattachment bar). The region between the separation and reattachment points can be an important backwater area for Colorado River fish. If the sand deposits associated with the debris fan are large enough for camping, they are referred to as beaches. The height of the sand above the river level is an important consideration for recreation and ecology. In addition to deposits associated with debris fans, deposits of sand (channel margin bars) (Figure 3.8) often continuously line the edge of the river in wide regions. These bars are deposited by currents in the main channel of the river and are associated with small, local eddies.

Since completion of Glen Canyon Dam in 1963, the average quantity of sand (load) passing the Bright Angel Creek confluence (Phantom Ranch) has decreased from 85.9 to 11 million tons per year (Reclamation 1995). This decrease in load occurred because the dam removes sediment from the water (Williams and Wolman 1984), thereby decreasing the amount of sediment available for transport.

Tributaries now supply most of the sediment to the Colorado River below Glen Canyon Dam. About 70% of the sediment load is delivered by the Paria and Little Colorado rivers, although this sediment contribution varies from year to year. For example, the total sand load in the Paria River at Lees Ferry was estimated to be 4.0 million tons in 1980 and 0.13 million tons in 1985 (Reclamation 1995). Debris flows in other, ungaged tributaries also contribute sand to the Colorado River downstream of Glen Canyon Dam (approximately 0.7 million tons per year). However, the quantity of sediment delivered by debris flows is highly variable in terms of magnitude and frequency.

Sediment may go through numerous cycles of temporary deposition, erosion, and transport while moving downstream. The bed of the river is composed of bedrock, boulders, cobbles, gravel, and sand. The location of these materials depends on the local river velocity, geology, and supply of incoming sediment. During periods of low flow, sediment is stored in pools and eddies. During high flows, some sand is transported downstream, whereas other sand is deposited on beaches and channel margin bars. In general, net erosion decreases downstream because of attenuation of the daily extremes in water levels and the addition of sand from tributaries.

The amount of sediment that water can transport is proportional to the flow in the river raised to the third or fourth power. Fluctuating flows transport more sediment than steady flows of the same volume because fluctuating flows are higher than steady flows during a portion of each day. Sand loads for historical steady and fluctuating releases having the same daily volume were calculated with a model developed for the Glen Canyon Dam EIS (Reclamation 1995). The results of the computations are listed in Table 3.9 for three U.S. Geological Survey (USGS) gaging stations on the Colorado River. For all three gages, fluctuating flows increased the sediment load by about 70% relative to steady flow conditions.

Following construction of the dam, beaches underwent a process of net erosion beginning in 1965 - especially between the dam and Lees Ferry, a reach with no major tributaries. These deposits stabilized by the late 1970s. Between 1974 and 1982, some beaches lost up to three vertical feet, while others gained one to two vertical feet. Overall, slightly more sand was lost than gained, suggesting a slow and gradual depletion of sand from the beaches studied (Reclamation 1995). After the high flows of 1983 and 1984, beach deposits changed appreciably. Major deposition occurred on upper terraces, whereas lateral erosion cut the lower faces of the beaches. Between October 1985 and January 1986, high rates of bank erosion were observed during 3.5 months of fluctuating releases, especially during the return to lower fluctuations (Reclamation 1995). Since 1986, erosion rates have decreased and sandbars have stabilized at levels similar to those of the 1970s.

Dam operations also affect debris fans at tributary confluences. Flows within power plant capacity remove some of the smaller sediments deposited in the main stem of the river. However, very large flood flows are needed to remove large boulders from debris fans, to increase the width of the channel, and to decrease the elevation drop (Reclamation 1995). For example, the Bright Angel Creek debris flow of 1966 deposited a large quantity of material in Bright Angel Rapid (confluence of Bright Angel Creek and the Colorado River) that was not removed by flows in the range of normal operations. However, the flood flows of 1983 returned the rapid to pre-1966 conditions.

TABLE 3.9 Computed Colorado River Sand Loads for Steady and Fluctuating Flows

Release Pattern	Sand Load (tons/day)		
	Lees Ferry	Little Colorado River Confluence	Phantom Rancha
Steady flow (15,700 cfs)	200	1,500	3,100
Fluctuating flow (3,600 to 23,700 cfs)	340	2,500	5,100
Percent increase over steady flow	70	67	65

[a] Located near the confluence of Bright Angel Creek.

Source: Reclamation (1995).

Like the sand deposits downstream of Glen Canyon Dam, the delta in Lake Mead can be affected by dam operations over the short term, particularly the frequency, duration, and magnitude of fluctuating flows (Reclamation 1995). Higher levels and durations of fluctuations increase the rate that sediment is delivered to Lake Mead and, therefore, increase the height and extent of the delta, as well as its rate of growth. However, over the long term, operations do not affect the amount of sediment reaching Lake Mead (Reclamation 1995).

3.3.1.3 Temperature

Seasonal water temperatures in the Colorado River varied from about 32° to 82°F for the period 1949-1962 prior to completion of the Glen Canyon Dam (Reclamation 1995). Since the dam was completed, maximum water temperatures have decreased and minimum temperatures have increased (ranging from 43° to 54°F). For the months of May through October 1977-1983, river water temperatures at the USGS gaging station at Lees Ferry averaged about 46°F.

Water temperature in the river increases slightly in a downstream direction, but seldom exceeds 60°F even 240 mi downstream (Reclamation 1995). Temperature variations over short distances are related to the location of the site and fluctuations in water levels. Shallow near-shore areas tend to be a few degrees warmer than deeper mid-channel sites. Lower temperatures are associated with high flows; higher temperatures are associated with low flows.

3.3.1.4 Floodplains

No floodplain maps exist for the area below Glen Canyon Dam. Such maps are generally produced for flood insurance purposes, which are unimportant for unpopulated regions. A 100-year flow was estimated with Gumbel's extreme value recurrence method (Viessman et al. 1977) and the maximum annual daily flows recorded at the Lees Ferry USGS gaging station between 1963 and 1990. The 100-year flow predicted by this model for post-dam conditions is 91,400 cfs. The highest recorded flow for the post-dam period occurred on June 29, 1983 (92,600 cfs). Because the 100-year flow is very similar to the maximum recorded post-dam flow, for this Electric Power Marketing EIS the 100-year floodplain was assumed to correspond to the high water level of the 1983 maximum flow.

3.3.2 Flaming Gorge Dam

Flaming Gorge Dam is part of the CRSP. It is located on the Green River about 30 mi north of Vernal, Utah (Figure 3.10). The affected environment for this EIS extends from the dam to the USGS gaging station near Jensen, Utah (about 93 mi downstream of the dam). This reach was chosen to be consistent with the U.S. Fish and Wildlife Service (USFWS) Flaming Gorge Biological Opinion (USFWS 1992b), which specifies that flows must achieve target values at the Jensen gage.

Figure 3.10

The affected environment for Flaming Gorge Dam lies within the Uinta Basin. The Green River cuts into Jurassic and Triassic rocks. The uppermost rocks are Glen Canyon Sandstone; lower lying units consist of shales. Below the dam, the river flows through Red Canyon (see Figure 3.16 in Section 3.3.2.1), which is entirely cut into Precambrian rocks - except at Little Hole where a parklike opening is underlain by the Tertiary Browns Park Formation, a thick fill of gravel, sand, clay, and volcanic ash (Hansen 1975).

In Browns Park, the Green River crosses the Uinta anticline above Swallow Canyon. Lodore Canyon, just downstream of Browns Park, is on the south limb of the anticlinal fold. Lodore Canyon is composed of Precambrian quartzite of the Uinta Mountain Group. Because of the dip in the surrounding strata, the river crosses successively younger rocks en route. At the mouth of the canyon, the river flows on Weber Sandstone, having crossed rocks of Precambrian, Cambrian, Mississippian, and Pennsylvanian age. Below Echo Park, the Mitten Park fault has raised the Precambrian rocks back again above the level of the river.

After meandering through Island Park and Rainbow Park below Lodore Canyon, the Green River flows through Split Mountain Canyon, an eroded anticline. Flowing swiftly over upturned beds, the river passes Jurassic rocks at Rainbow Park onto rocks of Mississippian age in the core of the Split Mountain anticline. On the south flank of this anticline, the Weber sandstone is eroded into an array of buttress-like forms. The river emerges at the mouth of the canyon, 118 mi below its point of entry at Flaming Gorge.

3.3.2.1 Flow and Stage

Before completion of Flaming Gorge Dam in 1963, flow in the Green River was unregulated and fluctuated seasonally on the basis of natural flow cycles. After the dam was completed, flows were restricted within a more narrow range; only two releases in excess of 7,000 cfs have occurred in the past 30 years (Figure 3.11). The presence of the dam has greatly changed the seasonal pattern of flow at Greendale. Historical spring flows that averaged about 7,000 cfs between 1951 and 1962 have been replaced with flows of about 3,000 cfs (Smith and Green 1991).

Figure 3.11

Water releases from the dam for power generation have ranged from 800 to 4,200 cfs, although a rewind of the system's generators allows water releases for power generation up to 4,950 cfs. The maximum power release is constrained by the size of the turbines, whereas the lower bound (800 cfs) is set by an agreement with the state of Utah to maintain a high-quality, coldwater fishery (Smith and Green 1991). An additional 4,000 cfs of water can be released through steel-lined jet tubes, and 28,800 cfs can be discharged over the spillway. Flows greater than 4,950 cfs are referred to as spills and produce no power in excess of the operating capacity.

Daily releases from the dam can vary from 800 to 4,950 cfs to meet power commitments. Figure 3.12 illustrates maximum and minimum daily water releases for moderate (1987), dry (1989), and wet (1983) water years. Maximum daily fluctuation exceedance curves for these years are shown in Figure 3.13. These three water years (October through the following September) were selected for this EIS because they are representative of different hydrological conditions. Less than ten years of hourly flow and release data were available for analysis. Water years 1983 and 1989 represented the wettest and driest years for which data were available and were deemed appropriate for the analysis because of the desire to represent extreme, worst-case conditions.

Flow-exceedance curves for historical water releases from Flaming Gorge Dam are shown in Figure 3.14 for water years 1983, 1987, and 1989. The lowest flow recorded is 800 cfs (Smith and Green 1991). For the selected dry year (1989), flow was maintained near 800 cfs for approximately 75% of the time and only exceeded 2,000 cfs approximately 10% of the time. For the selected wet year (1983), flow exceeded 4,000 cfs approximately 80% of the time and was in excess of 8,000 cfs approximately 30% of the time.

Daily fluctuations are greatest during a moderate water year (Figure 3.12). For a dry year, releases are nearly constant at a minimum value (approximately 900 cfs); whereas for a wet year, releases remain near the maximum value of the turbines to lower the level of water in the reservoir (approximately 4,500 cfs). For a moderate year, the largest fluctuations occur in the winter and spring (Figure 3.12) and range from about 900 to 4,400 cfs.

Figure 3.12

Figure 3.13 and Figure 3.14

Hourly releases within one month are illustrated in Figure 3.15. Dam releases range from about 1,300 to 4,200 cfs, and the water-release pattern is spiked. Below the confluence with the Yampa River, the variations in flow are dampened, and the flow appears to be nearly sinusoidal. During high runoff years, high monthly release volumes correspond with maximum dam release capacity; little daily variation occurs. During low water years, releases are held to a minimum and fluctuations are reduced (Smith and Green 1991).

Figure 3.15

For 1987, flow in the Green River, as recorded at the Jensen gage, ranged from about 1,000 cfs in August to 11,000 cfs in early May. Flaming Gorge usually stores some spring runoff for release in other seasons. Thus, during the spring, most of the flow at the Jensen gage comes from the Yampa River (e.g., during April 1987, about 75% of the flow at Jensen was from the Yampa River). During the fall and winter, on the other hand, the majority of water at Jensen comes from releases at Flaming Gorge Dam (e.g., during February 1987, about 80% of the flow at Jensen was from the dam). In general, yearly flows near Jensen can be characterized as low during the summer, fall, and winter, with a large spring flow associated with high flows on the Yampa River.

For the first 7 mi below Flaming Gorge Dam, the Green River flows through Red Canyon (Figure 3.16), a hard-rock canyon with fast current and moderate rapids. Waters are clear because the dam removes suspended sediment (Williams and Wolman 1984). Bed material in this reach is composed mostly of coarse gravel, cobbles, and boulders (Andrews 1986). The river has a pool-and-riffle form and ranges in depth from about 3 ft in the riffles to 25 ft in the pools; the average slope of the river (change in elevation per distance) is about 8.5 ft/mi (Wheat 1989).

The river changes character abruptly about 2 mi below Red Creek as the canyon opens into Browns Park, about 11 mi downstream of the dam (Figure 3.16). The river meanders through Browns Park (about 36.5 mi), attaining widths of up to 500 ft. Under normal flow conditions, the current is slow and the river is fairly shallow, with depths of about 3 ft; the average slope is about 2.3 ft/mi. Numerous sandbars occur in the reach. The banks of the river are composed of Holocene alluvium (Stephens and Shoemaker 1987), and cutbanks line the channel in the vicinity of channel meanders and valley plain terraces. In Browns Park, the river increases in turbidity as sediment is transported downstream from the bed and banks.

At the Gates of Lodore, 48 mi downstream of the dam (Figure 3.16), the river enters Lodore Canyon in the Uinta Mountains and flows through 19 mi of hard-rock canyon in Dinosaur National Monument. The current is swift and numerous rapids are present; the average slope of the river is 12.7 ft/mi (Wheat 1989). Lodore Canyon ends in Echo Park where the Green River is joined by the Yampa River (about 65 mi downstream of the dam), its main tributary in the study area. At Echo Park, the combined flows of the Green and Yampa rivers enter into Whirlpool Canyon (Figure 3.16). As for Lodore Canyon, the average slope of the river through Whirlpool Canyon is about 12.7 ft/mi (Wheat 1989).

Figure 3.16

Below Whirlpool Canyon, the river meanders through open country in Island Park and Rainbow Park (Evans and Belknap 1973). Many wooded islands are present in this reach as the river flows through the Browns Park Formation of gravels, sand, and clay. Water turbidity is much greater than in Browns Park because of sediment eroded along the flow path and sediment introduced by the Yampa River. At Split Mountain Canyon, the current again quickens as the river flows back into a hard-rock region. The average slope is about 12.7 ft/mi (Wheat 1989). Below Split Mountain Campground, the river enters a cultivated valley and flows slowly for the next 100 mi.

The time for a water wave to travel from Flaming Gorge Dam to Jensen, Utah, is a function of the volume of water released. High flows (4,000 cfs) have a travel time of about 30 hours (3 mph), whereas low flows (1,000 cfs) have a travel time of about 36 hours (2.6 mph). Thus, high flows travel about 20% faster than low flows. Fluctuating flows would travel at an intermediate velocity between the high and low flows because of interference effects (high flows catch up with low flows and pass them).

3.3.2.2 Sediment

Little fine sediment remains in the bed of the Green River between Flaming Gorge Dam and Red Creek near the beginning of Browns Park, and there are few upstream tributaries to contribute suspended sediment loads or debris flows to the main stem of the river. Beginning at Browns Park, the river meanders through a large alluvial plain in which a great deal of sediment is stored. As the river passes through Browns Park, it erodes and carries large quantities of sediment to downstream reaches. In Lodore Canyon, additional erosion occurs; however, because of the influx of sediment from Browns Park, the rate of erosion is lower. At the confluence of the Yampa River, an additional large quantity of sand (approximately 2 million tons annually) is delivered to the system (Elliott et al. 1984), further reducing downstream erosion. By the time the river reaches Jensen, a near equilibrium condition has been established, with no net erosion or aggradation taking place; however, the annual sediment load has decreased by about 54% since construction of the dam (Andrews 1986).

To predict whether the river is likely to develop an equilibrium condition between average discharge and sediment load, two values can be calculated from hourly dam releases: the coefficient of variation and the index of variability (Gordon et al. 1992). Large values of these coefficients indicate that the river is likely to be out of equilibrium and will either erode or aggrade its bed and banks. The values of these coefficients calculated for historical hourly releases are small, indicating that the sediment load in the Green River should be close to equilibrium (Appendix C, Section C.1.3).

Because no gage data are available for flow and sediment at Browns Park, the Engelund-Hansen technique (Appendix C, Section C.1.4) was used to calculate total sediment loads for water years 1987, 1989, and 1983. The results of these calculations are shown in Figure 3.17. Sediment in Flaming Gorge Reservoir is not considered here because such sediment would not be affected by hydropower operations due to the large size of the reservoir - about 3.8 maf (USFWS 1992b). Downstream of Flaming Gorge Dam, the Green River combines with the Colorado River and eventually flows into Lake Powell. Hydropower operations at Flaming Gorge Dam would not measurably affect sediment deposits in Lake Powell because Lake Powell is more than 300 mi downstream of the dam and there are a large number of tributaries that supply sediment to the Green, Colorado, and San Juan rivers.

Figure 3.17

3.3.2.3 Temperature

Before construction of Flaming Gorge Dam, the mean water temperature at the town of Green River, Utah, ranged from about 32° to 72°C (January and July, respectively) during the period 1951 through 1962 (Smith and Green 1991). After completion of the dam, water temperature and water temperature variations decreased in the vicinity of the dam.

In 1978, Reclamation modified the dam's penstocks (10-ft-diameter tubes that carry water from the reservoir to the turbines at the base of the dam) to permit selective withdrawal of warmer water from the reservoir. Steel intake extensions were fastened to the face of the dam, extending down to each of the three fixed-elevation penstock inlets. Shutter gates along the face of each extension could then be opened to withdraw water from selected elevations in the reservoir. For example, in the spring and fall, warmer water is released by withdrawing water from nearer the surface. With the multilevel intake, water temperatures are about the same at the Jensen gage (93 mi downstream from the dam) as they were pre-dam for the same period.

The water temperature measured in 1989 at the Greendale gage station varied from about 39°F in winter to about 60°F in summer (Figure 3.18). At the Jensen gage, the winter water temperatures are about the same as at Greendale; however, the summer temperatures are about 14°F higher (Figure 3.18). This increase in temperature results primarily from warm water input from the Yampa River. No measurements are available to determine the rise in temperature between the dam and the confluence of the Yampa River (65 mi). However, because the slowest travel time for releases is about one day, effects of solar insolation are expected to be small and the change in temperature would be minor.

Figure 3.18

3.3.2.4 Floodplains

No floodplain maps exist for the area below Flaming Gorge Dam because of the low population density. A 100-year floodplain was estimated with Gumbel's extreme value recurrence method (Viessman et al. 1977) and the maximum annual daily flows recorded at the Greendale USGS gaging station between 1963 and 1992. The 100-year water release predicted by this model for post-dam conditions is 12,200 cfs. Floodplains associated with the 100-year flood event therefore correspond very well with the high water levels of the maximum daily release for 1983 (Figure 3.14).

3.3.3 Aspinall Unit

The Aspinall Unit was developed as part of the CRSP to store water for multiple purposes and to generate hydroelectric power. Three dams and hydroelectric power plants along a 40-mi section of the Gunnison River in Colorado are included in the unit: Blue Mesa, Morrow Point, and Crystal. The dams and drainage basin for the Aspinall Unit are shown in Figures 3.19 and 3.20, respectively. For this EIS, the affected environment extends from the headwaters of Blue Mesa Reservoir to Crystal Dam and does not include areas below Crystal Dam because releases from the dam are not controlled to produce hydropower.

Figure 3.19

Figure 3.20

Blue Mesa Dam, constructed in 1965, is located on the Gunnison River about 30 mi below Gunnison, Colorado. Blue Mesa Reservoir has a total capacity of 941,000 acre-feet and an active capacity of 748,000 acre-feet (Reclamation 1983). At maximum water surface elevation, (7,519 ft) the reservoir occupies 9,040 acres and has a depth of 342 ft (Van Buren and Burkhard 1981).

Morrow Point Dam is located 12 mi downstream of Blue Mesa Dam on the Gunnison River and was constructed in 1970. The capacity of Morrow Point Reservoir is 117,910 acre-feet at maximum water elevation (7,160 ft), and the active capacity is 42,120 acre-feet (Reclamation 1983). The surface area for Morrow Point Reservoir is 817 acres at an elevation of 7,160 ft and a depth of over 400 ft (Van Buren and Burkhard 1981).

Crystal Dam, constructed in 1976, is located 6 mi downstream of Morrow Point Dam on the Gunnison River. Crystal Dam Reservoir has a total capacity of 25,236 acre-feet with an active capacity of 12,891 acre-feet at an elevation of 6,755 ft (Reclamation 1983). At that elevation, the reservoir has a surface area of 301 acres. The capacity of Crystal Reservoir is small, and the dam is operated by Reclamation for flow reregulation (smoothing downstream fluctuations) rather than storage. Crystal Reservoir release is generally dictated by the release from Morrow Point Reservoir. Conversely, Crystal Reservoir releases could require corresponding releases from Morrow Point Reservoir. The Gunnison Tunnel is located just downstream of Crystal Dam; it diverts part of the river water for irrigation, usually from March through October. The flow diverted was about 300,000 acre-feet in 1983, 390,000 acre-feet in 1987, and 430,000 acre-feet in 1989 (Lehman 1992). These diverted flows represent about 23% of the river flow during the diversion months for 1983, about 40% for 1987, and 70% for 1989. The remaining water enters the Black Canyon of the Gunnison (Figure 3.20).

The affected environment lies in the transition zone between two physiographic provinces: the Southern Rocky Mountains on the east and the Colorado Plateau on the west. Because no well-defined boundary exists between the two provinces, the affected environment has properties of both (Hansen 1987).

In the area of Blue Mesa and Morrow Point reservoirs, remnants of a broad volcanic cover overlie a crystalline basement. Proterozoic rocks on the shore of Blue Mesa Reservoir at Lake Fork and Cebolla Creek were formed between 570 and 1,600 million years ago. The major physiographic feature of the area is a nearly continuous palisade of resistant volcanic rock 2,000 ft or more above the canyon floor, which gradually climbs higher to the west. Of the many kinds of igneous rocks outcropping from the canyon walls, the most common can be classified as proterozoic granite - i.e., granodiorite, quartz monzonite, and pegmatite (Hansen 1987).

In the area of Crystal Dam, the rims and walls of the canyon are hard crystalline rock. The overlying sedimentary rocks are stripped back because they are less resistant to erosion. They form a subdued outer rim on the north side of the canyon, but this rim is largely removed to the south (Hansen 1987).

During the early and middle Paleozoic (290 to 570 million years ago), a moderately thick blanket of strata (Uncompahgre Highland) accumulated in the area. Beginning in the Pennsylvanian age (300 million years ago), a sharp mountainous uplift halted the deposition and started a long period of erosion that removed the strata. Because of extensive erosion, almost none of this original cover remains (Hansen 1987).

3.3.3.1 Flow and Stage

Before construction of the Aspinall Unit in 1965, flow in the Gunnison River varied greatly, with peak annual discharges of about 12,000 cfs. At times, flow exceeded 19,000 cfs (Hansen 1987). Damming and regulation of the river since the early 1960s have leveled out the flow of water through the area by eliminating former peak flows and adding supplemental flows during low water.

Flows out of Blue Mesa and Morrow Point dams vary seasonally and hourly. Highest flows normally occur in the spring and lowest flows in the summer. In addition to seasonal variations, dam releases are varied on an hourly basis to produce peaking power. Daily release fluctuations are illustrated in Figures 3.21 and 3.22 for Blue Mesa Dam and Morrow Point Dam, respectively, for moderate (1987), dry (1989), and wet (1983) water years. Flows below Crystal Dam vary much less than releases from either Blue Mesa or Morrow Point dams because the Crystal facility is used to reregulate flows Figure 3.23. For Crystal Dam, the lowest flows (500 cfs) occur in fall and the highest flows (2,500 cfs) in spring. Water releases from Crystal Dam are nearly constant on a daily basis. Maximum daily fluctuation exceedance curves for the three dams are shown in Figure 3.24. Daily fluctuations for both Blue Mesa and Morrow Point dams are pronounced, regardless of the wetness of the year.

Figure 3.21

Figure 3.22

Figure 3.23

Figure 3.24

3.3.3.2 Sediment

No beaches are present in the Aspinall Unit, and there are no associated debris flows in the affected area. Water released from one reservoir flows into the headwater of the next over well-armored reaches. Thus, sediment is not an important resource for the Aspinall Unit.

3.3.3.3 Temperature

Before construction of the Aspinall Unit, temperature in the Gunnison River varied seasonally from about 32°F to the upper 60s°F. With completion of the dams, variations in water temperature have been reduced because of the effect of the upstream reservoirs. Temperature profiles were obtained for Blue Mesa Reservoir from July through October 1980 for six locations and various depths (Van Buren and Burkhard 1981). Surface temperatures averaged about 66°F in July. At 100 ft below the surface, the water temperature averaged 52°F. The highest temperatures occurred in summer and then decreased in fall. At Morrow Point Reservoir, three temperature profiles were developed (Van Buren and Burkhard 1981). The highest surface temperatures occurred in July (63°F), whereas the temperature at 100 ft below the surface was lowest (45°F). Temperatures at Morrow Point Reservoir are less than those at Blue Mesa Reservoir because releases from Blue Mesa Dam occur at a depth of 171 ft below the surface where the water temperature is about 18°F cooler than at the surface. Although no temperature measurements are available for water in the Crystal Dam Reservoir or for the water released from the dam, the temperatures should be nearly the same as those for Morrow Point Reservoir.

3.3.3.4 Floodplains

No floodplain maps are available for the Aspinall Unit. A 100-year flow was estimated with Gumbel's extreme value recurrence method (Viessman et al. 1977) and the maximum annual daily flows recorded in the Gunnison River just below the diversion tunnel between 1963 and 1990. The 100-year water release predicted for post-dam conditions is 14,400 cfs. This value was exceeded before dam completion (19,000 cfs) but has not been equaled for the period of record used in the calculation; a maximum flow of 10,600 cfs occurred on June 26, 1983.

3.4 ECOLOGICAL RESOURCES

This section describes the aquatic and terrestrial biotic resources in the vicinity of Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit (Crystal, Morrow Point, and Blue Mesa dams). Topics include fish, aquatic habitats, aquatic food base, vegetation, wildlife, and threatened and endangered species. The scientific names and habitats of species mentioned in the text are listed in Appendix D, Section D.1.

3.4.1 Glen Canyon Dam

This section describes the ecological resources in and along the Colorado River between Glen Canyon Dam and Lake Mead. Resources in Lake Powell above Glen Canyon Dam are not discussed because they would not be affected by hydropower operations.

3.4.1.1 Aquatic Ecology

The construction of Glen Canyon Dam caused dramatic changes in the aquatic ecosystem of the Colorado River below the dam. Before the dam was constructed, productivity of the aquatic food base was very low, primarily because of high turbidity, low levels of light penetration, and large amounts of sand and silt constantly shifting along the river bottom. The filamentous green alga called cladophora (*Cladophora glomerata*) (Section 3.4.1.1.3), which is now present in large beds throughout the river between the dam and Lees Ferry, had a limited distribution in the river before the dam was constructed. Similarly, the small crustacean called gammarus (*Gammarus lacustris*) (Section 3.4.1.1.3) was uncommon and limited in its distribution.

Before construction of the dam, the fish fauna of the river consisted of native and introduced warmwater species, such as the Colorado squawfish, razorback sucker, humpback chub, bonytail chub, carp, and channel catfish. Water temperatures in the main channel varied seasonally from just above freezing up to 85°F (Carothers and Brown 1991), and coldwater species such as trout were confined primarily to a few tributaries. By the time the dam was completed, two introduced species, the carp and channel catfish, were the most common fish in the river. These species may have been important contributors to the decline of several native species (Minckley 1991).

After the dam was finished, the nature of the river changed. Water clarity and light penetration greatly increased, and under daily fluctuations in dam releases, cladophora abundance and distribution increased so dramatically that this species is now considered the foundation for the aquatic food base below the dam. Gammarus underwent a similar increase in abundance and distribution, and is now considered a major food item for a variety of fish, including trout. Water temperatures also changed as a consequence of the dam, becoming very stable and cold. The temperature of water released from the dam has ranged from 43°F to 54°F, with an annual average of about 46°F (Reclamation 1995). River temperatures increase slowly downstream of the dam and rarely exceed 60°F at Diamond Creek, about 240 mi downstream (Reclamation 1995). As a consequence, reproduction by the native and introduced warmwater species virtually ceased in the main channel, and a world-class coldwater trout fishery was established between the dam and Lees Ferry.

3.4.1.1.1 Fish

Thirty-two species of fish (Appendix D, Table D.1) have been reported from the lower Colorado River between Glen Canyon Dam and Lake Mead (Maddux et al. 1987; Carothers and Brown 1991; Minckley 1991). These fish include introduced trout, other introduced species, and native species.

Trout

Trout have been stocked in the Grand Canyon since the early 1920s (Carothers and Brown 1991). Currently, rainbow trout, brook trout, and brown trout occur in the Colorado River below Glen Canyon Dam. The rainbow trout is now the most valued recreational fish in the system and since the late 1970s has replaced the carp as the most abundant fish between Glen Canyon Dam and Lake Mead. Brown and brook trout are also present but are much less abundant than the rainbow trout. Brook trout are most common between Glen Canyon Dam and Lees Ferry and decline in abundance downstream. Brown trout are most abundant in the middle reaches of the river from the Little Colorado River to National Canyon (about 182 mi below the dam), and in some locations (such as near the mouth of Bright Angel Creek) the brown trout may be the dominant fish species (Maddux et al. 1987).

Stocking below Glen Canyon Dam was estimated to account for about 73% of the rainbow trout population in 1985 (Maddux et al. 1987). Preliminary information from more recent trout surveys (1989-1993) indicates that about 78% of the current trout population now results from natural reproduction (Arizona Game and Fish Department 1993). Rainbow trout spawn in the main channel of the Colorado River and its tributaries from November through April, primarily on gravel and cobble bars in shallow water, and most commonly above Lees Ferry (Section 3.4.1.1.2). Rainbow trout also successfully reproduce in many of the major tributaries below Lees Ferry, particularly Nankoweap, Clear, Bright Angel, Tapeats, and Deer creeks (Carothers and Brown 1991). The brown trout, which is typically a fall-spawning species throughout its range, reproduces in winter and spring, primarily in tributaries, while little or no natural reproduction by the brook trout occurs (Maddux et al. 1987). The diets of adult rainbow trout in the Colorado River below Glen Canyon Dam consist primarily of cladophora, aquatic insect larvae, and gammarus (Section 3.4.1.1.3). Early life stages of trout feed primarily on chironomid (midge fly) larvae, zooplankton (microscopic crustaceans that live in the water column), and freshwater worms called oligochaetes (Maddux et al. 1987).

Other Introduced and Native Fish

Introduced fish other than trout have been present in the Lower Colorado River Basin since the late 1800s (Minckley 1991). The present community of introduced fish below Glen Canyon Dam consists of 23 species (Appendix D, Table D.1), and the most common species other than trout are channel catfish, carp, and fathead minnow (Reclamation 1995). These species are most abundant in the middle and lower reaches of the river downstream from the dam, and spawning occurs primarily in the warmer waters of tributaries. Carp comprised 70-80% of all fish collected from 1970 to 1978 (Carothers and Brown 1991). Since then, the abundance of this species has declined dramatically for unknown reasons.

Only five native fish species now occur in the Colorado River between Glen Canyon Dam and Lake Mead - humpback chub, razorback sucker, flannelmouth sucker, bluehead sucker, and speckled dace. Healthy reproducing populations of flannelmouth sucker, bluehead sucker, and speckled dace are present in the Colorado River and its tributaries below Glen Canyon Dam (Maddux et al. 1987; Minckley 1991). The latter two species are most common in the lower reaches of the river and generally are absent from the tailwaters. Highest densities of the speckled dace occur in clear, high-gradient tributaries such as Shinumo and Bright Angel creeks (Carothers and Brown 1991). The flannelmouth sucker is common in the lower reaches of the Colorado River, but is rare in the main channel above Nankoweap Creek during most of the year. Spawning aggregations of this species occur at the mouth of the Paria River during spring and summer (Maddux et al. 1987; Carothers and Brown 1991; Minckley 1991).

Reproduction by bluehead and flannelmouth suckers and the speckled dace occurs primarily in the warm tributaries; cold water temperatures preclude successful reproduction in the Colorado River. Reproduction in the river by the bluehead sucker may be limited to the lowest reaches (from 180 to 240 mi below the dam) (Maddux et al. 1987), where water temperatures are warmer (55-64°F). Backwater areas between the Little Colorado River and Diamond Creek (about 240 mi below the dam) are thought to provide important nursery habitats for these species (Maddux et al. 1987).

The razorback sucker is very rare in the Grand Canyon portion of the Colorado River (Section 3.4.1.3.1). Only 14 specimens have been collected since 1978 (Minckley et al. 1991), and this species was placed on the Federal list of endangered species in 1991. A large population of humpback chub, which is also Federally listed as endangered, occurs in the Colorado River below the dam, centered on the Little Colorado River. The status of the razorback sucker and humpback chub in the river below the dam is discussed in more detail in Section 3.4.1.3.1.

3.4.1.1.2 Aquatic Habitats

Several habitats that are important to fish and that can be affected by hydropower operations have been identified in the Colorado River below the Glen Canyon Dam. These habitats include (1) trout spawning areas in the dam tailwaters, (2) tributaries used by trout and native fish for spawning, (3) backwaters and other quiet water areas along the Colorado River that serve as nursery habitats for native and endangered fish, and (4) the mouth of the Little Colorado River, which serves as a staging and nursery area for the Federally endangered humpback chub and other native fish.

Spawning trout construct nests (called redds) on bars of sediment that occur throughout the Glen Canyon Dam tailwaters. In the past, fluctuating releases, as well as low flows, from the dam have been reported to strand adult trout on these bars and to dewater trout redds, causing complete or near-complete spawning failure in affected areas (Maddux et al. 1987).

Tributaries provide spawning areas for a variety of fish, including rainbow trout, speckled dace, carp, fathead minnow, and bluehead and flannelmouth suckers (Maddux et al. 1987). Species such as brown trout, speckled dace, and the suckers use tributary mouths as staging areas during spawning migrations from the main channel into tributaries. Low flows may hinder access of spawning fish into some tributaries by decreasing water depths at the tributary mouths to levels lower than those navigable by some species (Maddux et al. 1987).

Backwaters and other quiet water areas are important to many warmwater species (Maddux et al. 1987; Carothers and Brown 1991). In summer and autumn, backwater and tributary mouth habitats are typically warmer and have lower current velocities than the main channel. These warmer and calmer areas provide shelter for larval and young-of-the-year fish from cold temperatures and fast currents and thus provide better conditions for growth and survival than does the main river channel. Backwaters (including eddies) also provide important refuges for adult fish from high currents in the main channel. The amount and quality of backwater habitat available to fish depends on a number of interrelated factors, including channel morphology, river flow, river stage, frequency and magnitude of floods, sediment load, and the amount of emergent vegetation present. Fluctuating flows can decrease the quality of backwaters to fish by alternately flushing and draining them. Stabilization of flows could improve habitat quality in the short term but over a long period of time could reduce backwater quality by allowing the encroachment of emergent vegetation. Occasional flood flows may be needed to maintain high-quality backwater areas.

The mouth of the Little Colorado River is a major staging area for the Federally listed endangered humpback chub (Section 3.4.1.3.1) and other fish preparing to enter the Little Colorado River to spawn. This area may also serve as a nursery for larval fish leaving the Little Colorado River (Maddux et al. 1987). The mixing zone at the mouth of the Little Colorado River appears to be an important transition zone for larval humpback chub leaving the warm waters of the Little Colorado River and entering the colder Colorado River.

*3.4.1.1.3 Aquatic Food Base

The base of the aquatic food chain in the Colorado River between Glen Canyon Dam and Lake Mead is dominated by the filamentous green alga cladophora, which attaches to hard substrates such as cobble and boulders; yellow-green algae called diatoms, which live on the cladophora; the small crustacean gammarus; and the larvae of midge flies, which are called chironomids (Maddux et al. 1987; Carothers and Brown 1991). Cladophora serves as important substrate for a variety of aquatic invertebrates and diatoms, which in turn are important food items for aquatic invertebrates and fish. Because of the close association of these food organisms with cladophora, there is a strong positive relationship between the abundance of cladophora and the overall productivity of the riverine food base (Carothers and Brown 1991).

Cladophora is the dominant alga in the upper reaches of the river below the dam. It is particularly abundant above the Paria River and at the mouths of tributaries, where it exists in dense beds in areas with hard substrates. The abundance of cladophora decreases downstream of the Paria River, and a blue-green alga called oscillatoria (*Oscillatoria* sp.)

becomes dominant in the lower reaches of the river (Blinn and Cole 1991; Reclamation 1995). The shift in dominance from cladophora to oscillatoria is probably related to changes in turbidity, light penetration, and water chemistry that occur as a result of tributary inputs to the main channel of the Colorado River (Carothers and Brown 1991). The effect on the food base of this shift is unclear, although the reaches dominated by oscillatoria are much less productive than areas dominated by cladophora.

Most of the algae attached to or living on cladophora, rocks, and other hard surfaces in the river are diatoms, which are used as food by gammarus, fish, and a variety of macroinvertebrates. The diversity of diatoms decreases downstream from the dam (Usher et al. 1987).

Common macroinvertebrates in the river are chironomids, gammarus, snails, freshwater worms called oligochaetes, and blackfly larvae. Gammarus is one of the most important food items for fish below the dam. The abundance of gammarus and other macroinvertebrates in the river decreases downstream from the dam (Leibfried and Blinn 1987). In general, macroinvertebrates are most abundant in the river above the confluence of the Little Colorado River (Leibfried and Blinn 1987).

The zooplankton community below Glen Canyon Dam is not diverse and is derived primarily from the zooplankton community present in Lake Powell (Haury 1986; Maddux et al. 1987; Blinn and Cole 1991). The density of zooplankton in the main channel is relatively constant from the dam to Lake Mead. However, in backwater areas and tributary mouths, the density is greater (Blinn and Cole 1991) and may be influenced by daily changes in flow and stage that result from hydropower operations. In backwaters and tributary mouths, the zooplankton serve as an important food for the larvae of a variety of native and introduced fish (Maddux et al. 1987).

Trout and other fish are known to consume items contained in the sestonic drift (organic material that occurs unattached in the river and is transported downstream by the current) (Reclamation 1988). Although the amount of sestonic drift increases during increasing flows, such as those that occur during flow fluctuations (Leibfried and Blinn 1987), overall productivity of the food base (as measured by cladophora production) is considerably lower in fluctuation zones than in permanently inundated areas. In addition, recolonization of areas in which cladophora becomes dislodged is slower under fluctuating flows (Arizona Game and Fish Department 1993). Tributaries may also serve as sources of macroinvertebrates in the sestonic drift of the main channel when organisms are dislodged by floods or other disturbances in the tributaries (Carothers and Brown 1991). Through the transport of organic material, sestonic drift provides an important connection between the highly productive areas of the Colorado River upstream of the Little Colorado River and the less productive reaches downstream of the Little Colorado River.

3.4.1.2 Terrestrial Ecology

This section describes the vegetation and wildlife in riparian areas along the Colorado River below Glen Canyon Dam. Species and habitats in adjacent upland areas are not discussed in detail because they are neither dependent on nor directly affected by river flow.

3.4.1.2.1 Vegetation

Between Glen Canyon Dam and Lake Mead, the Colorado River crosses three ecoregions - the Colorado Plateaus, Arizona/New Mexico Plateau, and Southern Basin and Range ecoregions (Omernik and Gallant 1987a). The Colorado Plateaus and the Arizona/New Mexico Plateau ecoregions are tablelands with high relief and are vegetated with desert shrubs and grasses. The physiography of the Southern Basin and Range ecoregion is plains with low mountains and supports desert shrubs and cactus.

The riparian habitat between the dam and Lake Mead is the largest protected riparian corridor in the western United States (Anderson and Ruffner 1987). Figure 3.25 depicts existing riparian habitat along the river; this habitat can be divided into an upper and lower zone relative to maximum and minimum power plant releases. Although riparian habitat is considered wetland under the USFWS wetlands classification system (Cowardin et al. 1979), only isolated patches would qualify as jurisdictional wetlands under the U.S. Army Corps of Engineers definition (COE 1987).

Figure 3.25

Before Glen Canyon Dam was completed in 1963, two zones of riparian vegetation occurred along the Colorado River (Anderson and Ruffner 1987; Reclamation 1988). Closest to the river, in the area exposed to annual scouring floods, ephemeral herbaceous and short-lived woody species became established between floods. Above this elevation (about the 90,000-cfs level), the plant community consisted of long-lived shrubs and trees that depended on occasional elevated flows for growth and reproduction (Anderson and Ruffner 1987; Reclamation 1988). This community was dominated by western honey mesquite, catclaw acacia, apache plume, redbud, and netleaf hackberry (Anderson and Ruffner 1987).

FIGURE 3.25

Riparian vegetation in this older community has remained relatively stable since the completion of Glen Canyon Dam (Pucherelli 1986), although the growth of mature trees has slowed (Anderson and Ruffner 1987), and it is expected that this vegetation will eventually be replaced by upland species. An estimated 1,870 acres of pre-dam riparian vegetation exists between the dam and Lake Mead (Reclamation 1995).

Following construction of Glen Canyon Dam, riparian vegetation became established closer to the river. This new vegetation consists of long-lived plant species that grow in the old ephemeral zone at and above the elevation of maximum power plant releases (31,500-cfs; Carothers and Brown 1991). Long-lived species became established at these lower elevations because of the elimination of large annual floods. This new upper zone vegetation is dominated by a mix of native and nonnative species, including tamarisk, desert broom, willows, and arrowweed (Pucherelli 1986). Vegetation in this part of the upper zone occupies about 1,320 acres between the dam and Lake Mead (Reclamation 1995).

Below the upper riparian zone is the area affected by fluctuating releases from the dam (Figure 3.25). This lower riparian zone is comparable to the old flood zone in that periodic inundations prevent colonization by many long-lived plant species. However, within the lower zone, marsh and other vegetation have become established, especially on protected beaches, in backwater areas, and near tributary mouths where fine sediments have accumulated (Carothers and Brown 1991). Common lower zone species include sedges, bulrush, rushes, cattail, scouring rush, and common reed.

After Glen Canyon Dam was completed, the number of marshes along the river increased - from about 10 in 1965 to 65 in 1976 (Stevens and Ayers 1993). Although 95% of these marshes were eliminated during the floods of 1983-1986 (Carothers and Brown 1991), a rapid reestablishment of marsh vegetation has occurred since then, and currently about 1,100 patches (totaling 62 acres) of marsh vegetation occur along the river (Reclamation 1995).

Since institution of interim flows that feature reduced fluctuations (8,000 to 20,000 cfs) in August 1991, the number of small marshes present has increased, especially in backwater areas at the 20,000-cfs level (Wegner 1992). Above that level, marshes appear to be in a drying trend because of the reduction in maximum releases under interim flows.

3.4.1.2.2 Wildlife

Numerous species of nongame wildlife use the riparian habitats below Glen Canyon Dam. In general, these species have responded favorably to changes to the river that have occurred since construction of the dam, and both population size and species diversity is greater now than before the dam was built (Brown 1988; Carothers and Brown 1991). Populations of most species have increased in response to increases in riparian vegetation. These species include many of the birds and small mammals present within the river corridor, including black-chinned hummingbird, common yellowthroat, Bell s vireo, yellow-breasted chat, pinyon mouse, and brush mouse. Other species appear to have responded to increases in insect populations rather than directly to changes in vegetation. Such species include most of the amphibians and reptiles (e.g., red-spotted toad, side-blotched lizard) and some birds (e.g., white-throated swift, violet-green swallow).

Although relatively few ducks and geese use the Colorado River below the dam, their numbers have increased since the dam was built. Most species occur only during migration in the spring and fall (Brown et al. 1984) and concentrate on the river in Marble Canyon (about 20 mi below dam) (Brown et al. 1987). Species occurring during migration include common merganser, green-winged teal, common goldeneye, and bufflehead. Canada goose, ruddy duck, and bufflehead are uncommon winter residents. A few species of ducks and geese breed along the river, but do so rarely; species known to breed there include mallard, green-winged teal, and American coot (Brown et al. 1987).

Shorebirds and herons using shoreline habitats (especially the lower riparian zone) along the river include spotted sandpiper, great blue heron, black-crowned night heron, and snowy egret. Most of these species (except the spotted sandpiper) are present year-round. The spotted sandpiper and killdeer breed along the river and nest on the ground above the high-water line.

Mule deer and bighorn sheep are the only game mammals that occur in riparian habitats below the dam (Carothers and Brown 1991). Both species are relatively common in the area, and no information indicates their populations have been affected by the dam. Mule deer are more prevalent along the forested canyon rim but do move down into the canyon during winter. Bighorn sheep frequent the steep side canyons above the riparian zone and occasionally come to the river to drink and forage, especially during the hotter summer months.

3.4.1.3 Threatened and Endangered Species

This section presents the current status of Federally and state-listed threatened, endangered, candidate, and sensitive aquatic and terrestrial species in and along the Colorado River below Glen Canyon Dam. Definitions of listing categories maintained by the Federal Government and the state of Arizona are presented in Appendix D, Section D.4. Correspondence with the USFWS regarding threatened and endangered species in the area is reproduced in Section D.4.5 of Appendix D.

3.4.1.3.1 Aquatic Species

Four Federally listed endangered aquatic species and one candidate for Federal listing occur or have occurred in the Colorado River below Glen Canyon Dam: humpback chub, bonytail chub, razorback sucker, Colorado squawfish, and flannelmouth sucker (Table 3.10). The occurrence and status of the Federally listed endangered species below the Glen Canyon Dam are discussed in the remainder of this section.

TABLE 3.10 Federally and State-Listed Threatened, Endangered, Candidate, and Sensitive Fish Species below Glen Canyon Dam

Common Name	Scientific Name	Federal Status[b]	State Status[c]	Occurrence within Area
Humpback chub	*Gila cypha*	E	AZ-E	Common in the Little Colorado River and the immediate upstream and downstream portions of the Colorado River (Maddux et al. 1987; USFWS 1990c; Minckley 1991). This is the only known population of humpback chub left in the Lower Colorado River Basin and the largest known population in existence.
Bonytail chub	*Gila elegans*	E	AZ-E	Historically occurred in the Grand Canyon, now extirpated from riverine habitats in the Lower Colorado River Basin (USFWS 1990d).

Colorado squawfish	*Ptychocheilus lucius*	E	AZ-E	Historically occurred in the Grand Canyon, now extirpated from the Lower Colorado River Basin (Minckley 1991; USFWS 1991c).
Razorback sucker	*Xyrauchen texanus*	E	AZ-E	Very rare between Glen Canyon Dam and Lake Mead; fewer than 20 specimens collected since 1978 (Bestgen 1990; Carothers and Brown 1991; Minckley 1991). No recruitment to the adult population in this reach is known to occur (Minckley 1991).
Flannelmouth sucker	*Catostomus latipinnis*	C2	AZ-NL	Rare or absent in the Colorado River above Nankoweap Creek, common in lower reaches (Maddux et al. 1987; Carothers and Brown 1991; Minckley 1991).

[a] List of species derived from USFWS (1991a,c,d); Harris (1991); Spiller (1991); Carothers and Brown (1991); Riley (1992).

[b] Federal listing codes: E = endangered, C2 = category 2 candidate (definitions provided in Appendix D, Section D.4.1).

[c] State listing codes: AZ-E = Arizona endangered, AZ-NL = not listed by Arizona (definitions provided in Appendix D, Section D.4.2).

Humpback Chub (Endangered)

The total population of the endangered humpback chub in the Grand Canyon below Glen Canyon Dam has been estimated at 7,000 to 10,000 adult fish (Minckley 1991). This population, which includes fish in the Colorado and Little Colorado rivers, is the largest self-sustaining population of humpback chubs remaining anywhere in the Colorado River Basin and is the only known reproducing population in the Lower Colorado River Basin. The humpback chub does not occur between the dam and the Paria River, is most abundant around the confluence of the Little Colorado River between 72 and 80 mi downstream of the dam, and has been collected as far as 220 mi downstream of the dam (Maddux et al. 1987; Reclamation 1995). Recently, young humpback chub have been collected in the Colorado River about 180 mi below the dam (Arizona Game and Fish Department 1993). These chub may be the offspring of a second, previously undocumented, population of adult chub or may be individuals originating from the Little Colorado River that have been carried downstream by floods.

The USFWS has designated approximately 379 mi of river in the Upper and Lower Colorado River basins as critical habitat for the humpback chub (USFWS 1994b). The designation includes the lower 8 mi of the Little Colorado River and about 174 mi of the Colorado River between 34 and 208 mi below Glen Canyon Dam.

Within the Colorado River, adult and juvenile humpback chubs are most often associated with eddies and boulder-sand substrates (Maddux et al. 1987; USFWS 1990c; Reclamation 1995), while young-of-the-year fish are most abundant in backwaters and other nearshore areas (such as talus shorelines) with a variety of substrates (Maddux et al. 1987; Reclamation 1995). The number and survival of young humpback chub in backwaters in the Colorado River may be affected by fluctuating flows associated with dam operations (Maddux et al. 1987; Reclamation 1995). Fluctuating flows drain and fill backwaters on a daily basis, and thereby reduce the quality of these habitats for young humpback chub by reducing temperature and food availability. Fluctuating flows may also flush young fish from the relatively sheltered environment of backwaters into the main channel of the river, where the young are exposed to colder water temperatures and higher currents. It is not known if young-of-the-year humpback chub in the Colorado River are important in maintaining an adult population in the river, or if the main channel population is maintained primarily by recruitment from the Little Colorado River.

In the Little Colorado River, spawning occurs from spring (March) through mid-summer (July) (Kaeding and Zimmerman 1983; Maddux et al. 1987; USFWS 1990c), following the peak of spring runoff and at water temperatures between 61° and 68°F (USFWS 1990c). All known successful reproduction occurs in the Little Colorado River (Kaeding and Zimmerman 1983; Maddux et al. 1987; USFWS 1990c). Spawning does not occur in the Colorado

River, apparently because of cold water temperatures. Water is released from the dam at an annual average of about 46°F and rarely exceeds 60°F by the time it reaches Lake Mead (Minckley 1991). Water temperatures of at least 60°F are needed for successful reproduction (USFWS 1990c).

Some young humpback chubs descend the Little Colorado River after hatching and use the mouth of this river as a nursery area (Maddux et al. 1987). When flows in the Colorado River are stable and relatively high, the confluence of the Little Colorado is a quiet, lakelike environment that serves as nursery habitat for young humpback chubs (Kaeding and Zimmerman 1983; Maddux et al. 1987). By autumn, these fish are large enough to ensure overwinter survival in the cold Colorado River (Maddux et al. 1987). Some young-of-the-year humpback chubs enter the Colorado River directly and occupy backwater and other nearshore habitats (Maddux et al. 1987; Reclamation 1995). The survival of these fish and their contribution to the Colorado River population of humpback chub is unknown.

The humpback chub eats a variety of aquatic and terrestrial insects. Below Glen Canyon Dam, the diet of the humpback chub consists principally of chironomids and blackfly larvae (Kaeding and Zimmerman 1983; Reclamation 1995).

Bonytail Chub (Endangered)

Historically, the bonytail chub was present throughout much of the Colorado River Basin, including the Glen Canyon and Lees Ferry reaches in the Lower Colorado River Basin (USFWS 1990d; Minckley 1991). Bonytail chub populations began to decline in the Lower Colorado River Basin early in the 20th century. This species had disappeared from the Salt and upper Gila rivers by the mid-1920s and was all but gone from the Colorado River by 1950, 12 years before completion of Glen Canyon Dam (USFWS 1990d). Today, the bonytail chub is considered extirpated (no longer present) between Glen Canyon Dam and Lake Mead; old individuals are occasionally collected from Lakes Havasu and Mohave (USFWS 1990d; Spiller 1991).

Major factors suggested for the decline of the bonytail chub throughout its historical range have included interactions with introduced fish species, habitat alterations (particularly lower summer water temperatures) caused by dams, water depletions for irrigation, and hybridization with humpback and roundtail chubs (USFWS 1990d).

Colorado Squawfish (Endangered)

The Colorado squawfish was common in the Lower Colorado River Basin until the 1930s, and then the population began to decline. It is considered extirpated in the Colorado River system below Glen Canyon Dam, (Spiller 1991; Tyus 1991a; USFWS 1991b).

The decline of the Colorado squawfish has been attributed to several factors, including habitat fragmentation resulting from dam construction, water withdrawals, altered water temperatures and flow regimes, channelization, and competition with and predation by introduced fish species (USFWS 1991b).

Razorback Sucker (Endangered)

Although once abundant and relatively widespread throughout the Colorado River and the Gila River basins, the razorback sucker is now very rare or absent from most of its former range (Bestgen 1990). The largest known existing population occurs in Lake Mohave below Hoover Dam in Arizona and Nevada; this population is estimated at about 60,000 adults (USFWS 1991c). The USFWS has designated approximately 1,724 mi of river in the Upper and Lower Colorado River basins as critical habitat for the razorback sucker (USFWS 1994b). The designation includes the Colorado River and its 100-year floodplain from the confluence of the Paria River to Hoover Dam, including Lake Mead to the full pool level (USFWS 1994b).

The decline of the razorback sucker throughout its historical range has been attributed to such factors as habitat loss due to dam construction, altered water temperatures, loss of nursery habitats as a result of diking and dam operations, altered flow regimes, changes in water chemistry and turbidity, and competition with or predation by introduced species (Bestgen 1990; Minckley et al. 1991; Tyus and Karp 1991).

The razorback sucker is very rare within the Colorado River between Glen Canyon Dam and Lake Mead and may never have been common in this reach (Minckley et al. 1991). This species persists in the river below Glen Canyon Dam in very low numbers, with only 14 specimens collected since 1979. All individuals that have been collected are adults (Minckley 1991), and apparently no recruitment (addition of new, reproductively capable adults) into this or any other wild population has occurred for more than 20 years. Cold water may prevent successful reproduction and recruitment below Glen Canyon Dam (Minckley 1991).

3.4.1.3.2 Terrestrial Species

Federally listed, state-listed, sensitive, or candidate terrestrial species that are known to occur or could occur along the Colorado River below Glen Canyon Dam are listed in Table 3.11. The table also lists the habitats or locations where those species occur. Federally listed and proposed species are discussed below.

Kanab Ambersnail (Endangered)

The Kanab ambersnail currently is known from only two small populations - one in south-central Utah and one in the Grand Canyon (USFWS 1992a). This small snail occurs in marshes fed by springs and seeps in the vicinity of sandstone or limestone cliffs. It requires a permanently wet soil surface, or shallow standing water, and vegetative cover. Cattails appear to be preferred by this species, but wetland grasses and sedges can also provide suitable habitat. Prior to adoption of interim flows in 1991, the Grand Canyon

TABLE 3.11 Federally and State-Listed Threatened, Endangered, Candidate, and Sensitive Terrestrial Species below Glen Canyon Dam a

Common Name	Scientific Name	Federal Statusb	State Statusc	Occurrence within Area
Plants Grand Canyon flaveria	*Flaveria macdougalli*	C1	AZ-HS	Found in springs and seeps in area; not in danger from dam operations (Stevens and Ayers 1993).
Invertebrates Kanab ambersnail	*Oxyloma haydeni kanabensis*	E	AZ-NL	Found in spring-fed wetland in Grand Canyon above the elevation of 32,000 cfs flows (USFWS 1992a); since establishment of interim flows in 1991, found down to river's edge at the elevation of 20,000 cfs flows.
Reptiles Chuckwalla	*Sauromalus obesus*	C2	AZ-NL	Common in cliff, desert, and riparian areas (Carothers and Brown 1991).
Birds				
White-faced ibis Osprey Bald eagle	*Plegadis chihi* *Pandion haliaetus* *Haliaeetus leucocephalus*	C2 NL T	AZ-NL AZ-T AZ-E	Potential occurrence in riparian marshes during migration (Brown et al. 1981). Potential occurrence along Colorado River during migration (Brown et al. 1981). Winters along Colorado River between dam and Lake Mead (Carothers and Brown 1991).
Northern goshawk	*Accipiter gentilis*	C2	AZ-C	Uncommon in coniferous forests of area (Brown et al. 1981); potential occurrence year-round in riparian woodlands along river.
Peregrine	*Falco*	E	AZ-C	Nests on cliffs along Colorado River between dam and Lake Mead

falcon	*peregrinus*			(Carothers and Brown 1991); some individuals may spend winter in the area (Brown et al. 1984).
Birds (Cont.) Mexican spotted owl	*Strix occidentalis lucida*	T	AZ-T	Potential occurrence year-round in riparian woodlands along river (Riley 1992).
Belted kingfisher	*Ceryle alcyon*	NL	AZ-C	Known to occur along Colorado River between dam and Lake Mead during migration (Brown et al. 1981).
Southwestern willow flycatcher	*Empidonax traillii extimus*	E	AZ-E	Nests in woody riparian vegetation along Colorado River between dam and Lake Mead (Carothers and Brown 1991); riparian areas of Colorado River below dam are proposed critical habitat (USFWS 1993).
Loggerhead shrike	*Lanius ludovicianus*	C2	AZ-NL	Transient in woody riparian vegetation along river between dam and Lake Mead (Brown et al. 1981).
Mammals Spotted bat	*Euderma maculatum*	C2	AZ-C	Recorded in Grand Canyon (Hoffmeister 1986); may forage above Colorado River and in riparian habitat.
Southwestern river otter	*Lutra canadensis sonora*	C2	AZ-E	Historically occurred in area; no recent evidence of occupation (Carothers and Brown 1991; Riley 1992).

[a] List of species derived from USFWS (1991a,d); Harris (1991); Spiller (1991); Riley (1992); Arizona Game and Fish Department (1988).

[b] Federal listing codes: C1 = category 1 candidate, C2 = category 2 candidate, E = endangered, NL = not listed, T = threatened, (definitions provided in Appendix D, Section D.4.1).

[c] State listing codes: AZ-C = Arizona candidate for listing, AZ-E = Arizona endangered, AZ-HS = Arizona highly safeguarded, AZ-NL = not listed by Arizona, AZ-T = Arizona threatened, (definitions provided in Appendix D, Section D.4.2).

population was restricted to a small marsh above the 32,000-cfs level that is fed by springs flowing down the cliff walls. Since interim flows, ambersnails have been found down to the elevation of 20,000 cfs flows.

Bald Eagle (Threatened)

The bald eagle is regularly observed in the winter along the Colorado River below Glen Canyon Dam. Bald eagles occur throughout the river corridor below the dam, but immature eagles concentrate at the confluence of Nankoweap Creek, where spawning trout provide an abundant food supply (Carothers and Brown 1991; Reclamation 1995). Up to 26 eagles have been observed at one time at the confluence of Nankoweap Creek (Reclamation 1995). Use of the river corridor by bald eagles is relatively recent and has occurred as eagle populations have increased throughout the western United States over the past decade.

Nesting by bald eagles has not been observed along the river between the dam and Lake Mead but is possible as evidenced by nesting activity within the region in 1990. Published results of annual bald eagle breeding surveys included 2 nests in Utah along the Colorado River (USFWS 1990a) and 26 nests in Arizona (Kjos 1992).

Peregrine Falcon (Endangered)

The peregrine falcon occurs along the Colorado River between Glen Canyon Dam and Lake Mead. Peregrines prefer high rocky cliffs for nest and perch sites, especially at locations adjacent to large rivers (USFWS 1977). Peregrines are linked to the productivity of the river and riparian ecosystem through their food requirements (Carothers and Brown 1991); they feed predominantly on birds, including ducks, shorebirds, and a variety of songbirds, that they overtake and capture in the air (USFWS 1977). Peregrines may travel up to 17 mi from nesting sites in search of prey (USFWS 1977).

The area below Glen Canyon Dam may support the largest breeding population of peregrine falcons within the contiguous United States (Carothers and Brown 1991); 37 pairs were counted in the river corridor in 1989, and this number apparently represents only a portion of the breeding population. Although peregrines usually occur in the area during the breeding season (March-October), some birds may be present during the winter (Brown et al. 1984).

Mexican Spotted Owl (Threatened)

Mexican spotted owls are rare residents in Arizona. They inhabit old-growth coniferous forest and wooded canyons. They roost during the day in shaded canyon areas or dense canyon trees; at night they hunt wood rats, mice, bats, and occasionally small birds and insects. These owls nest in caves and other cavities in cliffs, tree cavities, and abandoned raven, hawk, and eagle nests. The Mexican spotted owl is a potential year-round resident in the area below Glen Canyon Dam, but the species has not been observed within the area (Riley 1992).

Southwestern Willow Flycatcher (Endangered)

The southwestern willow flycatcher occurs in riparian habitats along rivers, streams, or other wetlands where dense growths of woody species such as coyote willow, desert broom, arrowweed, or tamarisk are present. The southwestern willow flycatcher nests in this habitat along the Colorado River below Glen Canyon Dam; the reach of the river between 55 and 87 mi below the dam has been proposed as critical habitat for this species (USFWS 1993). The number of willow flycatchers nesting in the Grand Canyon increased after construction of the dam because reduced flooding allowed an increase in riparian vegetation along the river (Reclamation 1995). In the 1980s, the population peaked in the canyon at a few dozen pairs; however, the population then began to decline, and in 1991 a survey found only two nesting pairs (Reclamation 1995).

3.4.2 Flaming Gorge Dam

This section describes ecological resources in and along the Green River between Flaming Gorge Dam and Jensen, Utah. Resources in Flaming Gorge Reservoir are not discussed because they would not be affected by hydropower operations.

3.4.2.1 Aquatic Ecology

Before completion of Flaming Gorge Dam in 1962, the Green River exhibited seasonal fluctuations in flow and temperature. Water temperatures in the river ranged from near freezing in winter to greater than 70°F in summer (Holden and Crist 1981). The fish community consisted of both native and introduced species, including several fish that are currently classified as endangered or threatened. Many of these species were successfully reproducing in the river above its confluence with the Yampa River. Trout were absent from this portion of the river (Holden and Crist 1981). The natural flow pattern of the river before construction of the dam (Figure 3.26) featured a large spring peak discharge, which is considered to be important in the reproductive cycles of many of the endangered and threatened species and other native fish.

Figure 3.26

To prepare the future Flaming Gorge Reservoir for the establishment of a trout fishery, the Wyoming and Utah fish and game departments, with assistance from the USFWS, in 1962 undertook a massive poisoning of approximately

440 mi of the Green River and its tributaries (Holden 1991) to remove "trash" fish, such as carp, channel catfish, and redside shiner, as well as native minnows and suckers. The fish poison rotenone was released in the Green River from the headwaters in Wyoming to the present location of Flaming Gorge Dam. Attempts to neutralize the rotenone below Flaming Gorge Dam failed, resulting in mortality of fish as far downriver as the lower end of Split Mountain Canyon. Fish that are currently listed as endangered were eliminated from the Green River above the location of the dam but not below it (Holden 1991).

Following completion of Flaming Gorge Dam, release of cold, clear water from the dam permitted an outstanding trout fishery to become established and eliminated most, if not all, successful reproduction by native fish species. An outstanding trout fishery existed below the dam between 1963 and 1967. However, in the late 1960s and early 1970s, the fishery experienced a dramatic decline, apparently because water temperature dropped below the optimal levels for trout (Holden and Crist 1981). To warm the tailwaters and improve conditions for the trout fishery, the penstock inlets of Flaming Gorge Dam were modified in 1978 (Section 3.3.2.3) to permit the release of warmer water from the reservoir. With the release of warmer water, trout production increased, and the downstream river reach became one of the best trout fisheries in the western United States. Many native fish are absent from the river above the Gates of Lodore because of the cold waters. Natural warming of the water occurs through the Browns Park region, and native fish are present in the river below the Gates of Lodore. Some native species (e.g., speckled dace) may successfully reproduce in the river between Gates of Lodore and the Yampa River confluence, but listed species are not known to reproduce in this reach. The controlled releases from the dam also eliminated spring peak flow in the river above the Yampa River confluence (Figure 3.26). Below the confluence, the Green River is more similar in temperature and flow to pre-dam conditions because of the inflow of the Yampa River.

3.4.2.1.1 Fish

A total of 33 species of fish have been reported from the Green River between Flaming Gorge Dam and Jensen, Utah, and from the lowermost reach of the Yampa River (Appendix D, Table D.2). The fish community below the dam, consisting of trout, warmwater introduced fish, and native species, is strongly affected by water releases from the dam and the inflow of the Yampa River. The Yampa River enters the Green River at Echo Park in Dinosaur National Monument, about 65 mi below Flaming Gorge Dam (Figure 3.16). Above the confluence, the character of the river is strongly affected by the clear, cold water released from the dam, and the fish community in this reach is dominated by trout. Below its confluence with the Yampa River, the Green River becomes warmer and more turbid and exhibits a more natural flow pattern (Figure 3.26). As a result, trout are less common, and native and warmwater introduced species are the major components of the fish community. The lower reach of the Yampa River is also important to the fish community of the Green River because it includes known spawning sites for razorback sucker, Colorado squawfish, and humpback chub, many of which inhabit the Green River below Echo Park as adults and move into the lower Yampa River to reproduce.

Trout

The Green River below Flaming Gorge Dam is considered one of the finest trout fisheries in the West; trout densities between the dam and Taylor Flat (16 mi below the dam) have been estimated to range from 185 to 900 fish per acre (Modde et al. 1991). Trout species in this area include rainbow, brook, and brown trout, as well as several strains of cutthroat trout (Appendix D, Table D.2). The Utah Division of Wildlife Resources currently manages the tailwaters below Flaming Gorge Dam as a "put and take fishery," with 90,000-125,000 fingerling trout (6-in. length) stocked annually since 1985 (Modde et al. 1991). Rainbow, cutthroat, and brook trout are annually stocked in the river between the dam and Little Hole, and some natural reproduction of these species also occurs in this reach (Modde et al. 1991). Brown trout have not been stocked into the Green River for several years, and current populations are sustained through natural reproduction.

Successful natural reproduction by trout in the Green River can be affected by daily, hourly, and seasonal fluctuations in water levels. Spawning trout can become stranded on gravel bars when flows are reduced, although stranding is apparently less common downstream of Flaming Gorge Dam than below Glen Canyon Dam. Exposure of trout eggs to the air can result in partial or complete reduction in emergence. Hourly and daily fluctuations may also affect survival of emergent trout by increasing their movements, which may reduce growth rates and increase susceptibility to predation.

The rainbow trout is the dominant species from the dam to Little Hole, constituting about 50% of the trout population. Brook and cutthroat trout are the next most abundant trout in this section of the river, constituting about 30% and 12% of the estimated trout population, respectively (Modde et al. 1991). At Little Hole, rainbow trout constitute about 70% of the total trout population. Brown trout (20% of the trout population) are the second most abundant trout species, while brook and cutthroat trout each constitute no more than 5% of the trout population.

Rainbow and brook trout densities generally decrease below Little Hole, while brown trout become more abundant. Densities of all trout species decrease in the Green River downstream of its confluence with the Yampa River because of increases in water temperature and turbidity. Rainbow and brown trout are locally abundant at the confluence of the Green River and Jones Hole Creek, which supports naturally reproducing populations of these trout species.

Brown trout and brook trout spawn in the fall and cutthroat trout in spring; rainbow trout spawn in both seasons (Modde et al. 1991). Trout redds occur in the 16-mi stretch of the river between the dam and the Taylor Flat Bridge. The greatest density of redds occurs immediately below the dam and between Little Hole and Red Creek (Modde et al. 1991). Brown trout redds have been identified only downstream of Little Hole. Young-of-the-year trout typically inhabit shallow (less than 16 in. deep) nearshore areas with low water velocity (less than 1 cfs).

Other Introduced and Native Fish

Other than trout, there are 17 introduced fish species and 10 native fish species in the Green River between the dam and Jensen (Appendix D, Table D.2). Introduced fish are also the most abundant component of the fish community of the Green River. Many of the introduced species entered the system after construction of the dam, some intentionally and some accidentally. Introduced fish are of particular concern because of their potential adverse impacts on native fish populations (Tyus et al. 1982; Minckley and Meffe 1987; Minckley 1991). Many of the introduced species present in the Green River system share habitats with the native species (Haines and Tyus 1990; Karp and Tyus 1990b; Tyus and Beard 1990; Tyus 1991a), and predation by and competition from introduced species have been suggested to be critical factors in the decline of native fish throughout the Colorado River system (Kaeding and Osmundson 1988; Marsh and Langhorst 1988; Karp and Tyus 1990a; Tyus and Nikirk 1990; Minckley et al. 1991).

The most common introduced species in the river are the channel catfish, carp, fathead minnow, and red shiner (Holden and Crist 1981; Tyus et al. 1982; Karp and Tyus 1990b; Haines and Tyus 1990; Tyus and Nikirk 1990). In general, these species are rare from the dam to Browns Park. However, they increase in abundance after that point and are the most abundant species in the Green River between the Yampa River confluence and Jensen. The fathead minnow and red shiner are very abundant in shoreline habitats around Jensen in summer and autumn and constitute more than 80% of the fish present in backwater habitats in that area (Haines and Tyus 1990). The introduced sand shiner, redside shiner, and creek chub are locally abundant around the Yampa River confluence but are rare or absent from other areas of the river.

Other introduced species historically have been present in low numbers and have had relatively limited distributions in the river. These species include the northern pike, green sunfish, black bullhead, walleye, bluegill, and largemouth and smallmouth basses (Appendix D, Table D.2). The northern pike and other predaceous fish species may present a threat to endangered fish in the system. This species was introduced into the Yampa drainage in 1977 and was first reported in the Green River in 1981 (Tyus and Beard 1990). Although uncommon in the past in the main channel, the northern pike has been increasing in abundance and may be numerous in some quiet backwater habitats below the Yampa River confluence (Modde 1993). Similar increases in abundance have been observed for the green sunfish and smallmouth bass. The relative absence of most of the introduced species above the Gates of Lodore (about 47 river miles below the dam) is most likely a result of colder water.

Reproduction by introduced warmwater fish is limited in the Green River above the Yampa River, especially above the Gates of Lodore (Holden and Crist 1981), presumably because of cold water. Many of the introduced species do, however, reproduce below the Yampa River (Holden and Crist 1981; Grabowski and Hiebert 1989; Haines and Tyus 1990; Tyus and Nikirk 1990). Larvae of introduced species dominate the larval fish community in backwaters below Split Mountain (Haines and Tyus 1990). Little or no successful reproduction by the northern pike and walleye occurs between the dam and Jensen. Juveniles and adults apparently enter the system from established reproducing populations in the upper Yampa River Basin (Tyus and Beard 1990).

The native fish community consists of 10 species (Appendix D, Table D.2) and is dominated by the flannelmouth and bluehead suckers and the speckled dace. These species are rare above the Gates of Lodore but are common or abundant below the Yampa River (Holden and Crist 1981; Karp and Tyus 1990b). The razorback sucker, humpback chub, bonytail chub, and Colorado squawfish are Federally endangered. These species are discussed in detail in Section 3.4.2.3.1.

Little or no successful reproduction by native fish, and none by listed species, occurs in the Green River above the Gates of Lodore (Holden and Crist 1981), presumably because of the cold water. Some reproduction by nonlisted native species occurs between the Gates of Lodore and the Yampa River, but most occurs downstream of the Yampa River (Holden and Crist 1981). Although native fish continue to produce large numbers of larvae each year, by summer and autumn most of these larvae have died. Predation and competition from introduced fish and human activities, including fluctuating flows from hydropower operations, have been suggested as causes for the loss of native fish larvae (USFWS 1992b).

3.4.2.1.2 Aquatic Habitats

Between Flaming Gorge Dam and Jensen, the Green River can be delineated into reaches of two general types: relatively high-gradient, narrow canyon reaches with cobble, boulder, and gravel substrates or low-gradient, alluvial reaches with sand substrates and flowing through meandering canyons or flat open terrain.

The reach between the dam and Taylor Flat provides the best habitat for trout in the Green River, and redds of rainbow, brook, brown, and cutthroat trout occur throughout (Modde et al. 1991). Eddies are preferred by adult rainbow and cutthroat trout. However, a variety of other habitats are used, and use changes seasonally and with changing flows. The amount of habitat available for trout is strongly influenced by flow and, on the basis of field measurements, is maximized in the tailwaters at flows between 800 and 1,200 cfs (Modde et al. 1991).

Below the confluence with the Yampa River, backwaters, flooded bottomlands, eddies, side channels, and other nearshore areas in the Green River serve as nursery habitats for larval and juvenile fish, staging areas for some endangered species such as the razorback sucker, and habitat for adult native and endangered fish (Haines and Tyus 1990; Tyus and Karp 1991). High spring flows, such as those identified in the Biological Opinion for Flaming Gorge Dam, are thought to create new backwater areas, remove debris, and replenish nutrients in old backwaters and flooded bottomlands (USFWS 1992b). The abundance of backwaters in summer and autumn in the Green River is affected by flow. The size and number of backwater areas in Island Park and near Jensen decrease with increasing flows and are greatest in these areas at flows between 1,100 and 1,600 cfs (Pucherelli et al. 1990). However, backwater size may have little or no relationship to the quality of the backwater as a nursery habitat; other factors, such as temperature, substrate type, and depth, may be important in determining nursery habitat quality. Although the abundance of flooded bottomlands is also affected by flow, flooding of many historic bottomlands is prevented by dikes that have been constructed for flood-control purposes. The importance of backwaters and flooded bottomlands to endangered fish species is discussed in Section 3.4.2.3.1.

3.4.2.1.3 Aquatic Food Base

The food base for fish in the Green River is dominated by macroinvertebrates and is strongly influenced by flow, available substrates, and the inflow of the Yampa River. Macroinvertebrates are most abundant above the Yampa River confluence (Holden and Crist 1981). In the tailwaters and canyons between the dam and Browns Park, large, stable substrates (e.g., boulders) and clear, cold water support abundant growths of cladophora and other attached algae. These algae are food for macroinvertebrates, including gammarus and chironomid, mayfly, blackfly, and caddisfly larvae (Holden and Crist 1981; Gosse 1982; Modde et al. 1991).

Low-gradient reaches at Browns Park, Island Park, Rainbow Park, and below Split Mountain lack cladophora except where occasional rapids and riffles provide suitable hard substrates. Macroinvertebrates in these low-gradient reaches include chironomids, oligochaetes, mayfly larvae, and biting midges and sandflies (Annear 1980; Holden and Crist

1981; Grabowski and Hiebert 1989).

Zooplankton density is low in the main channel, but it is greater in backwaters below the Yampa River (Grabowski and Hiebert 1989). Larger backwaters with narrow connections to the river, and thus with a lower water exchange rate and a greater retention time, have higher densities of zooplankton. The zooplankton in these backwater areas are important food for young native and introduced fish species (Grabowski and Hiebert 1989). Recent research indicates that zooplankton production in flooded bottomlands may greatly exceed that in backwater habitats and that food production in bottomlands is critical to the survival of razorback sucker larvae.

3.4.2.2 Terrestrial Ecology

This section describes the vegetation and wildlife in riparian areas along the Green River below Flaming Gorge Dam. Species and habitats in adjacent upland areas are not described in detail because they are not dependent on nor directly affected by river flow.

3.4.2.2.1 Vegetation

The Green River flows through three ecoregions . Wasatch and Uinta Mountains, Wyoming Basin, and Colorado Plateaus (Omernik and Gallant 1987a,b). Each ecoregion has characteristic physiography and vegetation . in the Wasatch and Uinta Mountains, conifers (especially Douglas fir) are the dominant vegetation; the Wyoming Basin is a relatively flat plain with hills or low mountains and shrub-steppe vegetation; and the Colorado Plateaus ecoregion is a highly dissected tableland dominated by desert shrubs.

Riparian vegetation occurs along most of the 93 mi of Green River between Flaming Gorge Dam and Jensen. Riparian vegetation is absent only in the few areas where sheer rock walls abut the river. Figure 3.25 depicts the riparian habitat found along the river and its relationship to flow levels. Although riparian areas are considered wetland by the U.S. Fish and Wildlife Service (Cowardin et al. 1979), only isolated patches of this habitat along the Green River would qualify as jurisdictional wetlands under the U.S. Army Corps of Engineers definition (COE 1987).

The riparian vegetation of the Green River corridor has changed since completion of Flaming Gorge Dam in 1963. The dam eliminated the characteristic high spring flood flows (9,000-19,000 cfs) and low summer and autumn flows (600-700 cfs). This characteristic seasonal pattern has been replaced by a shift in monthly releases to meet irrigation demands and daily fluctuations to produce hydropower (Section 3.3.2.1). Below the confluence with the Yampa River, flows in the Green River are strongly influenced by flows from the unregulated Yampa. The contribution of the Yampa River results in a more natural flow regime in the Green River below the confluence, but spring floods are still much reduced from pre-dam conditions.

Before construction of Flaming Gorge Dam, the vegetation along the river occupied two distinct zones (Fischer et al. 1983). Nearest the river, flooding occurred each year (to approximately 7,000 cfs, Figure 3.26) during the spring. Plants in this flood zone were predominantly annuals or scour-tolerant perennials such as wild licorice, dogbane, and sedges. Dominant species above the flood zone included box elder, squawbush, Fremont cottonwood, and coyote willow (Holmgren 1962). After construction of the dam and the elimination of annual floods, riparian vegetation colonized much of the old flood zone from adjacent riparian and upland areas. Species that spread by underground stems (such as wild licorice, common reed, and scouring rush) formed dense stands along the shoreline in some areas and, by stabilizing sediment deposits, appear to be gradually making the channel narrower and deeper with steep banks. The riparian area above the high water line (the upper riparian zone), including pre-dam riparian vegetation, currently occupies approximately 13.2 acres per mile (LaGory and Van Lonkhuyzen 1995). It is expected that pre-dam riparian vegetation will eventually be replaced by upland species.

Between Flaming Gorge Dam and Jensen, the Green River alternately flows through narrow canyons (Red Canyon, Canyon of Lodore, Whirlpool Canyon, and Split Mountain Canyon) and broad valleys (Browns Park, Island Park, and Rainbow Park) (Figure 3.16) that are quite different in terms of riparian vegetation. The moderate to steep slopes of the canyon areas are vegetated with pinyon pine, Utah juniper, Douglas-fir, or ponderosa pine. The riparian zone occurs on a predominantly rocky substrate (mostly cobble and boulder, with sand and gravel becoming more common farther downstream) and extends 25 to 35 ft above the low-water level (800 cfs). Above the normal high-water line (4,200 cfs), grasses; scouring rush; giant whitetop; wild licorice; and a variety of woody species, including box elder, coyote willow, tamarisk, and Fremont cottonwood, are common. The latter two species are more common farther downstream.

Through the wide valley areas, the river meanders within a broad, open floodplain of mostly sand and silt (and gravel in upstream areas). Steep cutbanks are common, and in some areas almost all banks are cut and severely eroded. The surrounding uplands support sagebrush, desert shrubs, and, in some areas, pinyon pine and Utah juniper. Islands and backwaters are frequent throughout these sections of river. The riparian zone is relatively broad (up to 200 ft wide) and extends to 15-20 ft above the low-water level. In the upper riparian zone, grasses, coyote willow, wild licorice, giant whitetop, and scouring rush are common. Large stands of Fremont cottonwood and box elder occur on high terraces. These stands became established before the dam was constructed and persist because the roots of the mature trees are deep enough to use deeper groundwater. Maintenance of these elevated riparian woodlands is a concern because regeneration requires occasional flooding (well above maximum power plant capacity) for seedling establishment, but normal dam operations prevent such flooding.

Marshes occur along the Green River between the dam and Jensen in backwater areas; side channels; on islands; and in low, flat, sandy or silty areas on the inside curves of the river where the current slows and sediments are deposited. Marshes also occur occasionally along the channel margin in protected areas, such as downstream of protruding rocks or cliffs. Marshes are most abundant in lower Browns Park and Island Park, where the river meanders extensively and many backwaters and side channels occur. Common species in these marshes are cattail, bulrush, rush, common reed, and scouring rush. Although no estimate is available of the amount of marsh acreage along the river, the lower riparian zone (between the elevations of 800- and 4,200-cfs flows), where most marshes occur, occupies about 5.3 acres per mile (LaGory and Van Lonkhuyzen 1995). No estimate is available of the amount of pre-dam marsh vegetation.

3.4.2.2.2 Wildlife

Numerous species of nongame vertebrate wildlife use riparian habitats along the Green River below Flaming Gorge Dam (Bogan et al. 1983). The greatest species diversity occurs in the riparian habitats of broad valleys, such as Browns, Echo, Island, and Rainbow parks. Wildlife is relatively sparse in canyon areas (e.g., Lodore, Split Mountain) because of the lack of habitat diversity. Representative species inhabiting riparian habitats include Woodhouse s toad, fence lizard, gopher snake, lazuli bunting, red-tailed hawk, deer mouse, and coyote.

The Green River provides excellent habitat for the river otter. Reintroduction of river otter to the Green River drainage began in 1989 and 1990 with the release of 23 otters along the river in Browns Park (Utah Division of Wildlife Resources 1992). Seventeen otters were released in Island and Rainbow parks in Dinosaur National Monument in 1991 (Cranney and Day 1993). Since then, otters have been seen between Flaming Gorge Dam and Island Park. Fish (especially carp) make up most of this species' diet. Abandoned beaver dens, clusters of boulders, or rock crevices near the water s edge are used as shelters.

The Green River and wetlands of the valley provide important breeding, migration, and wintering habitat for numerous waterfowl species (Aldrich 1992). Before the dam was constructed, annual spring floods inundated bottomland areas in Browns Park and other broad floodplain areas along the river. These flooded bottomlands provided important foraging areas for migrating waterfowl and were also used as major breeding grounds for several species. Browns Park National Wildlife Refuge and Browns Park Wildlife Management Area, situated along the river corridor in Browns Park, are managed to mitigate the effects of dam-induced reductions in spring flooding on these important waterfowl habitats. Within these management areas, bottomlands are artificially flooded each year by pumping river water into diked marshlands to create suitable waterfowl habitat.

Waterfowl species that commonly breed along the Green River corridor include Canada geese, mallard, common merganser, gadwall, green-winged teal, and redhead. In addition to these species, American widgeon, common goldeneye, and American coot are common during migration or winter. Waterfowl use unfrozen areas of the river during the winter.

Canada geese are particularly susceptible to changes in flow on the Green River (Holden 1992; Aldrich 1992). Islands and sandbars with low vegetation (e.g., grasses and forbs) are important nesting habitat for this species, and Browns Park is the most important nesting area for Canada geese in the area (Schnurr 1992). Most nesting occurs from March 15 to May 15.

Great blue heron, spotted sandpiper, and killdeer forage along shoreline and riparian habitats during the breeding season (Bogan et al. 1983). The great blue heron uses large trees (e.g., cottonwood) as nesting and roosting sites along the river. Killdeer and spotted sandpiper nest on the ground above the high-water line.

Several species of game mammals, including mule deer, elk, moose, pronghorn, and bighorn sheep, occur along the Green River corridor below Flaming Gorge Dam (BLM 1990; Schnurr 1992). All of these species use riparian habitats as foraging areas but are not restricted to riparian areas at any time of the year. Mule deer, elk, and pronghorn range widely throughout this portion of Utah and Colorado but move toward the river in the fall and use the river valley, especially Browns Park, as wintering range. Mule deer occur along the river throughout the year and are the most abundant game mammal in the area. They may currently exceed carrying capacity (BLM 1990). Moose numbers are low in the region but appear to be increasing (BLM 1990). Within the area, moose habitat occurs in Browns Park (Schnurr 1992). Bighorn sheep are common in riparian areas along the Green River in Canyon of Lodore (Schnurr 1992) and Whirlpool Canyon. These animals are the result of reintroductions begun in 1952 after a die-off of the natural population.

3.4.2.3 Threatened and Endangered Species

This section discusses the current status of Federally and state-listed threatened, endangered, candidate, and sensitive aquatic and terrestrial species below Flaming Gorge Dam. Definitions of listing categories maintained by the Federal Government and the states of Utah and Colorado are presented in Appendix D, Section D.4; correspondence with the USFWS regarding threatened and endangered species in the area is provided in Section D.4.5 of Appendix D.

3.4.2.3.1 Aquatic Species

Six Federally or state-listed, sensitive, or candidate fish species have been reported in the Green River between Flaming Gorge Dam and Jensen (Table 3.12). The occurrence and status of the Federally listed species are discussed below.

Humpback Chub (Endangered)

Below Flaming Gorge Dam, the humpback chub occurs primarily within Dinosaur National Monument in upper Whirlpool Canyon of the Green River and the lower Yampa River (Karp and Tyus 1990b; USFWS 1990c). The USFWS has designated the Yampa River within Dinosaur National Monument and the Green River from its confluence with the Yampa River to the southern boundary of Dinosaur National Monument as critical habitat for the humpback chub (USFWS 1994). The size of the humpback chub population within this part of the Green River Basin is not known, although this chub is most abundant in the lower Yampa River (Karp and Tyus 1990b). Within Dinosaur National Monument, adult humpback chub occur most often in shallow eddies within high-gradient, white-water reaches with cobble and sand substrates (USFWS 1990c; Tyus and Karp 1991). Aquatic insects constitute the bulk of the humpback chub diet (Karp and Tyus 1990b).

The humpback chub is known to spawn in the Yampa River within Dinosaur National Monument, and adults in reproductive condition have been collected from the Green River at Whirlpool Canyon, suggesting possible spawning in this reach of the Green River (Karp and Tyus 1990b). Humpback chubs in Dinosaur National Monument spawn in spring and early summer at water temperatures of about 68.F (Tyus and Karp 1991). Reproductive adults occur in shoreline eddies and may return to specific eddies to spawn in different years (Karp and Tyus 1990b). Spawning is not known to occur in the Green River above the Yampa River confluence, and reproduction in this reach is limited by cold water temperatures.

The decline of the humpback chub in the Green River, as well as throughout its historical range, has been attributed to such factors as stream alterations from dams, water withdrawals, channelization, competition with and predation by introduced fish species, and hybridization with related species (USFWS 1990c).

TABLE 3.12 Federally and State-Listed Threatened, Endangered, Candidate, and Sensitive Fish Species below Flaming Gorge Dam in the Green River

Common Name[a]	Scientific Name	Federal Status[b]	State Status[c]	Occurrence within Area
Colorado squawfish	*Ptychocheilus lucius*	E	UT-E CO-E	Absent from the Green River above the Canyon of Lodore; rare from the Gates of Lodore to Jensen and in lower Yampa River (Tyus and Karp 1991).
Razorback sucker	*Xyrauchen texanus*	E	UT-E CO-E	Absent from the Green River above the Gates of Lodore; rare from the Gates of Lodore to Jensen and in the lower Yampa River (Tyus and Karp 1991).
Humpback chub	*Gila cypha*	E	UT-E CO-E	Absent from Green River above the Gates of Lodore; rare from Gates of Lodore to Jensen and in lower Yampa River; most abundant in eddies of high-gradient reaches of Yampa River and in Whirlpool Canyon (Tyus and Karp 1991).
Bonytail chub	*Gila elegans*	E	UT-E CO-E	Historically present at the confluence of the Green and Yampa rivers; last verified specimen collected in 1979 from the lower Yampa River (Tyus and Karp 1991).
Roundtail chub	*Gila robusta*	C2	UT-T CO-NL	Historically common in the Green River from Browns Park through Island Park and in the lower Yampa River (Karp and Tyus 1990b); may now be uncommon or rare.
Flannelmouth sucker	*Catostomus latipinnis*	C2	UT-NL CO-NL	Rare in the Green River above the Gates of Lodore; common from the Gates of Lodore to Jensen (Tyus et al. 1982; Karp and Tyus 1990b).

a Lists of species derived from USFWS (1991a,c,d); Harris (1991); Holden (1992); Schnurr (1992); Williams (1992); Pague (1992).
b Federal listing codes: C2 = category 2 candidate, E = endangered (definitions provided in Appendix D, Section D.4.1)
c State listing codes: CO-E = Colorado endangered, CO-NL = not listed by Colorado, UT-E = Utah endangered, UT-NL = not listed by Utah, UT-T = Utah threatened (definitions provided in Appendix D, Section D.4.3 and D.4.4)..

Bonytail Chub (Endangered)

Before construction of Flaming Gorge Dam, the bonytail chub was present in the Green River above and below the Yampa River confluence (Schnurr 1992). Since then, the number of bonytail chub in the Green and Yampa rivers within Dinosaur National Monument has declined. Although the last verified bonytail chub collected from the Upper Green River Basin (above Jensen) was captured in the lower Yampa River in 1979 (Tyus and Karp 1991), this species is not yet considered extirpated from the region. A fish suspected of being a bonytail chub was collected from the upper Green River in 1987 (Tyus and Karp 1991). Major factors suggested for the decline of the bonytail chub throughout its historical range have included interactions with introduced fish species, habitat alterations (particularly lower summer water temperatures) caused by dams, water depletions for irrigation, and hybridization with humpback and roundtail chubs (USFWS 1990d).

The USFWS has designated about 312 mi of river in the Upper and Lower Colorado River basins as critical habitat for the bonytail chub (USFWS 1994). In the upper basin, the critical habitat includes the Yampa River within Dinosaur National Monument and the Green River from its confluence with the Yampa River to the southern boundary of Dinosaur National Monument.

Little is known about the life history of this species. The bonytail chub is generally considered a big-river species. In the Green River, adults were most common in pools and eddies rather than swifter, main-channel areas, and spawning is believed to have occurred in late spring and early summer at water temperatures of about 64.F (USFWS 1990d). Bonytail chubs in the Green River in Dinosaur National Monument fed on a variety of aquatic and terrestrial insects.

Colorado Squawfish (Endangered)

Historically, the Colorado squawfish was abundant throughout the big-river portions of the Colorado River Basin but is now absent from the lower basin (USFWS 1991b). Within the upper basin, the Colorado squawfish is most abundant in the Green River below the Yampa River and in the Yampa River itself (Tyus and Karp 1991; USFWS 1991b). The decline of the Colorado squawfish has been attributed to alteration and fragmentation of habitats by dams, loss of nursery habitats because of dam- and hydropower-induced hydrological changes, water depletions for irrigation, channelization, and interactions with introduced fish species (USFWS 1991b).

The USFWS has designated 1,148 mi of river in the Upper Colorado River Basin as critical habitat for the Colorado squawfish (USFWS 1994). The critical habitat includes a portion of the Green River evaluated in this EIS, namely that portion of the river from its confluence with the Yampa River to the southern boundary of Dinosaur National Monument.

The Colorado squawfish population in the Green River has been estimated to range from about 4,000 to 17,000 adult fish (Tyus 1991a) and appears to be stable or increasing. The Colorado squawfish does not occur in the Green River between Flaming Gorge Dam and the Gates of Lodore, primarily because of cold water, altered flow patterns, sediment loads, and water chemistry (USFWS 1991b; Schnurr 1992). This species is most common below the Yampa river confluence. Adult Colorado squawfish occur in eddies, pools, runs, and shoreline backwaters over silt, sand, gravel, and boulder substrates (Tyus and Karp 1991; USFWS 1991b). Young-of-the-year fish usually occur in shoreline backwaters (Tyus 1991b), especially in Island and Rainbow parks and near Jensen (C. Johnson 1992). These backwaters are particularly important to this and other endangered fish species in the Green River; alterations of these areas can have significant consequences to the population. For example, in the unusually wet years of 1983 and 1984, high releases (up to 10,000 cfs) occurred in late summer to protect the dam and as a consequence of flood control operations. These high releases are thought to have resulted in the loss of each year's young-of-the-year fish (USFWS 1992b).

Colorado squawfish in the Upper Green River Basin spawn over a four- to five-week period between late June and mid'August, soon after the peak in spring flows, at water temperatures between 64. and 77.F (USFWS 1991b). One of the two major spawning sites of the Colorado squawfish is in the lower Yampa River 15-31 mi upstream from the Green River (USFWS 1991b; C. Johnson 1992). Every spawning season, adult Colorado squawfish in the Upper Green River Basin migrate to the Yampa River spawning ground (Tyus 1990; 1991a). Spawning in the Green River above the Yampa River confluence is limited by cold water temperatures, and no successful reproduction is known to occur in this reach.

In the lower Yampa River, spawning occurs over gravel, cobble, and boulder bars (Tyus 1990) that are cleared of accumulated sediments during spring floods (Tyus and Karp 1991). Breeding adults concentrate in pools and eddies adjacent to the spawning bars, move onto bars to spawn, and then return to pools and eddies. Upon hatching, the larval fish are carried by the current downstream to nursery areas at Island and Rainbow parks, in the Jensen area, and other suitable areas farther downstream, where they concentrate in backwaters and other nearshore habitats (Tyus and Haines 1991).

The diet of very young Colorado squawfish consists primarily of zooplankton and small insect larvae (Grabowski and Hiebert 1989; USFWS 1991b). However, the young fish begin to eat other fish very early . 86% of the diet of juvenile Colorado squawfish is fish. Adult squawfish eat other fish almost exclusively.

Razorback Sucker (Endangered)

The Yampa River and the Green River from the Yampa to upper Desolation Canyon now contain the largest remaining riverine population of razorback suckers, estimated in 1989 to be between 800 and 1,100 adult fish (Lanigan and Tyus 1989). More recent estimates suggest the population may be much smaller, about 250-600 adult fish (Modde 1993). The razorback sucker does not occur in the Green River from Flaming Gorge Dam to the Gates of Lodore (Minckley et al. 1991) but does occur from the Gates of Lodore to Jensen and in the lower 13 mi of the Yampa River above its confluence with the Green River (Tyus and Karp 1991). Razorback suckers overwinter in a number of locations in the Green River, including Echo, Island, and Rainbow parks, near Jensen (Valdez and Masslich 1989), and in Split Mountain Canyon.

The USFWS has designated 1,724 mi of river in the Upper and Lower Colorado River basins as critical habitat for the razorback sucker (USFWS 1994). In the upper basin, the critical habitat includes a portion of the Green River that is evaluated in this EIS . that portion of the river from its confluence with the Yampa River to the southern boundary of Dinosaur National Monument.

The decline of the razorback sucker in the Green River has been attributed primarily to loss of habitat from dam construction, loss of spawning and nursery habitats from diking and dam operations, and the alteration of seasonal streamflow patterns (Tyus and Karp 1991; USFWS 1992b). Competition with and predation by introduced fish species may also be important factors in the decline of this species (Bestgen 1990; Minckley et al. 1991; USFWS 1992b).

Reproduction by the suckers in the Upper Green River Basin occurs from late April through mid-June during peak spring flows at water temperatures between 48. and 63.F (Tyus and Karp 1990). Spawning areas have been identified in (1) the lower Yampa River above Echo Park, (2) the Green River in Echo Park, and (3) between Split Mountain Canyon and Ashley Creek near Jensen (Tyus and Karp 1990; Schnurr 1992; C. Johnson 1992). Potential spawning areas have also been identified in Split Mountain Canyon and Island Park (Schnurr 1992). Razorback suckers spawn on riffles with cobble, gravel, and sand substrates (Tyus and Karp 1990). Spawning in the Green River above the Yampa River confluence is limited by cold water temperatures, and no successful reproduction is known to occur in this reach.

Although larvae are produced in the Green River above Jensen, there is little or no recruitment to the adult population (Tyus 1987; Minckley et al. 1991; Tyus and Karp 1991; Modde 1993). Predation and loss of flooded bottomland nursery habitat have been suggested as major factors affecting recruitment in the Green River and throughout the range of the razorback sucker (Minckley et al. 1991; Modde 1993).

Little is known about the diet of razorback suckers from the Green River. In other rivers and reservoirs, the razorback sucker consumes aquatic insects, zooplankton, and algae. Larvae prey on chironomid larvae, algae, and small zooplankton (Bestgen 1990).

3.4.2.3.2 Terrestrial Species

Federally listed, state-listed, sensitive, or candidate terrestrial species that are known to occur or could occur along the Green River below Flaming Gorge Dam are listed in Table 3.13. Habitats or location where these species occur are also included in the table. Federally listed species are discussed below.

TABLE 3.13 Threatened, Endangered, Candidate, and Sensitive Terrestrial Species below Flaming Gorge Dam on the Green River

Common Name[a]	Scientific Name	Federal Status[b]	State Status[c]	Occurrence within Area
Plants				
Ute ladies'-tresses	*Spiranthes diluvialis*	T	UT-NL, CO-1	Populations in alluvial soils along Green River within Browns Park (Coyner 1990) and in the vicinity of Split Mountain Canyon.
Ownbey thistle	*Cirsium ownbeyi*	C2	UT-S, CO-1	Population in alluvial soil at confluence of Yampa and Green rivers; endemic to Dinosaur National Monument area (Naumann 1990).
Giant helleborine	*Epipactis gigantea*	NL	UT-NL, CO-2	Potential occurrence in riparian areas of Green River; known populations in Split Mountain above river level (Naumann 1990).
Reptiles				
Utah milk snake	*Lampropeltis triangulum taylori*	NL	UT-S, CO-NL	Occurs in woody riparian vegetation along Green River (W. Johnson 1992).
Western smooth green snake	*Opheodrys vernalis blanchardi*	NL	UT-S, CO-NL	Potential occurrence in woody riparian vegetation along Green River (Stebbins 1966).
Birds				
Whooping crane	*Grus americana*	E	UT-E, CO-E	Potential occurrence in riparian marshes along Green River during migration (BLM 1990).
Greater sandhill crane	*Grus canadensis tabida*	NL	UT-NL, CO-E	Potential occurrence in riparian marshes along Green River during migration (BLM 1990).

TABLE 3.13 (Cont.)

Common Namea	Scientific Name	Federal Status[b]	State Status[c]	Occurrence within Area
Birds (Cont.)				
Western snowy plover	*Charadrius alexandrinus nivosus*	C2	UT-S, CO-SC	Potential occurrence on river beaches and mudflats along Green River during breeding season and migration (BLM 1990).
Long-billed curlew	*Numenius americanus*	3C	UT-S, CO-SC	Potential occurrence in riparian marshes along Green River during breeding season and migration (BLM 1990).
Northern goshawk	*Accipiter gentilis*	C2	UT-S, CO-NL	Potential occurrence year-round in cottonwood groves along Green River (Peterson 1990).
Swainson s	*Buteo swainsoni*	NL	UT-S,	Potential occurrence in cottonwood groves along Green River

hawk			CO-NL	(BLM 1990).
Bald eagle	*Haliaeetus leucocephalus*	T	UT-E, CO-E	Winters along Green River between dam and Jensen (Huffman 1992; Howe 1992); potential nest sites in cottonwood groves along river.
Osprey	*Pandion haliaetus*	NL	UT-S, CO-NL	Nests in dead trees along Green River near dam (Holden 1992).
Peregrine falcon	*Falco peregrinus*	E	UT-E, CO-E	Nests on cliffs along Green River in Dinosaur National Monument (Eason 1992a); potential occurrence during winter (USFWS 1977).
Mexican spotted owl	*Strix occidentalis lucida*	T	UT-S, CO-NL	Potential occurrence year-round in riparian woodlands of canyon areas along Green River (Huffman 1992; W. Johnson 1992).

TABLE 3.13 (Cont.)

Common Name^a	Scientific Name	Federal Status^b	State Status^c	Occurrence within Area
Birds (Cont.)				
Western yellow-billed cuckoo	*Coccyzus americanus occidentalis*	NL	UT-S, CO-NL	Potential occurrence during summer or migration in woody riparian vegetation along Green River (BLM 1990; W. Johnson 1992).
Black-chinned hummingbird	*Archilochus alexandri*	NL	UT-S, CO-NL	Occurs during summer and migration in woody riparian vegetation along Green River (Bogan et al. 1983; W. Johnson 1992).
Lewis s woodpecker	*Melanerpes lewis*	NL	UT-S, CO-NL	Occurs year-round in woody riparian vegetation along Green River (W. Johnson 1992).
Willow flycatcher	*Empidonax traillii*	NLd	UT-S, CO-NL	Occurs during summer and migration in woody riparian vegetation along Green River (Bogan et al. 1983; W. Johnson 1992).
Loggerhead shrike	*Lanius ludovicianus*	C2	UT-S, CO-NL	Occurs during summer and migration in woody riparian vegetation along Green River (W. Johnson 1992).
American redstart	*Setophaga ruticilla*	NL	UT-S, CO-NL	Occurs during summer and migration in woody riparian vegetation along Green River (W. Johnson 1992).
Wilson s warbler	*Wilsonia pusilla*	NL	UT-S, CO-NL	Occurs during summer and migration in woody riparian vegetation along Green River (W. Johnson 1992).
Yellow-breasted chat	*Icteria virens*	NL	UT-S, CO-NL	Occurs during summer and migration in woody riparian vegetation along Green River (Bogan et al. 1983; W. Johnson 1992).

TABLE 3.13 (Cont.)

Common Name[a]	Scientific Name	Federal Status[b]	State Status[c]	Occurrence within Area
Mammals Dwarf shrew	*Sorex nanus*	NL	UT-S, CO-NL	Occurs in woody riparian vegetation along Green River (W. Johnson 1992).
Spotted bat	*Euderma maculatum*	C2	UT-S, CO-NL	Potential occurrence of foraging individuals along Green River (BLM 1990).
River otter	*Lutra canadensis*	NL	UT-S, CO-E	Reintroduced population along Green River (Holden 1992).
Ringtail	*Bassariscus astutus*	NL	UT-S, CO-NL	Occurs in woody riparian habitat along Green River (W. Johnson 1992).

a List of species derived from USFWS (1991a,d); BLM (1990); Harris (1991); Holden (1992); Williams (1992); Pague (1992).
b Federal listing codes: C2 = category 2 candidate, 3C = no longer candidate for listing because common or well protected, E = endangered, NL = not listed, T = threatened (definitions provided in Appendix D, Section D.4.1).
c State listing codes: CO-1 = Colorado list 1, CO-2 = Colorado list 2, CO-3 = Colorado list 3, CO-E = Colorado endangered, CO-NL = not listed by Colorado, CO-SC = Colorado special concern, UT-E = Utah endangered, UT-NL = not listed by Utah, UT-S = Utah sensitive (definitions provided in Appendix D, Section D.4.3 and D.4.4).
d Southwestern willow flycatcher (*Empidonax traillii extimus*), proposed for Federal listing as endangered, is not found in the project area (Holden 1992).

Ute Ladies'-tresses (Threatened)

The threatened Ute ladies'-tresses, a small species of orchid, is known from scattered populations in open wetland and riparian areas of Colorado, Utah, and Wyoming. The Ute ladies'-tresses occurs most often in gravelly, sandy, or silty soil in sunny locations where the summer water table lies 1 to 2 ft below the soil surface. Suitable habitats are generally wet meadows dominated by grasses and sedges where competition for light is reduced by grazing, mowing, burning, or flooding in spring or early summer. Riparian populations occur in locations where soil moisture is high but that are at elevations above rivers and streams where flooding is infrequent, of short duration, and severe flood scouring less likely (Coyner 1990; USFWS 1990b). The unchecked growth of other herbaceous or woody competitors or the accumulation of large amounts of dead plant material can result in declines of ladies'-tresses populations. Other threats to the species include collection of live plants, alteration of habitat, late summer grazing, and alteration of the water regime.

One population of Ute ladies'-tresses occurs along the Green River within Browns Park. About 500 plants within this population are located in an open meadow; the nearest plants to the river are about 10 ft from the water s edge and 6 ft above the river's surface. The position of this population indicates that it may be dependent on dam releases near maximum power plant capacity (4,200 cfs), although this dependence has not been determined conclusively. Seven other plants have been found just downstream in a marshy area along an old river channel more than 300 ft from the water s edge. Another small population has been found near the river in the vicinity of Split Mountain Canyon.

Whooping Crane (Endangered)

Whooping cranes migrate through the region of Flaming Gorge Dam and the Green River Basin in the spring and fall. These cranes belong to a population established at Gray s Lake National Wildlife Refuge in southeastern Idaho as part of the recovery program for this species (Armbruster 1990). Efforts to establish the Gray s Lake population began in

1975. The current population consists of 13 cranes that have not yet nested but migrate annually with sandhill cranes to wintering grounds in and around the Bosque del Apache National Wildlife Refuge, New Mexico. Two areas are heavily used by migrating cranes and have been designated as critical habitat . Monte Vista National Wildlife Refuge and Alamosa National Wildlife Refuge. Both areas are in southern Colorado, away from the area of Flaming Gorge Dam (Armbruster 1990). Habitats used by whooping cranes during migration include agricultural fields, wetlands, and small reservoirs (Rose 1992). Whooping cranes have been observed in the vicinity of the Green River below Flaming Gorge Dam near Jensen, Utah. Wetlands along the river could be used occasionally by migrating individuals.

Bald Eagle (Threatened)

About 50 bald eagles winter along the Green River below Flaming Gorge Dam each year (Huffman 1992; Howe 1992). Eagles perch in large trees, especially cottonwoods, near open, ice-free water and forage for fish and occasionally waterfowl. Concentrations occur in broad, open areas of the valley with cottonwood groves, such as Browns Park and Island Park (Huffman 1992). Although nesting by the bald eagle has not been observed in the vicinity of Flaming Gorge Dam or the Green River, it appears possible given documented nesting activity elsewhere in Utah and Colorado (USFWS 1990b; Kjos 1992) and the availability of suitable large cottonwood trees in Browns, Island, and Rainbow parks.

Peregrine Falcon (Endangered)

The peregrine falcon occurs along the Green River below Flaming Gorge Dam and is most common in major canyons where potential nest and perch sites exist on cliff faces. The species nests within Dinosaur National Monument (Eason 1992a) along both the Green and Yampa rivers. Numbers of nests have increased within the past two decades; only one active nest site was known within the monument in 1976, but eight nesting pairs fledged a total of 13 young in 1992. Although peregrines usually occur in the area during the breeding season (March-October), some birds could occur during the winter (USFWS 1977). Additional background information on the falcon is presented in Section 3.4.1.3.2.

Mexican Spotted Owl (Threatened)

The Mexican spotted owl is a potential year-round resident in wooded canyons along the Green River below Flaming Gorge Dam. The species is thought to occur in Dinosaur National Monument, and there are indications that it has occurred there in the past (Huffman 1992). Additional background information on the species is provided in Section 3.4.1.3.2.

3.4.3 Aspinall Unit

This section describes ecological resources in and along the reservoirs of the Aspinall Unit (Figure 3.19) because hydropower operations affect water levels. Resources below Crystal Dam are not discussed because releases from Crystal Dam are controlled by Reclamation for water regulation, not to produce hydropower.

Figure 3.19

3.4.3.1 Aquatic Ecology

Flows in the Gunnison River have been regulated since the construction of the Taylor Park Reservoir in 1936. Before construction of the Aspinall Unit reservoirs (begun in 1961), the Gunnison contained most of the currently threatened or endangered fish species of the Upper Colorado River Basin (Tyus et al. 1982). In the vicinity of the Aspinall Unit, the fish community was relatively sparse, with probably no more than nine species native to the Upper Colorado River Basin (Stanford and Ward 1982). Rainbow and brown trout were introduced into the river around 1910, and a world-class trout fishery was established that replaced the native Colorado cutthroat trout.

The most productive pre-dam fishery in the Gunnison River occurred from the mouth of Tomiche Creek downstream to the upper reaches of the Black Canyon (Stanford and Ward 1982). This reach also exhibited the highest production and diversity of aquatic macroinvertebrates. With the construction of the Aspinall Unit dams, this reach was changed to a lake environment that now supports a kokanee salmon fishery. Following construction of the reservoirs, the production and diversity of macroinvertebrates declined, and some species were eliminated (Stanford and Ward 1982).

3.4.3.1.1 Fish

The Aspinall Unit reservoirs contain 16 fish species (Appendix D, Table D.3). Because of the cold water in the reservoirs, the seven trout and salmon species dominate the fish community.

Trout and Salmon

Trout and salmon that occur in the Aspinall Unit reservoirs include kokanee salmon, rainbow trout, brown trout, brook trout, and lake trout (Appendix D, Table D.3). Rainbow trout and kokanee salmon are the most abundant of these (Van Buren and Burkhard 1981).

Kokanee salmon are stocked in Blue Mesa Reservoir and into the East River about 25 mi upstream of the reservoir. Kokanee salmon fingerlings are released into the East River at the Roaring Judy Fish Hatchery each spring, usually in late April; approximately 1.2 million fingerlings were stocked into the East River in 1992 (Hebein 1992). These fingerlings move downstream into the upper Gunnison River and eventually into Blue Mesa Reservoir to mature. In autumn, adult kokanee salmon migrate back upstream to the fish hatchery area to spawn. Colorado Division of Wildlife personnel obtain eggs and roe from the returning kokanee salmon to provide stock for the hatchery for the following year. The young fish produced represent the major source of kokanee salmon for stocking efforts throughout Colorado. Fish raised in this hatchery are also used for fish stocking programs in other states (Hebein 1992). From 50,000 to 100,000 kokanee salmon fingerlings are released yearly into Blue Mesa Reservoir near Red Creek, High Bridge, Dry Creek, and Blue Mesa Dam to provide adequate numbers of adult kokanee salmon for the snagging fishery.

In Blue Mesa Reservoir, kokanee salmon prefer water temperatures of 60.F or less and in summer are most abundant in the deeper (50-100 ft), colder waters near the dam (Van Buren and Burkhard 1981). Because of warm water temperatures, the uppermost Iola Basin (Figure 3.19) of Blue Mesa Reservoir does not provide suitable habitat for kokanee salmon in summer months (Van Buren and Burkhard 1981). Morrow Point Reservoir is colder in summer than Blue Mesa Reservoir, and thus kokanee salmon occur at shallower depths (10-40 ft).

Rainbow trout are stocked annually into Blue Mesa Reservoir . 900,000 in 1992 (Hebein 1992). Little or no stocking of trout and salmon occurs in Morrow Point or Crystal reservoirs, but many of the fish stocked into Blue Mesa Reservoir enter the downstream reservoirs through the Blue Mesa and Morrow Point dams.

Brown trout populations in the reservoirs rely entirely upon natural reproduction for maintenance, since this species is no longer stocked in the reservoirs. Spawning beds have been observed in the Lake Fork inlet of Blue Mesa Reservoir, and other reservoir inlets may also provide suitable spawning habitat.

Other Introduced and Native Fish

Most of the introduced and native species that have been identified from the Gunnison River in the vicinity of the Aspinall Unit (Appendix D, Table D.3) are rare or incidental in the reservoirs, primarily because of the cold water.

Longnose and white suckers are the most abundant of the four introduced species (other than trout and salmon) in the reservoirs (Appendix D, Table D.3). Five native species of fish occur in the reservoirs . the mottled sculpin, Colorado River cutthroat trout, speckled dace, and flannelmouth and bluehead suckers (Stanford and Ward 1982; Hebein 1992). The flannelmouth and bluehead suckers are the most common of these.

3.4.3.1.2 Aquatic Habitats

Fluctuating reservoir levels resulting from hydropower operations alternately expose and inundate shoreline areas, affecting algae and macroinvertebrates that constitute the food base for some fish. For speckled dace, bluehead sucker, flannelmouth sucker, and mottled sculpin, the nearshore areas may serve as spawning sites, nursery areas, and habitats for adults.

The Sapinero Basin of the Blue Mesa Reservoir (Figure 3.19) is located closest to the dam and is the deepest and coldest of the three basins in the reservoir. In the summer, the Sapinero Basin provides important habitat for adult kokanee salmon in the reservoir (Van Buren and Burkhard 1981). In the summer, adult kokanee in Blue Mesa Reservoir are most abundant at depths of 50-100 ft (Van Buren and Burkhard 1981), where preferred water temperatures are most common. The reservoir inlet structure is located at an elevation of 7,348 ft, which is 171 ft below the maximum reservoir surface elevation, and draws water directly from the Sapinero Basin (Van Buren and Burkhard 1981). If the reservoir level is sufficiently low, a potential exists for adult kokanee to be drawn (entrained) into the inlet structure and killed during water releases. Most kokanee salmon entrained at Blue Mesa, Morrow Point, and Crystal reservoirs are young fish less than 1 year old (Van Buren and Burkhard 1981).

Some degree of entrainment will always occur at the dams, and kokanee that have been entrained and passed through Blue Mesa Dam are periodically observed in Morrow Point Reservoir (Hebein 1993). A relatively high amount of entrainment of young kokanee through Blue Mesa Dam was observed in the late spring and early summer of 1993 (Hebein 1993). The cause of this entrainment, as well as the role (if any) of hydropower operations in the observed entrainment, is not known. Sustained high-water releases from Blue Mesa Reservoir may produce a current leading to the reservoir inlet structure of the dam. Young kokanee, which are attracted to currents, could thus be drawn into the inlet structure and killed. The entrainment and fish loss observed in 1993 may have resulted from releases of large amounts of water from Blue Mesa Reservoir because of very high water conditions at the reservoir (Hebein 1993).

The tailwaters below Blue Mesa and Morrow Point dams are the only remaining riverine habitat between the upper end of Blue Mesa Reservoir and Crystal Dam. However, even these areas become lakelike under some conditions. These tailwater areas receive water releases from the dams, and at low surface water elevations in Morrow Point or Crystal reservoirs, the tailwater areas become riverine. At high surface water elevations, the reservoir waters back up into the tailwaters, and a lake environment is formed.

3.4.3.1.3 Aquatic Food Base

The aquatic food base in the Aspinall reservoirs and the effects of hydropower operations have not been studied extensively, and little information is available regarding the trophic dynamics of the reservoirs. The reservoirs are deep, cold, oligotrophic lakes. In general, oligotrophic lakes and reservoirs are low in nutrients and organic productivity, have nutrient-poor sediments, few rooted aquatic plants, a low production of unattached algae (called phytoplankton), and well-oxygenated deep waters (Cooke et al. 1986). Zooplankton are the major food of the kokanee salmon inhabiting lakes and reservoirs throughout North America (Scott and Crossman 1973; Sigler and Sigler 1987). Young kokanee salmon serve as important food for other fish, including rainbow and cutthroat trout (Scott and Crossman 1973; Sigler and Sigler 1987).

The benthic community in the tailwaters of the Blue Mesa and Morrow Point dams should be similar to the communities present in the Gunnison River above the reservoirs. Macroinvertebrates in the river include chironomids, mayflies, stoneflies, and caddisflies (Stanford and Ward 1982; Fuller and Stewart 1977).

3.4.3.2 Terrestrial Ecology

This section summarizes information on the vegetation and wildlife that occur in riparian areas along Crystal, Morrow Point, and Blue Mesa reservoirs. Species and habitats in adjacent upland areas are not discussed in detail because they are not dependent on water levels in the reservoir and therefore are not affected by hydropower operations.

3.4.3.2.1 Vegetation

The Aspinall Unit is in the Southern Rockies ecoregion (Omernik and Gallant 1987b). The reservoirs occupy areas that, for the most part, had been canyons or, in sections of Blue Mesa Reservoir, somewhat wider steep-walled valleys. Little of the original riparian vegetation escaped inundation upon completion of the dams. At normal reservoir levels, most riparian vegetation occurs along the tributaries of the reservoirs rather than along the shores of reservoirs themselves. Figure 3.25 depicts the riparian habitat found along the reservoirs.

Figure 3.25

Upland areas surrounding Blue Mesa Reservoir are moderately to steeply sloped and dominated by black sagebrush, Mountain big sagebrush, needlegrasses, Sandberg bluegrass, wheatgrasses, bottlebrush squirreltail, and blue grama (Chapman 1993a). Little riparian vegetation of any kind grows along the Blue Mesa Reservoir, either above or below the normal high-water line (only about 0.03 acre per mile of shoreline and 0-10 ft wide). In most areas, upland vegetation or bare rock occurs down to the water. However, some areas support riparian vegetation, mainly near the confluences with tributaries. In such areas, narrowleaf cottonwood, coyote willow, thinleaf alder, and sweet clover may be found. Approximately 10 acres of marsh dominated by sedges occurs where the Gunnison River enters the upstream end of Blue Mesa Reservoir. This marsh receives water when reservoir elevations are relatively high (around 7,510 ft MSL), and water enters the marsh through the boulders and fill material that form a road embankment.

Morrow Point Reservoir is surrounded by steep rocky slopes vegetated with Douglas-fir and white fir, along with aspen, sagebrush, and service berry and, to a lesser extent, pinyon pine, Rocky Mountain juniper, and Gambel oak. Little riparian vegetation of any kind occurs along the Morrow Point Reservoir. Much of the northern shore is unvegetated rocky cliffs; in other areas, upland vegetation extends down to the high water line. Vegetation does not exist between the high- and low-water lines because of repeated exposure and inundation. Pine Creek, Curecanti Creek, Blue Creek, and Round Corral Creek (tributaries to Morrow Point Reservoir) support riparian areas of narrowleaf cottonwood, willow, and thinleaf alder near the reservoir.

Crystal Reservoir also is surrounded by steep rocky slopes that are vegetated primarily with pinyon pine and Rocky Mountain juniper, along with stands of Douglas-fir, white fir, aspen, and Gambel oak. The upper riparian zone of Crystal Reservoir is dominated by box elder, narrowleaf cottonwood, and coyote willow for about 0.5 mi below Morrow Point Dam, where the flow is essentially riverine. Here, the riparian zone is 0-13 ft wide. In this riverine section, where daily fluctuations have ranged from 0 to 5,300 cfs during normal water years, some marsh vegetation (e.g., spikerush, horsetail, and grasses) occurs within the lower riparian zone. Farther downstream, a distinct riparian zone is lacking. Woody riparian vegetation, including box elder, narrow leaf cottonwood, and willow, occurs along the reservoir shore where Crystal Creek enters the reservoir.

3.4.3.2.2 Wildlife

Nongame species that occur in the areas around the Aspinall reservoirs include striped chorus frog, tiger salamander, leopard frog, bull snake, western garter snake, smooth green snake, sagebrush lizard, eastern fence lizard, red-tailed hawk, yellow warbler, lazuli bunting, song sparrow, dusky shrew, least chipmunk, and meadow vole (Garner 1992). Because of the limited amount of riparian vegetation around the reservoir (Section 3.4.3.2.1), these species are not expected to depend on reservoir water level.

Golden eagles and prairie falcons nest annually near the Aspinall reservoirs (Distel 1992; Garner 1992), and several areas along Blue Mesa Reservoir serve as golden eagle roost areas. Both species use cliff sites for nesting and roosting but do not forage over the water or in riparian areas.

The Gunnison River and Aspinall reservoirs provide habitat for the river otter and beaver (Garner 1992). Ten otters were reintroduced in 1979 below Crystal Dam (Klein 1992), but the current status of this species in the area is not known (Garner 1992). Beaver are common in the region and may occur along the reservoirs (Garner 1992).

Several species of waterfowl could occur on the reservoirs during the breeding season, migration, and in the winter

(Garner 1992). Ducks and geese that breed in the area include Canada goose, mallard, green-winged teal, blue-winged teal, northern pintail, and American widgeon. Common migrants would include these same species as well as northern shoveler and common goldeneye. It is unlikely that any of these species would occur during the winter since the reservoirs usually freeze over by mid-winter.

Herons and shorebirds expected to use shoreline habitats (especially lower riparian zone areas) include great blue heron, killdeer, and spotted sandpiper. These species are fairly common in the area during the breeding season and migration. A great blue heron nesting area occurs at the upstream end of Blue Mesa Reservoir near South Beaver Creek (Garner 1992).

Game mammals that occur in the vicinity of the Aspinall Unit include elk, mule deer, and bighorn sheep (Garner 1992; Tollefson 1992). All of these species are expected to use riparian habitats along the reservoirs, but none is restricted to these habitats at any time of the year.

Elk and mule deer range widely throughout the region. The area immediately surrounding Crystal and Morrow Point reservoirs receives little use from elk or mule deer, while that around Blue Mesa Reservoir serves as summer and winter range for both (Garner 1992). In severe winters, elk and mule deer move closer to Blue Mesa Reservoir and its tributaries but still use a wide area around the reservoir well beyond any riparian habitats.

The range of bighorn sheep includes the entire area along Crystal and Morrow Point reservoirs, but only limited areas around Blue Mesa Reservoir (Lake Fork of the Gunnison River and West Elk Creek arm of the reservoir) (Garner 1992).

3.4.3.3 Threatened and Endangered Species

The current status of Federally and state-listed threatened, endangered, candidate, and sensitive aquatic and terrestrial species along the reservoirs of the Aspinall Unit on the Gunnison River is summarized in this section. Definitions of listing categories maintained by the Federal Government and the state of Colorado are presented in Appendix D, Section D.4; correspondence with the USFWS regarding threatened and endangered species in the area is provided in Section D.4.5.

3.4.3.3.1 Aquatic Species

No Federal or state-listed threatened or endangered fish species occur in the Aspinall Unit reservoirs (Hebein 1992; Rose 1992). One Federal Category 2 species, the flannelmouth sucker, has been reported from Blue Mesa Reservoir (Tyus et al. 1982; Hebein 1992).

3.4.3.3.2 Terrestrial Species

Federally listed, state-listed, sensitive, or candidate terrestrial species that are known to occur or could occur along the reservoirs of the Aspinall Unit are listed in Table 3.14. Habitats or locations where these species occur are also included in the table. Federally listed species of the area are discussed below.

Whooping Crane (Endangered)

The small population of whooping cranes that migrates through the area of Flaming Gorge Dam (Section 3.4.1.3.2) also migrates through the region of the Aspinall Unit in the spring and fall. Habitats used during migration by these cranes include agricultural fields, wetlands, and small reservoirs (Rose 1992). Although whooping cranes have not been observed in the area, Blue Mesa Reservoir is in an area of relatively low topographic relief and is a potential stopping point for migrating cranes. The marsh at the upstream end of the reservoir could serve as suitable foraging habitat. The steep canyon walls of Crystal and Morrow Point reservoirs greatly reduce the suitability of these reservoirs to migrating cranes.

Bald Eagle (Threatened)

Bald eagles occur along each of the Aspinall Unit reservoirs in the winter (Garner 1992). Up to 52 eagles have been counted along the reservoirs during annual mid-winter surveys (Distel 1992). During the winter, eagles perch in large trees near open, ice-free water and forage for fish and occasionally waterfowl. Use of the area by bald eagles is relatively recent and has occurred as eagle populations have increased throughout the western United States over the past decade.

TABLE 3.14 Federally and State-Listed Threatened, Endangered, Candidate, and Sensitive Terrestrial Species in the Vicinity of the Aspinall Unit Reservoirs on the Gunnison River

Common Name[a]	Scientific Name	Federal Status[b]	State Status[c]	Occurrence within Area
Plants				
Gunnison milkvetch	*Astragalus anisus*	NL	CO-3	Observed near end of Soap Creek arm of Blue Mesa Reservoir (Klein 1992).
Skiff milkvetch	*Astragalus microcymbus*	C2	CO-1	Observed near upper end of Blue Mesa Reservoir (Klein 1992).
Rocky Mountain thistle	*Cirsium perplexans*	NL	CO-2	Observed near Crystal Reservoir (Klein 1992).
Sierra corydalis	*Corydalis casaena brandegei*	NL	CO-3	Observed near upper end of Blue Mesa Reservoir (Klein 1992).
Black Canyon gilia	*Gilia penstemonoides*	3C	CO-1	Observed on cliff faces in vicinity of Aspinall reservoirs and along Gunnison River (Klein 1992; O'Kane 1988).
Colorado desert-parsley	*Lomatium concinnum*	C2	CO-1	Observed near Crystal Reservoir (Klein 1992).
Hanging garden sullivantia	*Sullivantia purpusii*	3C	CO-4	Observed near Blue Mesa Reservoir (Klein 1992).
Birds Whooping crane	*Grus americana*	E	CO-E	Potential occurrence in marsh at upstream end of Blue Mesa Reservoir during migration (Rose 1992).
Greater sandhill crane	*Grus canadensis tabida*	NL	CO-E	Potential occurrence in marsh at upstream end of Blue Mesa Reservoir during migration (Peterson 1990).
White-faced ibis	*Plegadis chihi*	C2	CO-NL	Potential occurrence in marsh at upstream end of Blue Mesa Reservoir during migration (Peterson 1990).
TABLE 3.14 (Cont.)				

Common Name[a]	Scientific Name	Federal Status[b]	State Status[c]	Occurrence within Area
Birds (Cont.)				
Bald eagle	*Haliaeetus leucocephalus*	T	CO-E	Winters along shores of Aspinall reservoirs (Garner 1992; Rose 1992).
Peregrine falcon	*Falco peregrinus*	E	CO-E	Nests on cliffs along Morrow Point Reservoir; potential nest sites along Crystal and Blue Mesa reservoirs; may winter in area (Distel 1992).
Northern goshawk	*Accipiter gentilis*	C2	CO-NL	Observed during breeding season along Crystal Reservoir; may nest in woodlands of area (Distel 1992).
Loggerhead shrike	*Lanius ludovicianus*	C2	CO-NL	Occurs year-round in woody riparian vegetation in the area (Garner 1992).
Mammals Spotted bat	*Euderma maculatum*	C2	CO-NL	Potential occurrence of foraging individuals along reservoirs and Gunnison River (Hoffmeister 1986).
Southwestern river otter	*Lutra canadensis sonora*	C2	CO-E	River otter (not southwestern subspecies) introduced near Crystal reservoir and Gunnison River (Garner 1992); suitable habitat present for southwestern subspecies.

a List of species derived from USFWS (1991a,d); Harris (1991); Rose (1992); Klein (1992).
b Federal listing codes: C2 = category 2 candidate, 3C = no longer a candidate for listing because common or well-protected, E = endangered, NL = not listed (definitions provided in Appendix D, Section D.4.1).
c State listing codes: CO-1 = Colorado list 1, CO-2 = Colorado list 2, CO-3 = Colorado list 3, CO-E = Colorado endangered, C-NL = not listed by Colorado (definitions provided in Appendix D, Section D.4.3).

Although nesting has not been documented in the vicinity of the Aspinall Unit, nesting activity was reported elsewhere within the region in 1990. Published results of annual bald eagle breeding surveys included 10 nests in Colorado (Kjos 1992). Potential bald eagle nest trees along the Aspinall reservoirs include narrowleaf cottonwood and Douglas-fir.

Peregrine Falcon (Endangered)

The peregrine falcon has been observed in the vicinity of the Aspinall Unit, but it is less common there than in the vicinity of Glen Canyon and Flaming Gorge dams. Potential nest sites occur in cliffs along Crystal and Morrow Point reservoirs, but only one active nest was observed (on Morrow Point Reservoir) in 1991. Competition with golden eagles and great-horned owls may limit the peregrine falcon population in this area (Distel 1992). Although peregrines usually occur in the area during the breeding season (March - October), some individuals (possibly those that breed in the arctic) may be present during the winter (Peterson 1990; USFWS 1977). Additional background information on the peregrine falcon is presented in Section 3.4.1.3.2.

3.5 CULTURAL RESOURCES

This section describes the regional cultural backgrounds and summarizes current information on the presence of (1) prehistoric and historic archaeological sites and structures and (2) Native American cultural resources for each of the affected areas. A Class I Overview was conducted for segments of the Green, Gunnison, and Rio Grande rivers (Moeller et al. 1993). The Colorado River was covered by the National Park Service in a separate document (Fairley et al. 1994).

3.5.1 Glen Canyon Dam

3.5.1.1 Regional Prehistory, Ethnohistory, and History

The prehistory of northwestern Arizona can be subdivided into three major periods: Paleoindian, Archaic, and Formative. Remains from the Paleoindian period (9,000-7,000 B.C.), which reflect an emphasis on the hunting of large mammals (including mammoth and bison) and the manufacture of distinctive lanceolate projectile points (Jennings 1989), are confined to isolated surface finds in this region (Fairley 1989a, p.89). During the Archaic period (7,000 B.C.-A.D. 300), a more generalized economy based primarily on small game procurement and plant collecting developed in response to the drier environments of the postglacial epoch. In northwestern Arizona, the Archaic period is represented by various point types, sandals, split-twig figurines, and less diagnostic artifacts (Fairley 1989a, pp. 89-100); only sites of the late Archaic are well documented in the Grand Canyon river corridor (Fairley et al. 1994). The Formative period (A.D. 300-1200) is divided into Basketmaker and Pueblo phases and reflects the gradual development of agriculture and pottery (Fairley 1989a). Sites of the Pueblo II phase are particularly well represented and often contain dwelling and storage structures.

After A.D. 1200, puebloan people abandoned northwestern Arizona, and Numic-speaking peoples entered the region. At the beginning of the historic, or Euro-American, period, the Southern Paiute had been established in the Grand Canyon area for more than 200 years (Kelly 1964; Euler 1966). Ethnohistoric studies indicate that Southern Paiute bands occupied the plateau areas for plant collecting and large mammal hunting during the warmer months, moving into lower elevations and canyon bottoms during winter and early spring. Horticulture was practiced to a limited extent.

The Euro-American period began in 1540 with the first Spanish exploration of the Colorado River. During the Spanish-Mexican period (1776-1848), the area was visited by Mexican traders and Anglo-American fur trappers. Permanent Euro-American settlement of the region began after 1850 with the appearance of Mormon missionaries, ranchers, and farmers (Fairley 1989b). The U.S. government sponsored explorations of the Colorado River by John Wesley Powell during 1869-1872 (Powell 1875). Miners first entered the Grand Canyon at this time, and extensive mining for gold, copper, and other minerals continued through the 1920s (Fairley et al. 1994).

3.5.1.2 Prehistoric and Historic Archaeological Sites and Structures

The affected area for archaeological sites and structures was broadly defined in the Glen Canyon Dam EIS (Reclamation 1995) as an approximately 290-mi-long corridor extending along the Colorado River from Glen Canyon Dam to the headwaters of Lake Mead, although this area is much larger than the area that would actually be affected by hydropower operations. The minimum width of the corridor corresponds to the 300,000-cfs water level, and the maximum width includes all areas covered with sediment derived from the river (including fluvial sediment reworked by wind action) above that level (Fairley et al. 1994). Corridor width varies significantly according to valley morphology, ranging from narrow segments confined by sheer canyon walls (e.g., Upper Granite Gorge) to broad segments containing alluvial terraces, colluvial deposits, and dunes on high bedrock surfaces (Fairley et al. 1994; Hereford et al. 1993).

Prehistoric remains along the Colorado River were first described by Powell during his exploratory expeditions of 1869-1872 (Powell 1875). Between 1920 and 1953, several archaeological investigations (amateur and professional) were undertaken in the affected area, and a partial inventory of sites was compiled (e.g., Smithsonian Institution 1920; Taylor 1958). More intensive surveys were conducted during 1960-1970, documenting a total of 140 archaeological sites (Schwartz 1963, 1965; Euler and Taylor 1966; Euler 1967). The site inventory has been supplemented in a piecemeal fashion by new discoveries made during monitoring trips and other routine activities by NPS archaeologists since 1974 (Balsom 1985; Fairley et al. 1994).

To compile a more complete inventory of sites and structures for the Glen Canyon EIS, an intensive 100% survey of the entire affected area was undertaken in 1990-1991 (Fairley et al. 1991). The 1990-1991 survey was preceded by a preliminary survey of the corridor between Glen Canyon Dam and Lees Ferry in 1980, which recorded 24 sites and 23 isolated finds (Fairley et al. 1994). In October 1989, a pilot study of site erosion was conducted by NPS, Reclamation, and USGS at a site in the river corridor known as Furnace Flats (Balsom 1989). That study, which confirmed the presence of sites below the historical high water mark and identified a potential link between dam operations and site erosion, set the stage for the 1990-1991 comprehensive survey (Fairley et al. 1994). That survey entailed a surface examination of all accessible portions of the affected area (total area of 10,506 acres) along parallel transects (30-150 ft apart), adjusting to slopes and other landforms as necessary (Fairley et al. 1994). Although some additional sites may remain unrecorded in areas inaccessible due to topography, with poor surface visibility due to dense vegetation, and where remains are completely buried below the ground surface, the comprehensive inventory, which was undertaken in consultation with the Arizona State Historic Preservation Officer (SHPO), the Advisory Council on Historic Preservation (ACHP), and Native American tribes is adequate for compliance with applicable state and Federal regulations.

A total of 475 prehistoric and historic archaeological sites and structures and 489 isolated finds (e.g., charcoal stains without associated artifacts, possible rock alignments) are currently recorded within the affected area (Fairley et al. 1994). Archaeological sites containing prehistoric remains include lithic scatters, ceramic scatters, petroglyphs, agricultural features (e.g., check dams), structures (e.g., kivas), and rockshelters. These sites occur in a variety of topographic settings, such as river terraces, alluvial fans, dunes, and rockshelters. Most prehistoric occupations date to the late period (primarily Pueblo), although a few sites contain remains assigned to earlier periods (including late Archaic and Basketmaker II) (Fairley et al. 1994). The 80 sites assigned to the historic or Euro-American period include debris scatters, mining camps, structures (e.g., cabins), graves, inscriptions, and boat wrecks (e.g., the Ross Wheeler boat).

At the present time, 323 (or 66%) of the 475 prehistoric and historic sites in the affected area have been determined eligible for the *National Register of Historic Places* (NRHP) by the Arizona SHPO. Twelve sites have been determined ineligible, and one site requires additional testing in order to complete eligibility determination. The remaining 139 sites have not been evaluated. The isolated finds will be evaluated through continuing research and monitoring with the tribes, SHPO, and ACHP, as specified in the Programmatic Agreement on the Operations of Glen Canyon Dam.

3.5.1.3 Native American Cultural Resources

Native American cultural resources that could be affected by the hydropower operational scenarios under consideration in this EIS include archaeological sites that represent traditional or sacred properties, sacred locations or areas, landforms of religious or cultural significance, and biotic and abiotic resources of traditional cultural value. Potentially affected Native American cultural resources occupy the same area as potentially affected archaeological sites (Section 3.5.1.2). Native American tribes that have identified or may identify cultural resources in this area include the

Havasupai, Hopi, Hualapai, Navajo, Southern Paiute, and Zuni.

Collection and dissemination of information regarding the locations, significance, and other details of Native American cultural resources is restricted by the sensitivity of this information. Nevertheless, some of this information is available for inclusion in this EIS. A total of 75 archaeological sites of traditional cultural significance to the Havasupai and Hualapai tribes have been identified. Cultural resources of importance to the Hopi include springs, Salt Mines (including sacred sand at its base), birds with yellow feathers, all endangered and candidate listed species, aquatic organisms, marsh and riparian vegetation (especially reeds, willows, and cattails), and 156 archaeological sites. The Hualapai have also identified various cultural resources, including sacred locations in side-valley canyons, springs (e.g., Honga), mineral (e.g., hematite) collection areas, plants (specifically cattails, willows, arrowweed, mesquite, catclaw, agave, and yucca), mammals (including sheep, deer, elk, and others), and 75 archaeological sites (Reclamation 1995).

Less information is available regarding sites, areas, and resources of cultural or religious significance to the remaining affected tribes. The Navajo have identified a number of archaeological sites, traditional use areas, and landforms (including the terraces and beaches of the Colorado River) of cultural importance. Sites, areas, and resources of significance to the Southern Paiute (Kaibab, Shivwits, and San Juan) and Zuni are likely to occur in the affected area as well. Additional information regarding these cultural resources will be available in the near future (Reclamation 1995).

3.5.2 Flaming Gorge Dam

3.5.2.1 Regional Prehistory, Ethnohistory, and History

The prehistory of eastern Utah and western Colorado can also be subdivided into the three major periods Paleoindian, Archaic, and Formative. The Paleoindian period (9,000-5,000 B.C.), which apparently reflects an emphasis on the hunting of large mammals, is represented by distinctive lanceolate projectile point types (Schroedl 1977; Jennings 1989). In this region, Paleoindian remains are largely confined to isolated finds (Grady 1984; Truesdale et al. 1989), although late Paleoindian habitations have been discovered at two sites in Dinosaur National Monument (Breternitz 1970; Leach 1970). During the Archaic period (5,000 B.C.-A.D. 500), a more generalized economy (based heavily on small game procurement and plant collecting) developed. The Archaic is represented by various point types, as well as groundstone artifacts, basketry, and other items (Jennings 1978), and remains of this period are common in the region (Truesdale et al. 1989). The Formative period (A.D. 300-1300) reflects the introduction of agriculture, although hunting and gathering continued to play a major role in the economy. The Formative (or "Fremont Culture") is also well represented in the region (Breternitz 1970); diagnostic remains include pottery and former pithouses (Jennings 1978; Grady 1984).

During the period A.D. 1000-1300, the Fremont Culture disappeared, and the region was inhabited by the Numic-speaking tribes, including the Southern Paiute-Gosiute and Shoshone-Ute (Euler 1966). Their economy was primarily based on hunting and gathering, but some horticulture was also practiced. During warmer months, small groups exploited resources at higher elevations; larger groups inhabited the southern parts of the region during the winter months (Hughes 1977; Marsh 1982). An account of Ute religion, including burial practices, is provided by Delaney (1989), Marsh (1982), and others.

The first Euro-Americans, including Spanish explorers and early trappers, entered the region between 1776 and 1825 (Hafen 1972). By 1838, Fort Davy Crockett was established as a trading post in Browns Park near the mouth of Vermillion Creek (Eddy et al. 1982). After the decline of the fur trade, the region was traversed by several trails and ferries used in Euro-American settlement of the west after 1840 (Purdy 1959; Tennent 1981; Webb 1986). Cattle ranching began in Browns Park during 1850-1870, and outlaws (including Butch Cassidy) visited the area during these years. Dry farming was attempted between 1900-1930; after this period, residents of Browns Park returned to raising livestock.

3.5.2.2 Archaeological Sites and Historic Structures

Areas containing potentially affected cultural resources are confined to a narrow corridor along the Green River from Flaming Gorge Dam to the mouth of the Yampa River. The minimum width of this corridor was conservatively defined as 0.5 mi from each bank of the river, and the maximum width corresponds to the contour interval 60 ft above mean water level (as defined on current USGS topographic maps) (Moeller et al. 1993). Although many archaeological sites are located on and near the margins of Flaming Gorge Reservoir (Purdy 1959; Day and Dibble 1963), hydropower operations have negligible effects on reservoir levels. Below the Yampa River confluence, any effects of hydropower operations would be obscured by the impact of the Yampa River. Therefore, cultural resources in these areas are not considered part of the affected environment.

The affected area has been subject to at least 26 archaeological and historic site surveys (Moeller et al. 1993, Table 2). These surveys included 23 intensive 100% surveys employing pedestrian transect methods (e.g., Lindsay 1986; McFadden 1978), 2 systematic random sampling surveys also employing pedestrian transects (e.g., Madsen and Sargent 1979), and 1 historic inventory (Tennent 1981). Among the systematic random sampling surveys was the Peaking Power Project, which examined a 200-ft-wide corridor on each side of the river (40% sample) between Flaming Gorge Dam and Dinosaur National Monument (Norman and Merrill 1981). Overall, about 30% of the affected area has been subject to intensive archaeological survey, and approximately 100% of the non-canyon areas has been surveyed with nonintensive or random sampling methods (Moeller et al. 1993).

An inventory of archaeological sites and historic structures in the affected area was undertaken in 1991 for this EIS (Moeller et al. 1993). The inventory was based primarily on a review of existing literature and file data, including the surveys described above, but was supplemented with the results of a field study conducted in June 1992 (Moeller et al. 1995). Seventy-one prehistoric, 26 historic, and 2 combined prehistoric/historic sites are currently recorded in the area. With the exception of one prehistoric site reported from Red Canyon near Flaming Gorge Dam (Day and Dibble 1963, p.77) and a historic cabin (Wade and Curtis Cabin) formerly located in the Canyon of Lodore, sites are absent in the narrow bedrock canyons, presumably because of the absence of available geomorphic settings (e.g., floodplain) (Norman and Merrill 1981; Moeller et al. 1995). Sites do occur within the study corridor on the higher bedrock surfaces above the canyons.

The principal concentrations of sites are found in (1) Little Hole, (2) upper Browns Park (above Swallow Canyon), and (3) lower Browns Park. At least 20 sites are located in the Little Hole area, including prehistoric lithic scatters, a historic mining camp, and combined historic corral/prehistoric lithic scatter. The geomorphic setting of these sites is bedrock or the second terrace level (15 ft above river level). No sites are recorded on the first terrace, 6 ft above river level (Moeller et al. 1995). In upper Browns Park, at least 26 sites are reported within the corridor boundaries, including prehistoric lithic scatters, a historic irrigation ditch, and the John Jarvie Ranch (Tennent 1981). Although their geomorphic context is largely confined to bedrock or the second terrace, at least two prehistoric lithic scatters are situated on side-valley fan deposits (10-15 ft above river level) that overlie the first terrace (Moeller et al. 1995), and the John Jarvie Ranch is located on the first terrace. A total of 29 sites are located in lower Browns Park, including prehistoric lithic scatters, petroglyphs, Lodore School, Flynn Cabin, and Fort Davy Crockett. These sites are located on bedrock, the second terrace, and the first terrace (Moeller et al. 1995). One additional site is located on the first terrace above the confluence of the Yampa and Green Rivers, just below Canyon of Lodore.

Of the sites described above, three of the historic localities are currently listed on the NRHP. An additional 20 prehistoric, 18 historic, and 2 combination prehistoric/historic sites are considered eligible or potentially eligible for the NRHP.

3.5.2.3 Native American Cultural Resources

Native American groups that formerly occupied the affected area may identify sites, areas, or resources of religious or cultural significance within the corridor boundaries. These resources may include former living sites, burials, traditional use areas, sacred sites, and resources of cultural significance (e.g., sacred plants). Representatives of the San Juan Southern Paiute, Southern Ute Tribe, and Northern Ute Tribe (Uintah and Ouray Reservation) were contacted for identification of cultural resources (Sabo 1992a,b). The Northern Ute Tribe is currently compiling an oral history of the tribe, which may yield information regarding cultural resources in the affected area (Chapoose 1994). In October 1994, representatives of the Northern Ute Tribe and Western visited archaeological sites below Flaming Gorge Dam.

3.5.3 Aspinall Unit

3.5.3.1 Regional Prehistory, Ethnohistory, and History

The regional prehistory and ethnohistory for the affected area is the same as that presented for Flaming Gorge Dam (Section 3.5.2.1). However, local history for the Gunnison River differs to some degree from that of the Green River. Spanish explorers and traders first reached the Gunnison River in 1765 and returned in 1776, 1805, and 1813 (Hafen 1948). During the 1830s, a fur trading post (Fort Robidoux) was constructed on the Gunnison River near the mouth of the Uncompahgre River (Hafen 1948). Increased Euro-American settlement of the area, which began with the influx of gold miners after 1859 and continued with the establishment of cattle ranches during 1871-1874, eventually led to conflicts with the Ute. In 1880, the Ute ceded most of their lands in Colorado and were removed to the Uintah Reservation in Utah (Fritz 1941). The discovery of coal in the area in 1879 encouraged further mining exploitation, and in 1881-1882, railroad lines reached the town of Gunnison (founded in 1874). The growth of fruit agriculture led to the establishment of other towns in the area, including Montrose, Grand Junction, and Delta. By the 1890s it had become the primary fruit producing area of the state. Large-scale irrigation projects were developed to support the agricultural industry, and in 1904-1909, Reclamation excavated a tunnel through the Uncompahgre Mountains to divert water from the Gunnison River to the Uncompahgre River for irrigation (Fritz 1941).

3.5.3.2 Archaeological Sites and Historic Structures

Areas containing potentially affected cultural resources are confined to the margins of the Blue Mesa Reservoir and a narrow corridor extending from Blue Mesa Dam to Crystal Dam. The minimum width of this corridor was conservatively defined as 0.5 mi from each bank of the reservoirs, and the maximum width corresponds to the contour level 60 ft above reservoir level (as indicated on USGS topographic maps) (Moeller et al. 1993). Because Crystal Dam functions as a reregulation dam, areas downstream of this unit were eliminated from consideration.

The affected area has been subject to six archaeological and historic site surveys (Moeller et al. 1993, Table 5). They include an early unsystematic survey of Blue Mesa Reservoir (Lister 1962); a 100% intensive survey of Curecanti National Recreation Area, employing fifteen 150-ft pedestrian transects (Stiger 1977, 1980); two small intensive surveys (NPS 1990b; Weber 1991); and two unsystematic surveys below Blue Mesa Dam (Buckles 1964; Breternitz 1974). About 80% of the affected area has been intensively surveyed (Moeller et al. 1993).

Archaeological sites and historic structures in the affected area were inventoried (Class I) in 1991 for this EIS. The inventory was based on a review of existing literature and file data (primarily derived from the surveys described above) (Moeller et al. 1993). A total of 144 sites are currently recorded within the corridor boundaries; 92% of them are located along the margins of Blue Mesa Reservoir (Stiger 1977, 1980). The remaining sites are on high bedrock surfaces above the river between Blue Mesa Dam and Morrow Point Dam. Two exceptions are a section house and other structures associated with the Denver and Rio Grande Railroad near the mouth of Curecanti Creek and a prehistoric site; both are located at the bottom of the canyon. No sites are recorded between Morrow Point Dam and Crystal Dam.

As in the case of the Green River (Section 3.5.2.2), archaeological surveys indicate that few remains are located in the canyon bottoms (Buckles 1964; Breternitz 1974; Stiger 1977, 1980). Within the corridor boundaries, 133 sites are concentrated around Blue Mesa Reservoir. They include 130 prehistoric sites, most of which are classified as lithic scatters or campsites. Several of these sites are associated with features, including traces of former structures, or stone quarries. Five of the prehistoric sites may also contain historic remains. The three historic sites include steel bridges and a trash scatter. Prehistoric sites are located on bedrock and alluvial sediment and are often associated with tributary streams. Thirteen sites are completely submerged, three are partially submerged, and seven sites occur within 20 ft of the high water level (as indicated on USGS topographic maps).

Of the sites described above, 67 occur within the Curecanti National Register District; these sites are listed as a collective unit on the NRHP. Eligibility determinations have not been made for the remaining sites, although at least some of them (77) appear potentially eligible.

3.5.3.3 Native American Cultural Resources

Native American cultural resources of the affected area are the same as those described for Flaming Gorge Dam in Section 3.5.2.3.

3.6 LAND USE

Public lands dominate land ownership in the states of Utah, Colorado, Arizona, and Wyoming, through which the Colorado, Gunnison, and Green rivers flow. A large portion of the public land is Federally owned and consists primarily of national parks, monuments, forests, and reservation lands. The state of Utah alone contains all or part of eight national forests, five national parks, five national monuments, five Native American reservations, three national wildlife refuges, and two national recreation areas. The BLM administers the largest portion of Federal land in each of the four states. Recreation is a key component in the management of the region's public lands and plays a critical role in the area's physical, social, and economic environment.

3.6.1 Glen Canyon Dam

The affected area for Glen Canyon Dam is an approximately 290-mi-long section of the Colorado River that meanders through Coconino and Mohave counties in northwestern Arizona and stretches continuously from Glen Canyon Dam through the Lees Ferry reach of Glen Canyon National Recreation Area and through Grand Canyon National Park into the headwaters of Lake Mead near Separation Canyon (Figure 3.27). The corridor includes the river and a narrow strip of land along each side of the river that extends up to 500 ft beyond either shoreline.

Recreation is the dominant land use in the affected area. The largest urban area within 75 mi of the affected area is Flagstaff, Arizona, about 80 mi southeast of the village of Grand Canyon. In 1990, the population of Flagstaff was 45,857 persons (U.S. Bureau of the Census 1991a). Page, Arizona (1990 population of 6,598) is located on a mesa above Lake Powell and the Colorado River, about 2 mi southeast of Glen Canyon Dam.

Figure 3.27

The affected section of the Colorado River runs exclusively through public and tribal lands. Beginning at Glen Canyon Dam, the river flows south through the lower reaches of Glen Canyon National Recreation Area (Glen Canyon NRA), and through Grand Canyon National Park. The river passes below sections of the Navajo Indian Reservation and the Hualapai Indian Reservation before flowing into Lake Mead NRA. Glen Canyon NRA, Grand Canyon National Park, and Lake Mead NRA are administered by the NPS.

Land in Grand Canyon National Park is managed according to zoning classifications defined in the park's Statement for Management (NPS 1985). Most of the park's 1.2 million acres is zoned under a "natural" classification. Approximately 95% of the park is currently under consideration for designation as a wilderness (NPS 1993). A few inactive, privately owned mining claims totaling 357 acres are located on the northern side of the Colorado River north of Grandview Point. The Grand Canyon National Park Statement for Management (NPS 1985) includes a map of zoning categories in the park. A new general management plan is being developed.

Most of the land in Coconino and Mohave counties in Arizona is Federally owned. Native American reservation lands account for 37% of the land in Coconino County; the USFS manages about 30%; the NPS controls 7%; and about 15% is privately owned (Aber 1992). The BLM is the principal landowner in Mohave County, with jurisdiction over about 50% of the land in the county. NPS lands account for 12% of the land in the county, and about 20% is privately owned (White 1992). Grazing is the primary agricultural activity on private lands in Coconino and Mohave counties, but no agricultural activity occurs in the affected area. The Coconino County comprehensive plan was last updated in 1990 (Aber 1992). An updated version of the Mohave County comprehensive plan is expected to be completed by the end of 1993.

Agency land and resource management plans, county comprehensive plans, and other land use control guidelines or documents that govern the Colorado River segment examined in this EIS are listed in Table 3.15.

TABLE 3.15 Land Use Planning and Management Documents Pertaining to the Glen Canyon Dam Area

Jurisdiction	Agency	Document Title	Year Updated
Coconino County (Arizona)	County	Comprehensive Plan Zoning Ordinance	1990 1981
City of Page (Arizona)	City	Zoning Code Community Master Plan Gateway Area Specific Development Plan	1981 1989 1989
Mohave County (Arizona)	County	Comprehensive Plan	1993
Grand Canyon National Park (Arizona)	National Park Service	Final Master Plan Statement for Management Colorado River Management Plan	1976 1985 1989

The regional transportation network includes two interstate highways (I-15 and I-40), two other Federal highways (U.S. 180 and U.S. 89), three Arizona state highways (Routes 64, 67, and 98), and several county roads. Commercial airline service is available in Page, Flagstaff, and Tusayan, which is located 7 mi south of Grand Canyon National Park.

3.6.2 Flaming Gorge Dam

The affected area of the Green River is in the eastern sections of Daggett and Uintah counties in northeastern Utah and the western portion of Moffat County in northwestern Colorado (Figure 3.28). The affected area consists of a narrow corridor about 95 mi long from Flaming Gorge Dam to a point upstream of Jensen, Utah. The width of the corridor includes the river and extends 500 ft inland from either shoreline. Vernal, Utah, about 40 mi south of Flaming Gorge Dam, had a population of 6,644 persons in 1990 (U.S. Bureau of the Census 1991b) and is the largest urban area in the vicinity. Recreational activities dominate land use within the affected area.

Figure 3.28

Except for a few small privately owned ranches, the affected area consists primarily of public lands under the jurisdiction of the state of Utah and several Federal agencies. Included are portions of Flaming Gorge NRA, the state of Utah's Browns Park Waterfowl Management Area, Browns Park National Wildlife Refuge, and Dinosaur National Monument (Figure 3.28).

Management of public lands along the Green River between the dam and the Colorado state border (about 29 mi) is governed by a 1983 interagency agreement between the USFS, BLM, and Utah Division of Wildlife Resources (BLM 1991). The USFWS administers Browns Park National Wildlife Refuge. Dinosaur National Monument, which occupies about 211,000 acres in Moffat County, Colorado, and Uintah County, Utah, is managed by the NPS (NPS 1986a).

Grazing is the principal agricultural activity on private lands in the three counties containing the affected area, with crop production occurring on less than 5% of the private land in each county. Although little agricultural activity occurs within the affected area, some grazing allotments have been issued near the river. These allotments are administered by the BLM in the upper reaches of the corridor and by the NPS in the parcels in Dinosaur National Monument. No mining or logging occurs near the river. All three counties have master plans or other planning documents.

Special land uses in or adjacent to the affected area include a nationally recognized historic ranch and a wilderness study area (Figure 3.28). The John Jarvie Ranch, a national historic site administered by the BLM, is on the northern shore of the Green River in Browns Park. The Diamond Breaks Wilderness Study Area is a 3,900-acre tract bounded by the Green River on the north and by Browns Park National Wildlife Refuge and Dinosaur National Monument on the east. The study area is administered by the BLM according to interim management policy criteria, which provide direction until Congress either approves a Wilderness Area designation for Diamond Breaks or drops it from consideration (BLM 1991).

The Green River from Flaming Gorge Dam to a point just beyond Split Mountain campground in Dinosaur National Monument is being considered for inclusion in the National Wild and Scenic Rivers System (Eason 1992b). If the river stretch is included, the USFS, BLM, and NPS would retain administrative control of the river but would modify existing land management policies to comply with regulations associated with a change in designation. Most of the study area segment located in Dinosaur National Monument is also being considered for designation as a Wilderness.

All agency land and resource management plans, statements for management, county comprehensive plans, or other land use control guidelines or documents that govern the affected area are listed in Table 3.16.

The transportation network that provides access to the Green River area below Flaming Gorge Dam consists of state and Federal highways and county roads. U.S. 191 runs north from Vernal over Flaming Gorge Dam and into Wyoming. U.S. 40 is an east-west artery that runs through Vernal and links the area with Salt Lake City (175 mi west) and Denver (330 mi east). Commercial airline service is available in Vernal.

TABLE 3.16 Land Use Planning and Management Documents Pertaining to the Flaming Gorge Dam Area

Jurisdiction	Agency	Document Title	Year Updated
Flaming Gorge National Recreation Area (Utah and Wyoming)	Forest Service	Management Plan	1977
Diamond Mountain Resource Area (Utah)	Bureau of Land Management	Resource Management Plan	1992
Little Snake Resource Area (Colorado)	Bureau of Land Management	Resource Management Plan	1989
Green River, from dam to Utah/Colorado state line	Forest Service	Green River Scenic Corridor Management Plan	1985
Dinosaur National Monument (Colorado)	National Park Service	Statement for Management General Management Plan	1990 1986
Uintah County (Utah)	County	Interim Land Use Policy Plan Community Development and Housing Needs Policy Plan	1991 1992
Moffat County (Colorado)	County	Comprehensive Plan	1982

3.6.3 Aspinall Unit

The Aspinall Unit is within the boundaries of the Curecanti NRA in southwestern Colorado. Curecanti NRA contains Blue Mesa, Morrow Point, and Crystal reservoirs (Figure 3.29). Black Canyon of the Gunnison National Monument borders the Curecanti NRA on the west. Grand Junction, Colorado, with 29,034 residents in 1990, is the largest urban area within 75 mi of the Aspinall Unit (U.S. Bureau of the Census 1991c). Recreation is the dominant land use at the Aspinall Unit and on the public lands that surround it.

Figure 3.29

The Curecanti NRA is in southwestern Colorado on the Gunnison River between the cities of Gunnison and Montrose. The national recreation area occupies about 40,500 acres in the southwestern section of Gunnison County and the eastern reaches of Montrose County (NPS 1990a). Large portions of both counties consist of state and Federally owned land (Figure 3.29). The affected area includes the reservoirs of Curecanti NRA and a strip of land, 500 ft wide, that surrounds each reservoir. It consists of Federal lands under the jurisdiction of Reclamation and the NPS. Since 1965, the NPS has administered recreational use and development of land in the Curecanti NRA (Reclamation 1992).

Land in Curecanti NRA is managed under four broad zoning categories . park development, natural, historic, and special use zones. The park development zone includes boat ramps, marinas, visitor centers, and campgrounds. Most of the recreation area is zoned under the "natural" classification. The Curecanti National Recreation Area General Management Plan (NPS 1980) contains a map and descriptions of these zoning categories.

Most of Gunnison County consists of Federally owned land. The USFS has jurisdiction over about 60% of the county land (Schmidt 1992). The county has no comprehensive or master plan, but private lands are governed by land use resolutions that were last amended in 1989 (Williams 1993).

Montrose County contains the western edge of Curecanti NRA and all of the Black Canyon of the Gunnison National Monument. The BLM owns more than 40% of the land in the county (Schmidt 1992). The county's master plan, adopted in 1987, applies to the eastern half of the county.

Most of the private land in the two-county region is used for livestock grazing. Some grazing has occurred in the recreation area, but such use has been limited and may eventually be eliminated (NPS 1990a). Crop production accounts for less than 10% of the land in both counties (U.S. Bureau of the Census 1989).

A small portion of land in the region is developed for commercial and light industrial uses. Two commercial recreation complexes are located north of U.S. 50 just beyond the Curecanti NRA in the Iola Basin portion of Blue Mesa Reservoir. Both complexes are located within a quarter mile of the reservoir and have developed campgrounds, full recreational vehicle hookups, and food services.

Agency land and resource management plans, county comprehensive plans, and other relevant documents governing land use in the affected area are listed in Table 3.17.

The transportation network in the vicinity of the Aspinall Unit includes an interstate highway, state and Federal highways, and county roads (Figure 3.29). Interstate 70 runs west from Denver and passes north of the affected area. U.S. 50 runs east-west along the southern edge of Curecanti NRA before crossing Blue Mesa Reservoir near Dillon Pinnacles. State Highway 92 parallels the northern edge of the recreation area. State Highway 149 enters Curecanti NRA from the south and joins U.S. 50 on the eastern end of Blue Mesa Reservoir. State Highway 437 provides indirect access to the east portal of Curecanti NRA. Commercial airline service is available in Montrose, Gunnison, and Grand Junction.

TABLE 3.17 Land Use Planning and Management Documents Pertaining to the Aspinall Unit

Area

Jurisdiction	Agency	Document Title	Year Updated
Gunnison Resource Area (Colorado)	Bureau of Land Management	Resource Management Plan	1992
Uncompahgre Basin Resource Area (Colorado)	Bureau of Land Management	Resource Management Plan	1988
Curecanti National Recreation Area (Colorado)	National Park Service	General Management Plan Statement for Management	1980 1990
Gunnison County (Colorado)	County	Land Use Resolution	1989
Montrose County (Colorado)	County	Uncompahgre Valley Master Plan	1988

3.7 RECREATION

The recreational resources and recreational activity use rates on the Colorado River below Glen Canyon Dam, on the Green River below Flaming Gorge Dam, and on the reservoirs of the Aspinall Unit are described in Sections 3.7.1, 3.7.2, and 3.73, respectively. Recreational resources include boat ramps, riverside campsites, campgrounds, beaches, and river rapids.

3.7.1 Glen Canyon Dam

The affected environment for Glen Canyon Dam consists of a corridor containing the Colorado River that begins at the dam in the southern reaches of the Glen Canyon National Recreation Area (Glen Canyon NRA) and runs approximately 255 mi downstream through most of Grand Canyon National Park and into the headwaters of Lake Mead near Separation Canyon (Figure 3.2).

A major trout fishery is located between the dam and Lees Ferry (15.5 mi below the dam), and fishing and boating are the dominant recreational activities within this reach. In 1991, almost 210,000 anglers, boaters, raft-bound floaters, and hikers - approximately 7% of the 3,210,890 that visited Glen Canyon NRA that year used this segment of the river (Doland 1992). Recreational facilities include 18 primitive beach campsites and a fully developed campground at Lees Ferry. Six of the primitive campgrounds are not available at flows exceeding 15,000 cfs (Reclamation 1995).

Boat access to the Colorado River in Glen Canyon NRA is limited to a dock below the dam and to the boat ramp at Lees Ferry; only commercial launches are allowed at Glen Canyon Dam. Day floaters (i.e., those who float downstream between the dam and Lees Ferry for all or part of a day) usually launch from the dock. However, dock use is restricted to flows below 29,500 cfs (Bishop et al. 1987). At higher flows, day floaters launch at Lees Ferry and motor upstream to a point near the dam before floating downriver. Anglers typically launch at Lees Ferry and move up and down the river according to fish-movement patterns. The facilities at Lees Ferry are shared by users of Glen Canyon NRA and Grand Canyon National Park.

Below Lees Ferry, the river runs through almost 240 mi of Grand Canyon National Park. One of the nation's most popular natural attractions, the park drew over 4 million visitors in 1991 (NPS 1992a). According to NPS estimates, approximately 10% of all annual visitors engage in some activity below the canyon's rims (NPS 1985).

Recreational use along the river within Grand Canyon National Park is dominated by white-water boating. An internationally recognized white-water river, the Colorado River in the park contains more than 150 rapids. The prime white-water boating season is May 1 through September 30. In 1991, 19,427 commercial and 3,281 private passengers ran the river in Grand Canyon National Park for all or part of its length (Cherry 1993). The NPS limits white-water boating in the park to 169,950 user days per year. Access to the river within the park is limited to a few trails (most notably Bright Angel and Kaibab) and to boat ramps at Lees Ferry and Diamond Creek. Lees Ferry is the launching point for trips down the river, whereas Diamond Creek and Pearce Ferry (located in Lake Mead NRA) are usually used as take-out points.

In addition to the trails and boat ramps, recreational resources in the affected portion of Grand Canyon National Park include approximately 250 beach campsites. The number and size of beach campsites varies with flow regimes.

3.7.2 Flaming Gorge Dam

The affected environment below Flaming Gorge Dam consists of a corridor containing the Green River from Flaming

Gorge Dam in Flaming Gorge NRA through Dinosaur National Monument (Figure 3.28). The river below Dinosaur National Monument has relatively few recreational users or facilities and is not examined in this analysis.

Opportunities for developed and dispersed recreation are abundant in the affected corridor and surrounding area. Developed recreational facilities include visitor centers, amphitheaters, picnic grounds, and fully equipped campgrounds. Dispersed recreation opportunities in areas of minimal or no development include backcountry trails, primitive campgrounds, and isolated spots along the water. Examples of dispersed recreational activities in the river corridor include angling, boating (e.g., rafts and drift boats), hiking, hunting, camping, and wildlife observation. Of these, angling and boating are most directly affected by changes in stream flow.

Because the composition of recreational activities varies by location, the Green River was divided into two segments for purposes of analysis. The upper segment runs from Flaming Gorge Dam to the Colorado border. The lower segment consists of that portion of the river that flows from the Colorado border through Dinosaur National Monument.

3.7.2.1 Flaming Gorge Dam to the Colorado Border

The portion of the Green River that extends from the spillway below Flaming Gorge Dam in Flaming Gorge NRA to the Colorado border is approximately 29 mi long and was visited by an estimated 115,000 persons in 1991 (Sams 1992). Individuals engage in a variety of recreational activities along this stretch of the river, including shore and boat angling, nonangler boating (such as rafts and canoes), hiking, and camping.<10> However, shore and boat angling are the dominant recreational activities, accounting for an estimated 104,650 user days in 1991 (Pratt et al. 1991). This figure reflects a large surge in the popularity of trout angling on the Green River, which resulted from the implementation of regulations in 1985 designed to improve the quality of the sport (Pratt et al. 1991).

Nonangler boating is less popular than angler boating as a primary recreational activity, accounting for approximately 5,750 user days in 1991 (Pratt et al. 1991). The vast majority of nonangling boaters are only on the river for all or part of a given day, usually launching at the spillway ramp and leaving the river at Little Hole. This segment of the Green River is made up almost entirely of Class I and Class II rapids (only one rapid is Class III). Class I and II rapids usually generate waves less than 1 ft high and are considered ideal for novice boaters; rapids with a designation of Class III or above require more advanced white-water skills. Typically, the recreational quality of a rapid is diminished in flows that are very low or relatively high.<11> Because the Green River has relatively low flows during the peak boating season, few experienced boaters are drawn to it. Consequently, most of the nonangling boaters using this segment of the Green River are novices.

Water levels on the Green River can fluctuate by several feet over the course of a day. Optimal flows for recreation vary according to activity. For shore fishing, low flows between 800 and 1,100 cfs are preferred because they allow wading into the river to cast. For boat fishing, flows close to 1,500 cfs are ideal. According to USFS officials administering recreation on the Green River between Flaming Gorge Dam and the Colorado border, flows exceeding 5,000 cfs in this reach pose a safety threat to novice boaters, and flows in excess of 6,000 cfs are considered dangerous for experienced boaters and rafters (Yates 1992b). Flows exceeding 6,000 cfs rarely occur between the dam and the Yampa River and were last recorded in 1984. Flow rates are generally lower in summer and higher in spring, particularly late spring. The Green River flow regimes are discussed in Section 3.3.2.

The peak use times for angling and nonangler boating are fairly distinct (Pratt et al. 1991). Although angling takes place on and near the river throughout the year, the two peak angling seasons are the spring season from April to mid-June and the fall season from September through October; the fall season attracts fewer anglers (9-15%) than the spring season (30-35%). The peak season for nonangler boating begins in mid-June and runs through Labor Day. About 60% of all nonangler boating occurs during this period (Pratt et al. 1991).

An estimated 89% of the shore angling, boat angling, and nonangler boating on the Green River between the dam and the Colorado border occurs in the first 7 mi of the river, between the spillway and Little Hole (Pratt et al. 1991). In addition to several Class I and II rapids, this section of the river contains the best fishing within the affected area. Most of the recreational activity that takes place on the river between Little Hole and the Colorado border consists of fishing (shore and boat) and seasonal hunting.

Recreation on the river between Flaming Gorge Dam and the Colorado border is supported by a number of developed facilities. The tailwaters area has a concrete ramp and improved facilities (toilets and water). Little Hole has two sets of twin concrete ramps, modern restrooms, running water, several picnic tables, and parking areas that were expanded and paved in the summer of 1992. Riverside camping is prohibited above Little Hole.

For those boating on the river below Little Hole, several primitive riverside campgrounds and boat ramps are available. Most of these campgrounds are located high enough above the river level to be spared from the effects of floods. None of these riverside campgrounds are affected by the flows associated with dam operations. The campgrounds at Indian Crossing and Bridge Hollow offer well water and are the most developed. An inventory of river rapids, campgrounds, and boat ramps available on the Green River between Flaming Gorge Dam and the Colorado border is presented in Figures 3.30 through 3.32.

Figure 3.30

Figure 3.31

Figure 3.32

Currently, only commercial fishing and rafting require a permit on this segment of the river. However, a study commissioned by the USFS (Pratt et al. 1991) recommended the establishment of daily use limits for two segments of the river. For the segment running from the dam to Little Hole, a limit of 750 persons per day would be imposed during the peak floating season. River use would be limited to 600 persons per day during the spring fishing season and to 350 persons per day during the off-season. A use limit of 400 persons per day was recommended by Pratt et al. (1991) for all seasons on the segment from Little Hole downstream to the Bridge Hollow campground (approximately 9 mi).

3.7.2.2 Colorado Border through Dinosaur National Monument

The segment of the Green River that runs through Browns Park National Wildlife Refuge was not included in the analysis because of the limited amount of recreation that occurs in the area (Carlson 1992). However, the potential for canoeing and other forms of flatwater boating is high in the refuge, and use of this segment of the river could increase in the future. The majority of recreational use occurring on the river below the Colorado border takes place in Dinosaur National Monument, which is administered by the NPS. The monument's major attractions are an internationally recognized paleontological quarry and exhibit and the Green and Yampa rivers and the canyons through which they flow. The Green River enters the monument just above the Gates of Lodore (Figure 3.33) and runs in a southwesterly direction for approximately 55 mi before exiting downstream of Split Mountain in the western reaches of the monument. The Yampa River flows into the Green River in the central part of the monument.

Figure 3.33

Dinosaur National Monument had more than 465,000 visitors in 1991 (NPS 1991) and more than 507,000 visitors in 1992 (Eason 1993b). Most visitors spend less than one day there, engaging in such activities as a visit to the quarry or a self-guided sightseeing tour of the canyon country on Harpers Corner Scenic Drive. Most overnight visitors are campers in one of the developed drive-in campgrounds or rafters on the Green River who typically spend three to five days and two to four nights in the river corridor. Estimates of total visitation and the number of overnight stays for 1988-1991 are presented in Table 3.18.

Recreation on the Green and Yampa rivers primarily consists of nonmotorized boating or rafting. Both rivers contain several Class II and III rapids. In addition, both rivers contain rapids ranking as Class IV and V, depending upon location and water levels. The primary or high-use boating season within Dinosaur National Monument runs from early May to mid-September. River running on the Yampa River is limited to the early part of the season. Low flows usually restrict recreational activity on the Yampa River by mid-July. In 1991, boating in the monument consisted of 35,704 user-days (NPS 1992b). Although raft trips can begin on both the Green and Yampa rivers, most trips through the monument ultimately end on the Green River, usually at Split Mountain. Most trips on the Green River begin at the Gates of Lodore.

In order to raft the Green River within the monument, individuals must either go through a commercial outfitter or receive a permit for a private raft trip. Currently, 11 commercial outfitters are authorized to undertake a combined total of 300 launches during the high-use season. An equal number of permits for private launches are distributed through a lottery conducted during January of each year. Commercial launches usually involve 15 to 20 persons, whereas the average for private launches is somewhat lower. The NPS also authorizes a limited number of "special population" trips for individuals, including persons with disabilities and persons engaged in various forms of therapy (Carlson 1992).

TABLE 3.18 Annual Visitation and Overnight Use at Dinosaur National Monument, 1988-1991

Year	Annual Visitors	Overnight Stays[a]
1988	493,651	46,611
1989	455,816	55,132
1990	469,378	72,374
1991	468,392	69,098

a Based on estimates of persons camping in drive-in campgrounds, boat-in campgrounds, and nondesignated areas (picnic areas, overlooks, etc.).

Sources: National Park Service, Monthly Public Use Reports (NPS 1988, 1989, 1990c, 1991).

Although releases from Flaming Gorge Dam determine flow rates on the Green River in the upper part of Dinosaur National Monument, flow rates below the confluence with the Yampa River can change substantially according to Yampa River flows. A minimum flow rate of approximately 800 cfs is considered adequate for rafting on the Green River in Dinosaur National Monument; however, higher flow rates are preferred (Eason 1992c). Typically, flow rates on the Green River above the Yampa River confluence drop to the 800-cfs threshold by late June or early July.

Boating user days in Dinosaur National Monument fell by approximately 11% between 1988 and 1989 (NPS 1992b) because of dry conditions. Since that time, use rates have steadily risen toward their former levels, and the monthly distribution of use rates has remained fairly stable. Demand for permits has consistently exceeded the available supply by a considerable margin (approximately 10:1). Although user days represent combined use rates for the Green and Yampa rivers, they are applicable to an analysis of the effects of flow change on the Green River because almost everyone who rafts within the monument spends at least some time on that river.

The monument offers 21 primitive riverside campgrounds containing 33 group sites and five developed drive-in campgrounds. A sixth drive-in campground, Split Mountain, is located on the Green River in the southwestern corner of the monument. In recent years, it has been closed to the public. Its boat ramp, however, is used as a termination point for most raft trips. Most of the primitive riverside campgrounds are located on small terraces a few feet above the river in zones well above the reach of hydropower releases. In Lodore Canyon, the majority of campgrounds and camp landings would be affected only by flows exceeding 13,000 cfs, a value well above normal and historic hydropower operations. Below the Yampa confluence, several campgrounds and camp landings would be affected only by flows exceeding approximately 40,000 cfs (Eason 1993a). An inventory of the monument's recreational resources (including principal rapids, campgrounds, boat ramps, and scenic overlooks) is presented in Figure 3.33.

Several beach areas along the river could be affected by fluctuations in flow related to hydropower generation. The largest of these include a broad beach at the confluence of the Yampa and Green rivers in Echo Park and smaller beaches at Rippling Brook, Rainbow Park, and Split Mountain. At lower flows (800 to 2,000 cfs), other beachlike areas become exposed at numerous spots along the river.

3.7.2.3 Miscellaneous Recreation

Hiking along or near the Green River is a popular pastime for many of the visitors to the area. Several trails provide access to the Green River within the confines of the affected area. Most of these are located in the upper 20 mi of the corridor and in Dinosaur National Monument. The Little Hole National Recreation Trail runs from Flaming Gorge Dam to Little Hole for approximately 7 mi. It is the most heavily used of the area trails. Parts of it become submerged at flows exceeding 5,000 cfs, which is above maximum power plant capacity. Dinosaur National Monument has self-guiding nature trails near the river at Gates of Lodore and Split Mountain. The Jones Hole Creek Trail, which is also self-guiding, runs along Jones Creek, beginning near the Jones Hole Fish Hatchery and terminating at the confluence of Jones Creek and the Green River (Figure 3.33). Echo Park, which is located at the confluence of the Green and Yampa rivers, offers hiking, camping, fishing, and top-quality sightseeing; it is one of the more popular destinations in Dinosaur National Monument.

Other recreational attractions in the affected area include the Lodore Cemetery and Schoolhouse and the John Jarvie Ranch Historic Site (Section 3.6.2). In addition to a small museum, the Jarvie Ranch features a shaded riverside picnic area that can accommodate up to 30 persons. The Jarvie Ranch is located on the north side of the Green River in the Utah portion of Browns Park, approximately 0.25 mi upstream of the Taylor Flat Bridge.

3.7.3 Aspinall Unit

The affected environment for the Aspinall Unit consists of Blue Mesa, Morrow Point, and Crystal reservoirs and their respective shorelines. The entire affected area is located within the confines of the Curecanti NRA (Figures 3.34 and 3.35), which is administered by the NPS. It is surrounded by national forest and BLM lands and is adjacent to Black Canyon of the Gunnison National Monument. Recreationists participate in a variety of activities ranging from wind surfing on Blue Mesa Reservoir to gold medal<12> trout fishing on the Gunnison River below Crystal Dam. Fishing, boating (motorized, nonmotorized, and sailing), camping, wind surfing, sightseeing, snowmobiling, and ice fishing are the area's most popular recreational activities. Several trails are also available that provide a wide range of hiking experiences. Curecanti NRA was visited by 1,089,929 persons in 1991 and is one of Colorado's most popular summer spots (Zichterman 1992a). Peak recreational use in Curecanti NRA occurs from late May through the second week of September.

Figure 3.34

Figure 3.35

Recreational opportunities on the Blue Mesa, Morrow Point, and Crystal reservoirs are discussed in Sections 3.7.3.1, 3.7.3.2, and 3.7.3.3, respectively. An inventory of recreational resources and facilities available in Curecanti NRA is provided in Figures 3.34 and 3.35.

3.7.3.1 Blue Mesa Reservoir

Blue Mesa Reservoir is the largest constructed lake in Colorado (NPS 1990a) and accounts for about 80% of total annual visitation in Curecanti NRA (Zichterman 1992c). The reservoir consists of three large basins that support a variety of recreational activities and facilities: Sapinero Basin, Cebolla Basin, and Iola Basin (Figure 3.34). Fishing and boating are the dominant recreational activities in Sapinero Basin, which is located directly behind the dam and is the deepest (approximately 300 ft) and largest of the basins. Sailing, wind surfing, and water skiing are popular on Cebolla Basin, which is approximately 200 ft deep and is east of Sapinero. Fishing, boating, water skiing, and wind surfing are the primary activities on Iola Basin, which occupies the eastern section of Blue Mesa Reservoir and is approximately 100 ft deep.

Blue Mesa Reservoir's recreational facilities include two marinas, five concrete boat ramps, several developed and boat-in campgrounds, numerous hiking trails, and a visitor's center at Elk Creek (Figure 3.34). The marinas at Lake Fork and Elk Creek have tapered boat ramps and feature floating docks and stores to compensate for fluctuating reservoir levels.

3.7.3.2 Morrow Point Reservoir

Morrow Point Reservoir, which had over 112,000 visitors in 1991 (Zichterman 1992b), is a narrow fiordlike body of water that stretches for 11 mi below Blue Mesa Dam. The Pine Creek, Curecanti Creek, and Hermits Rest trails provide the only access to the shores of Morrow Point Reservoir. Boats are allowed on the reservoir, but these are limited to small carry-in boats such as rafts, canoes, and kayaks. Fishing (boat and shore) and hiking are the major recreational activities occurring on and along Morrow Point Reservoir. Camping is encouraged in Morrow Point's two primitive campgrounds. Visitors who camp along the shoreline run the risk of camp inundation. A 32-passenger tour boat operates on the reservoir (Figure 3.35), and it becomes stranded at water levels below an elevation of 7,151 ft. However, in 1994, the NPS plans to either eliminate the tour boat or replace it with two pontoon boats that can operate on reservoir levels above an elevation of 7,147 ft (Chapman 1993b).

3.7.3.3 Crystal Reservoir

Crystal Reservoir, approximately 6 mi in length, is narrow and is accessible only from the Mesa Creek and Crystal Creek trails (Figure 3.35). Fishing is the principal recreational activity on Crystal Lake, and boating activity is limited to small hand-carried craft. A single boat-in campground is located east of the Crystal Creek inlet. The reservoir was visited by 1,421 persons in 1991 (Frank 1993).

3.8 VISUAL RESOURCES

The physical attractiveness of a particular region, area, or place contributes to its aesthetic value. Although sounds and smells are important factors in aesthetic value, visual elements exert the most influence. Almost every natural visual element and landscape typical of the west-central United States occurs in the areas affected by the Glen Canyon, Flaming Gorge, and Aspinall Unit dams. Some natural features, such as the Grand Canyon of the Colorado River or the Black Canyon of the Gunnison River, are recognized worldwide for their unique scenic value.

The USFS and BLM have developed visual resource management systems to classify and administer viewsheds (USFS 1973, 1974; BLM 1991). These systems identify three viewing proximity zones that define the distance between an observer and an object or feature. The visual resource analysis in this Power Marketing EIS includes viewing proximity zones that differ only slightly from those defined in the USFS and BLM systems. The foreground viewing zone consists of the view from between the edge of the feature or collective features and 0.25 mi; the middle-ground zone stretches from 0.25 to 3 mi; and the background zone radiates outward from 3 mi. The affected area for Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit consists of the foreground and middle-ground viewing zones only; views from beyond 3 mi would not be affected by hydropower operations.

3.8.1 Glen Canyon Dam

The Colorado River corridor is visually unique because of its variety in landform, texture, and color. The Grand Canyon forms a chasm that is 1 mi deep and up to 18 mi wide. A visitor can view its impressive physical beauty from several perspectives . standing on one of its rims, descending a canyon trail, or standing along the river's edge. Spectacular vistas are available throughout the region.

The affected area was conservatively defined as the entire canyon and its North and South Rims. Prominent viewpoints on the South Rim of the canyon include Hopi, Mohave, and Pima points. Bright Angel Point and Cape Royal overlook the canyon and beyond from the North Rim. Vegetation in the forests surrounding the affected area consists of spruce, pine, fir, and quaking aspen. Tamarisk, mesquite, apache plume, and coyote willow are some of the common species of vegetation that inhabit the inner canyon and are found near the river.

No official inventory of visual resources has been conducted for the affected area of Glen Canyon Dam.

3.8.2 Flaming Gorge Dam

Just below Flaming Gorge Dam, the Green River flows through the steep rose-colored walls of Red Canyon. Vegetation is dominated by small shrubs, pinyon pine, and Utah juniper. Stands of box elders are located intermittently along the river. White water occurs on this stretch of the river through a series of riffles and rapids.

After leaving Red Canyon, the river meanders slowly through Browns Park. Browns Park is characterized by pale, rolling hills that give way to mesas and terraces near the river's shore. The desertlike landscape is dominated by sagebrush, greasewood, and other small shrubs. Tamarisk stands and cottonwood groves of varying sizes are scattered along the edge of the river. White water is relatively scarce on the Browns Park segment of the river.

The Green River and surrounding area offer many views, vistas, and observation points. Harpers Corner Scenic Drive offers several views of Dinosaur National Monument canyon country. As the river enters Dinosaur National Monument, it flows through deep canyons. Steamboat Rock, which towers over the confluence of the Yampa and Green rivers and has a large beach area, is one of the monument's most prominent landmarks. In Island Park, the river loops through a broad, flat area. Here the landscape is dominated by mountains in the distance, desert shrubs away from the river, and stands of box elder or cottonwoods inside the bends of the river.

Visual intrusions into the natural environment of the affected area include boat ramps, bathrooms, vault toilets, and two bridges. Most of these intrusions are located between the dam and the Colorado border. Other intrusions include the El Paso pipeline, which enters the affected area from Gorge Creek near Little Hole; the Mapco pipeline, which crosses the river below Sears Creek; and several irrigation-related structures located along the river's edge in Browns Park (USFS 1984).

A partial inventory of visual resources in the affected area has been conducted by the USFS and BLM; the stretch of river flowing from the Utah-Colorado border through Dinosaur National Monument has not been inventoried. However, the segment of the river running through the monument has been identified as meeting all criteria for qualifying as a wild river under wild and scenic status. Under the USFS Visual Management System, the portion of the Green River located in Flaming Gorge NRA below Flaming Gorge Dam has a "retention" classification (Baird 1992), which means that management activities and human imprints (such as fences, paths/roads, and facilities) do not significantly alter or detract from the natural landscape. According to BLM Visual Resource Management criteria, the section of the Green River that flows between the eastern edge of Flaming Gorge NRA and the Utah-Colorado border is categorized as Class II (BLM 1991). Some altering of the landscape can occur in Class II areas, but management activities and structures should not attract a viewer's attention.

3.8.3 Aspinall Unit

No official inventory of visual resources has been conducted for the lands adjacent to the Aspinall reservoirs or Curecanti NRA, although a variety of visual elements are present. Blue Mesa Reservoir provides a scenic contrast to the surrounding terrain, with bays that reach into remote and steep canyons. Light-colored barren hills that surround Blue Mesa give way to mesas containing sparse stands of fir. The Curecanti Needle and Dillon Pinnacles are spires sculpted from volcanic deposits by the forces of erosion. Mountain meadows offer a variety of floral displays, and local vegetation varies in type and color with changes in elevation. Sagebrush and desert shrubs dominate near the reservoir, and cottonwood trees grow near the mouths of creeks draining into Blue Mesa.

Morrow Point Reservoir and Crystal Reservoir are narrow bodies of water enclosed by the towering dark walls of Black Canyon. Vegetation is dominated by intermittent stands of Douglas and white fir that grow from the water's edge to the top of the canyon. Scattered communities of pinyon-juniper surround the reservoirs.

State Highway 92, which runs north of Morrow Point Reservoir, is a scenic highway that features several vistas and an overlook area above Blue Mesa Dam. The stretch of U.S. 50 that runs along the southern shore of Blue Mesa Reservoir has been designated the West Elk Scenic Byway.

<10>Most camping, hiking, and sightseeing activities occurring on the Green River between Flaming Gorge Dam and the Colorado border are associated with floating or fishing.

<11>In low flows, exposed rocks or sandbars can become obstacles to boats; in high flows, rapids can become submerged or dangerous.

<12>A "gold medal" designation is given by the Colorado Wildlife Commission to those rivers and streams that offer large trout and outstanding angling (Colorado Division of Wildlife 1991)

[1] The additional areas served by some of Western's customers include 2 counties in California, 22 counties in Nebraska, 2 counties in Montana, 4 counties in Texas, 1 county in Oklahoma, and 1 county in South Dakota.

[2] In this EIS, analyses of impacts to utilitiesare reported for broad utility categories to protect the confidentiality of Western's customers.

[3] The forecasts of the variables that are discussed here were generated with the REMI modeling system for each of the subregional economies. A discussion of the REMI modeling system and corresponding assumptions is providedin Appendix A, Section A.5. Further discussion of the REMI modeling system can be found in Allison and Griffes (1995). Although the contract period runs from 1989 to 2004, the study period included the years 2004 through 2008 in order to adequately address the potential socioeconomic impacts attributable to the commitment-level alternatives over a 15-year period.

[4] Gross regional product is a measure of the value of total output produced in a year and adjusted for the effects of price changes.

[5] All dollar amounts are expressed in 1994 dollars.

[6] The relationship between use values and nonuse values is strongly influenced by such factors as the design of the study, the uniqueness of the resource in question, and the size of the relevant population used to calculate each value (see Appendix A, Section A.6).

[7] For a detailed explanation of Western's electric power systems operation, see the hydropower section of Chapter 3 of the Glen Canyon Dam EIS (Reclamation 1995).

[8] The point where the four states of Arizona, Colorado, New Mexico, and Utah meet.

[9] In the case of Morrow Point, the turbine generator and step-up transformer are located inside the rock cavity near the bottom of the canyon.

4 ENVIRONMENTAL CONSEQUENCES

This chapter presents the impacts of the commitment-level alternatives and operational scenarios that are considered in this EIS. The presentation is divided into two major parts. Section 4.1 discusses the impacts of the commitment-level alternatives on each of the resource categories and attributes described in Chapter 3. Section 4.2 discusses the effects of the operational scenarios at each hydrogeneration facility on the same set of resource categories and attributes. Because there are larger differences between the impacts of each commitment-level alternative on socioeconomics than on the natural environment, the socioeconomic implications of the proposed action are addressed first in this chapter.

Throughout this chapter, the terms slight, moderate, and large are used to convey the importance of the projected impacts on the resource or attribute being evaluated. These relative terms were assigned to impacts after the analysis was completed and are based on professional judgment. Wherever possible, actual projections of percent change in a resource or attribute are presented along with these designations.

4.1 CONSEQUENCES OF COMMITMENT-LEVEL ALTERNATIVES

The major focus of Section 4.1 is on the impacts of each alternative on socioeconomic variables, including regional population, income, employment, and output; the financial condition of the affected utilities; retail rates; and selected economic sectors. The potential impacts of the commitment-level alternatives on air resources are also considered in detail. All impacts are presented relative to the baseline of the no-action alternative under supply option A (defined as continuation of historical operations at Glen Canyon Dam, year-round high fluctuations at Flaming Gorge Dam, and seasonally adjusted high fluctuations at the Aspinall Unit, combined with all necessary power purchases).

While the natural and cultural resources discussed in the previous chapter are also addressed (Section 4.1.3), the discussion is limited to describing, in general terms, the indirect impacts of each commitment-level alternative on the resource in question. These indirect impacts could result from differences among alternatives with regard to the need for new or replacement generating capacity. Such need would arise from the loss of cost-effective hydropower resources. These indirect impacts would be site-specific, and the resources affected and level of impacts could vary widely. Consequently, it is not possible to conduct a more thorough impact assessment for these resources at this time. However, any new construction or any other new action that would result in additional resource impacts beyond those already addressed would be subject to an environmental review before the proposed action was implemented.

4.1.1 Socioeconomics

4.1.1.1 Introduction

This section examines the impacts that each of the commitment-level alternatives could have on the range of economic conditions of the affected environment (as described in Chapter 3). The purpose of the socioeconomic impact analysis is to determine the effects of changes in Western's commitment levels on the economies and populations of the localities and communities that receive electrical power provided by Western. These impacts were measured as the percentage change from the no-action alternative/supply option A, which was considered the baseline for this assessment. Impacts were measured by computing the effects of changes in commitment levels on the financial viability of the utility customers served by Western, the rates charged to the ultimate end users, and the effects of these changes on regional economic conditions. The analysis was based on a series of models of (1) the systems of the major utilities purchasing power from Western, (2) the financial conditions of the utilities purchasing power from the Western system, (3) the present status of electricity rates in the subregions covered, (4) the status of SLCA/IP project repayment, and (5) the subregional economies affected by the action. The analyses and inputs required for the economic impact assessment are illustrated schematically in Figure 4.1.

Figure 4.1

As Figure 4.1 illustrates, the analysis began with the specification of a commitment-level alternative. The commitment-level alternatives analyzed in this EIS represent various amounts of capacity and energy that Western could supply to electric utilities on a long-term basis. Utilities combine this capacity and energy with their other electrical resources to meet demands. The task of ensuring that total generating resources are sufficient to meet current and future demand is accomplished through a process called power resource planning. Analysis of an individual utility's power resource plans was accomplished with a power systems analysis model. The analysis produced a generating capacity expansion plan for each utility system. This expansion plan projects future additions to generating capacity needed to meet demand. Alternatives associated with low commitment levels produced power expansion plans that called for utilities to add more new generating capacity facilities than did alternatives associated with high commitment levels.

The result of the power systems analysis was an estimate of the change in generation and purchased power costs incurred by Western's customers attributable to each of the commitment-level alternatives. Secondary impacts could also be experienced by noncustomers (e.g., investor-owned utilities within the region). Some of these impacts could be positive. However, because such impacts would be smaller than the direct impacts, they are not described here. (The power systems analysis method is summarized in Section A.2 of Appendix A; details of the method and results are provided in Veselka et al. [1995a].) Various SLCA/IP commitment-level alternatives would also result in different SLCA/IP firm power rates. Western's Power Repayment Study model was used to estimate the SLCA/IP firm power rate corresponding to each commitment-level alternative. As is shown in Figure 4.1, the changes in auxiliary power costs and the SLCA/IP firm rate were then combined to determine the change in a customer's wholesale power costs.

FIGURE 4.1

The estimated changes in individual customers' wholesale power costs were used as input to the rate impacts and financial viability analysis. Available information was used to estimate the change in electricity rates by class of customer and to predict any effects the situation could have on the financial conditions of the utilities. Estimates of the price elasticity of demand, which plays a key role in both rate setting and financial viability, were also included in the financial analysis. Details of the price elasticity analysis are provided with the demand analysis documented in Morey and Ungson (1993). The methods used in the financial analysis are summarized in Appendix A, Section A.3.1, and details of the rate impacts and financial viability analysis are provided in Bodmer et al. (1995).

The impact of commitment-level alternatives on conservation and renewable energy programs undertaken by long-term firm sale utility customers was also evaluated. Although these activities often include energy consumption efficiency, peak load reductions, use of renewable energy sources, and cogeneration, only consumption efficiency and load management activities were considered likely to be affected. The analysis of the impact of commitment-level alternatives on these programs focused on commitment-level alternative 4, which would result in the largest increase in electricity rates. Conservation measures that may occur in addition to those induced by changes in electricity rates were not considered as part of the analysis conducted for the EIS. More information on the methods of analysis can be found in Section A.4 of Appendix A.

Electricity is used in the production of most goods and services. Thus, a change in the price of electricity could cause firms, factories, farms, and other industrial and commercial establishments to alter their production techniques and possibly increase or decrease production. In addition, new firms could be created or existing firms could go out of business. Thus, a change in retail rates for electricity could change regional economic conditions. With the REMI modeling system, the regional economic analysis translated the rate effects at the utility level into consequent impacts on population, income, GRP, and employment for each of the subregions considered in this assessment. Additional analysis was performed with the IMPLAN modeling system to measure the impacts of the various commitment-level alternatives on output, personal income, and employment in two high-reliance counties and on low-income groups in the nine subregions. (Details of the regional analysis are provided in Appendix A, Section A.5, and Allison and Griffes [1995].)

Because the source of electrical capacity and energy can affect the level of socioeconomic impact, three different supply options were examined for this EIS. Each supply option consisted of two components: the hydropower component and any purchases or exchanges from alternative sources, such as fossil fuel units, needed to meet a particular commitment level. These supply options were defined as follows:

Supply Option A: Continuation of historical operations at Glen Canyon Dam, year-round high fluctuations at Flaming Gorge Dam, and seasonally adjusted high fluctuations at the Aspinall Unit, combined with all necessary power purchases;

Supply Option B: Low fluctuations at Glen Canyon Dam, year-round high fluctuations at Flaming Gorge Dam, and seasonally adjusted high fluctuations at the Aspinall Unit, combined with all necessary power purchases; and

Supply Option C: Seasonally adjusted steady flows at Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit, combined with all necessary power purchases.

The supply options were selected to cover (1) the entire range of dam operations that could occur at Glen Canyon and Flaming Gorge dams and at the Aspinall Unit, and (2) the maximum, median, and minimum impacts on wholesale power costs. Information on the procedures used to select the supply options analyzed in the EIS can be found in Palmer and Ancrile (1995). Combinations of operational scenarios whose impacts approximate those of supply option A include any combination that incorporates a continuation of historical operations, maximum power plant capacity, or restricted high fluctuations at Glen Canyon Dam; any of the four operational scenarios at Flaming Gorge Dam; and either of the operational scenarios at the Aspinall Unit. Combinations whose impacts approximate those of supply option B include any combination that incorporates moderate fluctuations or low fluctuations at Glen Canyon Dam; any of the four operational scenarios at Flaming Gorge Dam; and either of the operational scenarios at the Aspinall Unit. Finally, combinations whose impacts approximate those of supply option C include any combination consisting of seasonally adjusted steady flows, existing monthly steady flows, or year-round steady flows at Glen Canyon Dam; any of the four operational scenarios at Flaming Gorge Dam; and either of the operational scenarios at the Aspinall Unit.

4.1.1.2 Utility Industry Impacts

Impacts were estimated for each of the utility systems served by Western that could be affected by the commitment-level alternatives. The simulation methods and the level of modeling detail employed for each of the system size categories differed significantly. Large systems were rigorously modeled in order to quantify the impacts of changes in Western's commitment levels on the generation and transmission companies that purchase and resell Western's power. On the other hand, small systems (i.e., those with little or no generating capacity of their own) were analyzed less formally with spreadsheet models that estimated increased costs from alternative power suppliers.

The modeling process for large systems estimated growth in generating capacity (incorporating demand-side management programs) and provided estimates of production costs by simulating the operations of each utility. The major modeling functions in this portion of the analysis included (1) making a risk assessment of long-term firm capacity and energy on the basis of hydrologic resources; (2) estimating Western's hourly firm loads; (3) formulating integrated resource plans for large systems; (4) simulating hourly dispatch and spot market sales for affected utility systems, including the SLCA/IP; (5) estimating alternative supplier costs for small systems on the basis of historical data and a database of projected contract rates from alternative suppliers; and (6) performing feasibility checks.

These electric utility simulation models were integrated and configured so that the modeling system projected the future behavior of electric utilities under baseline conditions and measured the impacts of changes in Western's commitment levels under various supply option constraints. Estimates of spot-market transactions between companies were modeled and simulated to estimate the short-term wholesale market. The impacts of spot-market transactions were modeled independently of SLCA/IP rates estimated by Western. However, they are included in the estimate of total power system costs for each utility system. A more detailed description of the modeling techniques is provided in Veselka et al. (1995a).

The crux of the utility impact assessment is the rate and financial viability analysis. The purpose of that analysis was to quantify the full range of impacts that changes in the costs and quantities of Western's power could have on its utility customers. These impacts might appear as changes in the financial health of the reselling utility and/or changes in price and the quantities consumed by residential, commercial, industrial, and other retail consumers. In essence, this portion of the analysis estimated the economic impacts that could arise in cases where changes in Western's commitment levels might create financial diffi- culties for a utility.

Alternative commitment levels could change the cost of power to Western's customers, since Western's wholesale rates must be adjusted to meet its debt repayment obligations. In addition to producing changes in Western's rates, different commitment levels might also affect the cost of alternative power and the capacity expansion plans of the utilities (as estimated by the power systems analysis). These increasing costs would be manifested through increases in consumer rates, through deterioration of the utility's financial condition, or both. For this reason, there is a direct link between the financial condition of the utilities that sell power and the prices that consumers pay for electricity. For example, if costs increased and rates stayed constant, the impact of the cost increase would appear as a deteriorating financial condition of the utility. Alternatively, if the entire cost increase was passed on to the customers of the utility in the form of higher electric rates, there would be no financial impact on the utilities. As changes in costs occur, the utility manager decides (on the basis of multiple constraints) whether to increase or decrease the utility's financial health or to increase or decrease rates to utility customers. This decision process was simulated through the rate and financial analysis. A short description of this simulation model is provided in Appendix A, Section A.3, with more detail available in Bodmer et al. (1995).

The impacts presented below are based on the results of the entire utility modeling process, including the power systems analysis of the large utility systems and the rate and financial viability analysis of all of the utility systems by category. A general finding of the analysis of the potential impacts to each of the utilities for each of the commitment-level alternatives is that the magnitude of the impact, measured as a change in the utility's retail rates, varies directly with the degree to which the utility system relies on Western for long-term firm capacity and energy and the price of the customer's auxiliary utility supplier. This relationship is illustrated schematically in Figure 4.2, which shows average rate impacts (in terms of percentage changes) as a function of reliance level. Although high-reliance utilities only receive 22% of power sold to Western customers (see Table 3.6), reliance levels rather

Figure 4.2

than the size of purchases from Western are the key determinants of the magnitude of rate impacts. The impacts discussed below and summarized in Tables 4.1 through 4.5 are described more fully in Bodmer et al. (1995). Table 4.6 compares average rates charged by Western customer utilities with the average rates charged by all utilities in the six main states in which Western power is sold. The no-action commitment-level alternative, combined with supply option A, constitutes the baseline for the socioeconomic impacts for the EIS.

4.1.1.2.1 No Action

Combined with supply option B, the no-action commitment-level alternative would result in a weighted average increase in retail rates of approximately 1% (Table 4.1). High-reliance municipals in New Mexico would see their rates increase by the largest percentage, to $105/MWh in 2008 (Table 4.3). Under supply option C, the weighted average increase in rates would be 8%, with high-reliance municipals in New Mexico experiencing the largest percentage increase, to $112/MWh in 2008 (Table 4.4).

As indicated in Table 4.5, under supply options B and C, the number of low- and high-reliance utilities with a coverage ratio of 2.0 or more would remain unchanged. In contrast, there would be one additional low-reliance utility with a coverage ratio of less than 1.1 under these same supply options. The number of high-reliance utilities with a coverage ratio less than 1.1 would increase by one under supply option B and three under supply option C.

4.1.1.2.2 Commitment-Level Alternative 1 (Preferred Alternative)

Combined with supply option A, commitment-level alternative 1 (the preferred alternative) would result in a weighted average increase in retail rates of just over 1% (Table 4.1). High-reliance cooperatives in Arizona would see their rates increase by the largest percentage, to $74/MWh in 2008; while high-reliance municipals in Utah would see their rates decline approximately 12% to $64/MWh (Table 4.2). Under supply option B, rates would rise by a weighted average 3%, with high-reliance municipals in New Mexico experiencing the largest percentage increase, to $105/MWh in 2008; while high-reliance municipals in Utah would see their rates decline approximately 11% to $65/MWh (Table 4.3). Under supply option C, the weighted average increase in rates would be 5%. High-reliance cooperatives in Arizona would experience the largest percentage increase, with an average rate of $81/MWh in 2008 (Table 4.4).

As indicated in Table 4.5, under supply options A, B, and C, the distribution of both low- and high-reliance utilities with respect to coverage ratio ranges would remain unchanged.

Table 4.1

Table 4.2

Table 4.3

Table 4.4

Table 4.5

4.1.1.2.3 Commitment-Level Alternative 2

Combined with supply option A, commitment-level alternative 2 would result in a weighted average increase in retail rates of just over 1% (Table 4.1). High-reliance municipals in Utah would see their rates increase by the largest percentage, to $82/MWh in 2008 (Table 4.2). Under supply option B, rates would rise by a weighted average 3%, with high-reliance municipals in Utah experiencing the largest percentage increase, to $84/MWh in 2008 (Table 4.3). Under supply option C, the weighted average increase in rates would be 6%. High-reliance cooperatives in Utah would experience the largest percentage increase, with an average rate of $86/MWh in 2008 (Table 4.4).

As indicated in Table 4.5, under supply options A, B and C, the distribution of low- reliance utilities with respect to coverage ratio ranges would remain unchanged. The

TABLE 4.6 Average 1991 Electricity Retail Rates by State and End-User Class

Location	Utilities	Rates ($/MWh) by End-User Class		
		Residential	Commercial	Industrial
Arizona	All utilities	91	83	56

	Western customers	85	73	46
Colorado	All utilities Western customers	71 69	57 62	46 46
Nevada	All utilities Western customers	59 56	63 53	49 58
New Mexico	All utilities Western customers	91 98	82 78	48 53
Utah	All utilities Western customers	71 64	61 61	38 46
Wyoming	All utilities Western customers	60 66	52 55	35 44
U.S. average		80	75	48

number of high-reliance utilities with a coverage ratio of 2.0 or more would also remain unchanged under supply options A, B and C. The number of high-reliance utilities with a coverage ratio less than 1.1 would increase by one under supply option C.

4.1.1.2.4 Commitment-Level Alternative 3

Commitment-level alternative 3 would result in a weighted average increase in retail rates ranging from 3% (supply option A) to 5% (supply option B) and 8% (supply option C) (Table 4.1). High-reliance municipals in Utah would see their rates increase by the largest percentage under all three supply options. Under supply option A, rates would increase to $82/MWh in 2008 (Table 4.2); under supply options B and C, rates would rise to $83/MWh (Table 4.3) and $87/MWh, respectively (Table 4.4).

Under supply options A, B and C, the distribution of low-reliance utilities with respect to coverage ratio ranges would remain unchanged (Table 4.5). The number of high-reliance utilities with a coverage ratio of 2.0 or more would also remain unchanged under supply options A, B and C. The number of high-reliance utilities with a coverage ratio less than 1.1 would increase by one under supply option C.

4.1.1.2.5 Commitment-Level Alternative 4

Commitment-level alternative 4 would result in a weighted average increase in retail rates ranging from 13% (supply option A) to 14% (supply option B) and 15% (supply option C) (Table 4.1). High-reliance municipals in Utah would see their rates increase by the largest percentage under all three supply options. Under supply option A, rates would increase to $95/MWh in 2008 (Table 4.2); under supply options B and C, rates would rise to $96/MWh (Table 4.3) and $103/MWh (Table 4.4).

As indicated in Table 4.5, under supply options A, B, and C, the distribution of both low- and high-reliance utilities with respect to coverage ratio ranges would remain unchanged.

4.1.1.2.6 Commitment-Level Alternative 5

Commitment-level alternative 5 would result in a weighted average increase in retail rates ranging from 10% (supply option A) to 12% (supply option B) and 15% (supply option C) (Table 4.1). High-reliance cooperatives in Utah would see their rates increase by the largest percentage under all three supply options. Under supply option A, rates would increase to $128/MWh in 2008 (Table 4.2); under supply options B and C, rates would rise to $130/MWh (Table 4.3) and $134/MWh (Table 4.4).

As indicated in Table 4.5, under supply options B and C, the number of low- and high- reliance utilities with a coverage ratio of 2.0 or more would remain unchanged. The number low-reliance utilities with a coverage ratio of less than 1.1 would increase by one under supply option C. The number of high reliance utilities with a coverage ratio less than 1.1 would increase by one under supply options B and C.

4.1.1.2.7 Commitment-Level Alternative 6

Commitment-level alternative 6 would result in a weighted average increase in retail rates ranging from 4% (supply option A) to 5% (supply option B) and 10% (supply option C) (Table 4.1). High-reliance municipals in New Mexico would see their rates increase by the largest percentage under all three supply options. Under supply option A, rates would increase to $112/MWh in 2008 (Table 4.2); under supply options B and C, rates would rise to $115/MWh (Table 4.3) and $118/MWh, respectively (Table 4.4).

As indicated in Table 4.5, under supply options A, B and C, the number of low- and high-reliance utilities with a coverage ratio of 2.0 or more would remain unchanged. The number low-reliance utilities with a coverage ratio of less than 1.1 would also remain unchanged under all three supply options. The number of high-reliance utilities with a coverage ratio less than 1.1 would increase by one under supply option C.

4.1.1.3 Conservation and Renewable Energy Analysis

The impact of commitment-level alternatives on conservation and renewable energy programs was evaluated by examining the impacts on consumption efficiency and load management activities by long-term firm sale utility customers. The analysis of the impact of commitment-level alternatives on these programs focused on commitment-level alternative 4, which would result in the largest increase in electricity rates. Conservation measures that are currently in place or that are required by regulatory agencies were included in the analysis of alternatives, including the no-action alternative. Conservation measures used by customer utilities do not vary among the alternatives. Therefore, the analysis of the impacts of alternatives on conservation focused on those changes that would result from changes in electricity rates that are a consequence of different commitment levels and supply options. Conservation measures that may be utilized in the future for other reasons were not evaluated because these cannot be predicted at this time.

The analysis indicated that commitment-level alternatives would not differ significantly in their impacts on conservation and renewable energy activities by long-term firm sale utility customers. This situation is due to the narrow variation in the hourly marginal system costs under each alternative after accounting for power purchased by customers from Western. This narrow variation from hour to hour does not permit cost-effective implementation of peak-load management activities. Furthermore, the low cost of power supplied by Western, along with the excess baseload capacity of many customers, results in few cost-effective energy conservation programs and no significant difference among alternatives with respect to cost-effectiveness. A full discussion of methods and findings can be found in Cavallo et al. (1995).

As indicated in Tables 4.2 through 4.4, the majority of commitment-level alternatives and supply options would cause retail rates for electricity to increase and lead to a decrease in electricity consumption, the magnitude of which would depend on demand elasticities. For the majority of impact scenarios, this increase in price would provide consumers with an incentive to undertake conservation measures in order to minimize the overall increase in their electrical bill. Where rates are predicted to stay constant or fall slightly, as is the case with alternative 1, additional measures designed to encourage energy conservation might also be warranted. The impacts of commitment-level alternatives on non-price-induced conservation measures undertaken by consumers were not included in the analysis of socioeconomic impacts in the EIS.

4.1.1.4 Regional Economic Impacts

As was discussed in the previous section, a change in Western's commitment levels could result in a change in rates charged to electricity consumers. This change could in turn affect the level of economic activity and, consequently, growth in the affected subregions. The REMI and IMPLAN modeling systems were used to measure the potential impacts of a change in electricity rates on the economies of each subregion by examining trends in population, income, gross regional product (GRP), and employment; and in the two high-reliance counties on output, personal income, and employment. None of the impact estimatesin the nine subregions analyzed was found to be statistically different from zero. In the two high-reliance counties, the impacts of each alternative were found to be very small.

Higher electricity rates could have caused an increase in the cost of doing business that in turn could have lead to (1) a decline in competitiveness in products made by industries within each subregion, and (2) the substitution by existing customers toward products made outside the affected region. In extreme cases, rate increases could have created an incentive for some businesses to move out of the affected region, or discouraged new businesses from moving in. Both effects would have adversely affected employment, income, and GRP. As higher electricity rates consequently changed the geographic distribution of employment opportunities, population growth and in-migration could have been discouraged. The magnitude of these possible effects would have depended on the importance of electricity prices in production decisions, as well as in locational decisions made by households. With respect to industry relocation, existing research suggests that threshold levels of changes must be exceeded before such impacts would occur (Calzonetti et al. 1991).

The results of the regional analysis with the REMI modeling system are summarized in Table 4.7 (rounded to two significant digits) to show the subregions in which the maximum impacts are estimated to occur. The results of the analysis of impacts in the two counties with high reliance on Western power are shown in Table 4.8. A full discussion of the impacts of each alternative in each subregion for each of the variables can be found in Allison and Griffes (1995).

4.1.1.4.1 Impacts on Population, GRP, Disposable Income, and Employment

The regional analysis indicates that over the forecast period, a change in Western's commitment levels would have a very minimal (if any) impact on aggregate economic activity in each of the nine subregions, or on output, personal income, or employment in the two high- reliance counties. This conclusion also applies to each of the supply options that were considered in the analysis. Moreover, the relatively robust growth rates in disposable income, gross regional product, and employment in most of the nine subregions would offset any losses that would come as a result of any of the alternative and supply option combinations. Because the secondary impacts of additional capacity were not evaluated, the estimates of regional impacts are conservative (see Section A.5.3 of Appendix A for more explanation).

The impacts of electricity rate changes that would occur on population, GRP, income, and employment are projected to be different in each of the nine subregions. Estimates show that, in absolute terms, impacts would be largest in the Colorado Metropolitan, Utah Metropolitan, and Great Basin subregions for each commitment-level alternative. The Wyoming Metropolitan Subregion failed to show measurable impacts for any of the commitment-level alternatives or supply options for the four variables considered. Impacts in this subregion therefore represent the minimum of the range of impacts for each commitment- level alternative and supply option. A detailed description of the distribution of impacts across each of the subregions and over the entire forecast period is provided in Allison and Griffes (1995).

TABLE 4.7 Maximum Estimated Impacts of Commitment-Level Alternatives and Supply Options on Population, Gross Regional Product, Disposable Income, and Employment [a]

Gross								
Alternative/ Supply Option	Population		Regional Product		Disposable Income		Employment	
	Sub-region[b]	Percent Change[c]	Sub-region[b]	Percent Change[c]	Sub-region[b]	Percent Change[c]	Sub-region[b]	Percent Change[c]
NA/B	2	-0.02	2	-0.03	2	-0.05	2	-0.02
NA/C	2	-0.13	2	-0.20	2	-0.15	2	-0.13
1A	9	+0.05	5,9	+0.05	9	+0.09	9	+0.05
1B	9	+0.04	9	-0.04	9	+0.08	5	+0.04
1C	2	-0.13	2	-0.20	2	-0.15	2	-0.13
2A	2	+0.13	2	+0.20	2	+0.15	2	+0.14
2B	5	-0.10	5	-0.10	5	-0.14	5	-0.08
2C	5	-0.13	5	-0.13	5	-0.19	5	-0.11
3A	2	+0.07	2	+0.10	2	+0.08	2	+0.07
3B	5	-0.07	5	-0.08	5	-0.11	5	-0.06
3C	5	-0.12	2	-0.13	5	-0.18	5	-0.09
4A	9	-0.16	9	-0.16	9	-0.27	9	-0.14
4B	9	-0.17	9	-0.18	9	-0.29	9	-0.14
4C	5	-0.21	5	-0.23	5	-0.36	5	-0.19
5A	9	-0.09	9	-0.06	9	-0.15	9	-0.06
5B	9	-0.12	2	-0.09	9	-0.19	9	-0.08
5C	9	-0.15	2	-0.16	9	-0.24	9	-0.10
6A	2	+0.07	2	-0.05	9	-0.08	9	-0.04
6B	9	-0.06	9	-0.06	9	-0.09	9	-0.04
6C	9	-0.11	2	-0.15	9	-0.14	9	-0.07

[a] The data were estimated using the REMI model, which is described in Appendix A (Section A.5), and are rounded to two significant digits.

[b] 1 = Arizona Metropolitan Subregion, 2 = Colorado Metropolitan Subregion, 3 = Nevada Metropolitan Subregion, 4 = New Mexico Metropolitan Subregion, 5 = Utah Metropolitan Subregion, 6 = Wyoming Metropolitan Subregion, 7 = High Plains Subregion, 8 = Rocky Mountains Subregion, and 9 = Great Basin Subregion.

[c] Percentage change from no-action alternative/supply option A (baseline).

TABLE 4.8 Maximum Estimated Impacts of Commitment-Level Alternatives and Supply Options on Output, Personal Income, and Employment in High-Reliance Counties a

Alternative/ Supply Option	Percentage Change by County[b]					
	County A			County B		
	Output	Personal Income	Employ-ment	Output	Personal Income	Employ-ment
NA/B	-0.02	-0.03	-0.01	-0.07	-0.07	-0.03
NA/C	-0.10	-0.13	-0.05	-0.55	-0.61	-0.22
1A	-0.02	-0.02	-0.01	+0.11	+0.12	+0.04
1B	-0.06	-0.07	-0.03	+0.03	+0.03	+0.01
1C	-0.12	-0.16	-0.06	-0.44	-0.48	-0.17
2A	-0.02	-0.03	-0.01	+0.03	+0.04	+0.01
2B	-0.05	-0.07	-0.02	-0.10	-0.11	-0.04
2C	-0.07	-0.08	-0.03	-0.26	-0.28	-0.10
3A	-0.04	-0.05	-0.02	-0.15	-0.16	-0.06
3B	-0.07	-0.08	-0.03	-0.24	-0.26	-0.09
3C	-0.11	-0.13	-0.05	-0.47	-0.52	-0.19
4A	-0.12	-0.15	-0.06	-0.82	-0.90	-0.32
4B	-0.14	-0.18	-0.06	-0.85	-0.94	-0.34
4C	-0.20	-0.25	-0.09	-1.00	-1.10	-0.40
5A	-0.21	-0.27	-0.10	-0.73	-0.81	-0.29
5B	-0.27	-0.34	-0.13	-0.88	-0.97	-0.35
5C	-0.34	-0.42	-0.16	-1.08	-1.19	-0.43
6A	-0.09	-0.11	-0.04	-0.33	-0.36	-0.13
6B	-0.12	-0.15	-0.06	-0.43	-0.47	-0.17
6C	-0.18	-0.23	-0.08	-0.72	-0.79	-0.28

[a] The data were estimated with the IMPLAN modeling system, which is described in Appendix A (Section A.5), and were rounded to two significant digits.

[b] Percentage change from no-action/supply option A (baseline).

For the two high-reliance counties, deviations from the baseline in output, personal income, and employment in the three years examined would be less than 1.5% for each of the alternatives and supply options, and would be less than

1% in most cases (see Table 4.8). Because different models were used, the results of the analyses for high-reliance counties and subregions are not directly comparable. However, the relative importance of impacts of each commitment-level alternative and supply option for the two counties and for each subregion can still be compared by examining the percentage change in each variable from the baseline for each of the scenarios at each geographic scale.

In addition to the impact on aggregate economic activity in each subregion, electricity rate changes also have the potential to differentially affect activity in specific sectors. Analysis of the effects of changes in retail rates on employment in specific manufacturing and service industries, however, did not reveal impacts that were statistically significant. No attempt is made, therefore, to discuss the sectoral impacts of Western's commitment-level alternatives.

4.1.1.4.2 Environmental Justice

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, was issued on February 11, 1994. Under that order, each Federal agency is directed to "make environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority and low income populations." This section addresses environmental justice issues related to commitment-level alternatives.

Changes in electricity rates resulting from each commitment-level alternative and supply option combination have the potential to affect households in all income and population groups. Although all income groups within individual customer utility service territories would experience the same absolute change in electricity rates, changes in rates associated with any of the commitment-level alternatives or supply option combinations would have a greater relative impact on lower income households. This is because expenditures on electricity are a larger part of low-income household budgets than they are for other income groups, and because low-income groups are less able than other household income groups to change their electricity consumption behavior in the short term.

The impact of each alternative/supply option combinations on households with annual incomes of less than $30,000 was estimated using the IMPLAN modeling system to include the overall effect of each combination on low-income groups in each of the subregions in the affected area (see Section A.5 for a description of the methodology used). The impact on minority populations was estimated by comparing the distribution of minority groups in each subregion with the magnitude of the impacts of each alternative and supply option in each of these subregions.

Commitment-level alternatives and hydropower operational scenarios are not expected to have significant adverse effects on existing populations of fish and wildlife (see Section 4.2.4) or the availability of water resources. Therefore, no disproportionately high or adverse impacts are expected on low-income or minority populations that may rely on those resources for subsistence.

Impacts on Low-Income Households

Changes in annual incomes resulting from each alternative and supply option were estimated for 11 household income groups in each of the 9 subregions. The analysis was undertaken for three representative years — 1993, 2000 and 2008.

The results of the analysis indicated that income of households with annual incomes of less than $30,000 would change slightly for most alternative/supply option combinations, with less than 1% of households in this group likely to experience a decrease in annual incomes of more than $500 (Table 4.9). In most cases, fewer than 0.01% of households would experience a change in annual incomes under each commitment-level alternative and supply option. The largest impact on low-income households would occur in the Great Basin subregion in 1993 under alternative and supply option combinations 4C and 5C, with approximately 0.7% of households experiencing a change in annual income of more than $500. Smaller impacts would occur in the same subregion in 2000 and 2008 under these alternative and supply option combinations, and under alternative and supply option combinations 1C, 2C, 3C, and 6C in the Great Basin and High Plains subregions in each of the three years. In all cases, changes in incomes for low income groups would be very slight. More information on the impact of each commitment-level alternative and supply option on low-income households can be found in Rose and Frias (1993) and Allison and Griffes (1995).

Impacts on Minority Populations

Section 4.1.1.4.1 showed that the regional impacts of the power marketing alternatives would be most significant in the Great Basin and Utah metropolitan subregions, with smaller impacts in the Colorado metropolitan subregion. In these subregions, alternative/supply option combination 4C would have the largest impact on population, gross regional product, disposable income, and employment. Smaller impacts would result from alternative/supply option combinations 4A, 4B, and 5C. The alternatives are, therefore, likely to have more of an effect on the Hispanic and American Indian population in the Great Basin subregion, with less of an affect on minority groups in the remaining subregions. However, because the impacts of each of the alternatives and supply options in each of the subregions would be small, the impacts on minority groups would also be expected to be small.

TABLE 4.9 Maximum Estimated Impacts of Commitment-Level Alternatives and Supply Options on Low Income Households: Percentage of Households with Annual Incomes of Less Than $30,000 Receiving Annual Income Decreases of More than $500

Commitment-Level Alternative/ Supply Option	Subregion[a]	Percentage in 1993	Subregion	Percentage in 2000	Subregion	Percentage in 2008
NA/B NA/C	9 9	0.20 0.45	7 9	0.14 0.38	7 7	0.14 0.31
1A 1B 1C	all 7 9	0.00 0.12 0.28	all 7 7	0.00 0.15 0.35	all 9 7	0.00 0.12 0.28
2A 2B 2C	all 5 7	0.00 0.07 0.22	all 5 7	0.00 0.07 0.22	all all 7	0.00 0.00 0.21
3A 3B 3C	all 9 9	0.00 0.07 0.32	all 9 7	0.00 0.05 0.19	all all 7	0.00 0.00 0.20
4A 4B 4C	5 9 9	0.07 0.22 0.66	all 8 9	0.00 0.15 0.63	all all 9	0.00 0.00 0.66
5A 5B 5C	9 9 9	0.05 0.30 0.66	all 9 9	0.00 0.05 0.31	all all 7	0.00 0.00 0.21
6A 6B 6C	all 9 9	0.00 0.29 0.44	all 9 7	0.00 0.05 0.22	all all 7	0.00 0.00 0.21

[a] 1 = Arizona Metropolitan Subregion, 2 = Colorado Metropolitan Subregion, 3 = Nevada Metropolitan Subregion, 4 = New Mexico Metropolitan Subregion, 5 = Utah Metropolitan Subregion, 6 = Wyoming Metropolitan Subregion, 7 = High Plains Subregion, 8 = Rocky Mountains

Subregion, and 9 = Great Basin Subregion.

Source: The data were estimated using the IMPLAN modeling system, which is described in Appendix A (Section A.5).

4.1.1.4.3 Impacts on Irrigated Agriculture

As a result of a change in Western's long-term firm commitments, irrigation districts and cooperatives with a high reliance on Western power could experience changes in the costs of electricity and the costs associated with electrical irrigation. For example, in the case of a price increase, farmers typically reduce water use rates and acreage in marginally profitable crops and increase use of other inputs, including surface water, chemical applications, and management labor. The analysis of impacts on irrigated agriculture indicates that a change in commitment-level alternative/supply option combinations could induce some slight adjustments in agricultural production practices for many farmers.

Table 4.10 summarizes the maximum estimated impacts of the commitment-level alternative/supply option combinations on state agricultural net income in the year 2008. For each commitment-level alternative/supply option combination, the state that would experience the largest impact was determined by comparing percentage changes in state net agricultural income between the baseline and the results under each commitment-level alternative/supply option combination. Table 4.10 indicates that the largest impacts would occur under alternative/option 4C in Utah. Under this commitment-level alternative/supply option combination, net income would fall by $779,000 — a reduction of about 1.2% of total state net agricultural income. Most of this reduction would be accounted for by a reduction of slightly more than $655,000 in net income from irrigated hay. This amount would account for about 84% of the reduction in total state agricultural income. The impacts attributable to

TABLE 4.10 Maximum Estimated Impacts of Commitment-Level Alternative/Supply Option Combinations on Agricultural Output and Net Revenues in the SLCA/IP Service Area in 2008 a

Alternative/ Supply Option	State	Net Revenue Change, State (1994$)	Net Revenue Change, State (%)	High Impact Crop	Net Revenue Change, Crop (1994$)	Share of Total State Impact from High Impact Crop (%)
NA/B	Arizona	-57,500	-0.04	Cotton	-37,700	65.5
NA/C	Arizona	-462,900	-0.34	Cotton	-303,700	65.6
2A	Arizona	-299,000	-0.22	Cotton	-196,100	65.6
2B	Arizona	-419,500	-0.31	Cotton	-275,200	65.6
2C	Arizona	-596,400	-0.43	Cotton	-391,300	65.6
4A	Utah	-709,700	-1.08	Hay	-597,300	84.1
4B	Utah	-734,600	-1.12	Hay	-618,200	84.1
4C	Utah	-778,000	-1.19	Hay	-655,400	84.1

5A	Arizona	-449,500	-0.33	Cotton	-294,900	65.6
5B	Arizona	-569,100	-0.41	Cotton	-373,400	65.6
5C	Arizona	-723,700	-0.53	Cotton	-474,900	65.6

[a] Numbers presented are relative to the no-action alternative/supply option A (baseline).

Source: Edwards et al. (1995).

commitment-level alternative/supply option combinations 4A and 4B would be similar, but slightly smaller in magnitude. As is indicated in Table 4.10, the impacts to net agricultural income associated with each of the other commitment-level alternative/supply option combinations would be smaller than those attributed to alternative/option 4C for each of the six states included in the analysis.

Table 4.11 summarizes the maximum estimated impacts of the commitment-level alternative/supply option combinations on acreage planted, ground water use, and surface water usage in the year 2008. For each commitment-level alternative/supply option combination, the high-impact crop is the one accounting for the largest share of the change in net income for the state. As with the case above, the largest impacts would occur under alternative/option 4C in Utah. These impacts are characterized by a movement away from irrigated cropping and toward dryland cropping. Irrigated acreage would decline by an estimated 4,500 acres, a reduction of 0.5% below the baseline. This movement away from irrigated cropping would involve a reduction in electrically pumped groundwater of almost 45,000 acre-feet, or about 8.7% below the baseline. Use of surface water and other groundwater would also decline, but to a much smaller degree. Impacts attributable to the remaining commitment-level alternatives/supply option combinations would be smaller than those associated with alternative/option 4C.

4.1.2 Air Resources

The potential impacts of Western's commitment-level alternatives have been assessed with regard to local and regional air quality, regional emissions of greenhouse gases, and the acoustic environment. In response to the different capacity and energy-level commitments by Western under various commitment-level alternatives (Table 2.1), the levels and mix of electric energy produced with different fuels by generating units owned by the region's utility systems would change, causing changes in the associated air pollutant emissions and associated air quality impacts. The assessment presented here was based on the results of (1) a series of analyses to estimate changes in capacity factors and air pollutant emissions for individual generating units owned by the region's utility systems affected by Western's commitment-level alternatives and (2) air quality modeling to estimate ambient air quality impacts of individual generating units.

The analyses, information, and input data required for the air quality assessment are shown schematically in Figure 4.3. The analyses used the results of power systems modeling performed for this EIS for the period 1993 through 2008, including (1) projected data for electric energy production and fuel use at existing and projected new generating units, (2) electric energy purchases by the region's utilities affected by Western's commitment-level alternatives, (3) Western's long-term and short-term firm sales commitments, and (4) Western's hydroelectric generation. Computations of changes in electric energy generation, capacity factors, and air pollutant emissions of individual generating units were made for selected commitment-level alternatives — (1) the no-action alternative, moderate power and high energy; (2) alternative 2, high power and low energy;

Figure 4.3

TABLE 4.11 Maximum Estimated Impacts of Commitment-Level Alternative/Supply Option

Combinations on Irrigated Acreage Planted, Surface Water Use, and Ground water Use in the SLCA/IP Service Area in 2008 [a]

Alternative/ Supply Option	State	Change in Irrigated Acreage		Change in Surface Water Use		Change in Groundwater Use, Electric Pumped		Change in Groundwater Use, Other	
		Acres	Percent	Acre-Feet	Percent	Acre-Feet	Percent	Acre-Feet	Percent
NA/B	Arizona	0	0	+200	+0.01	-3,500	-0.2	+20	+0.01
NA/C	Arizona	0	0	+1,800	+0.08	-27,800	-1.6	+260	+0.07
2A	Arizona	0	0	+1,200	+0.06	-18,000	-1.0	+170	+0.05
2B	Arizona	0	0	+1,600	+0.08	-25,200	-1.4	+240	+0.07
2C	Arizona	0	0	+1,900	+0.09	-36,200	-2.1	+230	+0.06
4A	Utah	-4,000	-0.44	-2,400	-0.16	-41,000	-8.3	-340	-0.24
4B	Utah	-4,200	-0.45	-2,500	-0.16	-42,300	-8.3	-350	-0.25
4C	Utah	-4,500	-0.48	-2,600	-0.18	-44,700	-8.7	-380	-0.27
5A	Arizona	0	0	+1,600	+0.08	-27,200	-1.5	+210	+0.05
5B	Arizona	0	0	+2,000	+0.10	-34,300	-1.9	+260	+0.07
5C	Arizona	0	0	+2,600	+0.12	-43,500	-2.5	+330	+0.09

[a] Numbers presented are relative to the no-action alternative/supply option A (baseline).

Source: Edwards et al. (1995).

FIGURE 4.3

(3) alternative 4, low power and low energy; and (4) alternative 5, low power and high energy — in the selected years 1993, 1998, and 2008. In addition to commitment-level alternatives, three supply options described in Section 4.1.1.1 were also considered. Air pollutant emissions were calculated by multiplying the projected data for fuel use at individual generating units or electric energy purchases of individual utilities by appropriate emission factors.

For the local air quality assessment, additional analyses involved (1) air quality impact modeling for selected new generating units, using the Industrial Source Complex Model recommended by the EPA (1986); typical plant parameters; and meteorological data for selected locations within the six-state study region and (2) a subsequent assessment based on the results of the air quality modeling and the significance of capacity factor changes at individual generating units under the selected commitment-level alternatives.

Assessments of potential impacts on regional air quality and greenhouse gas emissions also required (1) estimation of emissions associated with changes in electricity generation by the region's utilities to compensate for changes in Western's hydroelectric generation from long- term and short-term firm sales commitments and to cover Western's long-term firm purchases and (2) a subsequent comparison of the differences in net totals of those emissions among selected commitment-level alternatives. Details of the input data and information and the analyses conducted for air quality impact assessments are provided in Chun et al. (1995).

The projected new generating capacity additions needed to replace retired units and to meet the region's growing power demands include diesel engines, gas turbines, combined cycle units, and pulverized coal power plants of various sizes (Chun et al. 1995). Construction and operation of these new generating units would result in (1) emissions of air pollutants, including those from fossil-fuel combustion, and (2) noise emissions from equipment. Detailed assessments of potential air quality and noise impacts would be needed once individual facilities are proposed at specific sites, but such detailed, site-specific assessments are beyond the scope of this EIS.

4.1.2.1 Air Quality

4.1.2.1.1 Local Air Quality

Potential impacts on local air quality of Western's commitment-level alternatives were assessed for existing generating plants as well as for projected new units. The existing peaking plants with units having more than a 10% change in the annual capacity factor relative to the no-action alternative during any one of the three years evaluated are all small plants that have an individual total plant generating capacity of 19 MW or less and are located in relatively small cities. The percent changes in annual capacity factor(1) from the no-action alternative range from 0 to -7% for alternative 5 in 1993 to 30 to 73% for alternative 4 in 2008. However, none of these plants have annual capacity factors greater than 85% in any of the three years considered. Because air quality impacts of these small peaking plants are small even at a 100% annual capacity factor (Chun et al. 1995), projected changes in the annual capacity factors at these plants are not expected to result in any significant ambient air quality impacts.

The existing intermediate- and baseload plants with units having more than a 10% change in annual capacity factor from the no-action alternative during any one of the three years evaluated are all coal-fired plants that have a total plant generating capacity between 235 and 2,268 MW and are located in rural areas of Colorado, New Mexico, Utah, or Wyoming. The percent changes in annual capacity factor from the no-action alternative (on a plantwide basis) are 5% or less, except for one plant with an annual capacity factor change ranging from -1% under alternative 5 in 2008 to 11% under alternative 2 in 1998. However, this amount of change would be within the total generating capacity of the plant and within the New Source Performance Standards (Chun et al. 1995) and is expected to have minimal impact on ambient air quality.

The projected new peaking units having more than a 10% change in annual capacity factor from the no-action alternative during 1998 and 2008 include gas turbines with a unit generating capacity between 8 and 69 MW and diesel engines with a unit generating capacity between 1.5 and 11 MW. The percent changes in annual capacity factor from the no-action alternative range from -11 to 0% for alternative 2 in 1993 to -15 to 28% for alternative 4 in 2008. However, none of these units have annual capacity factors greater than 28% in 1998 or 2008. Because air quality impacts of these peaking units are small even at 100% annual capacity factor, the projected changes in annual capacity factors at these units are not expected to result in any significant ambient air quality impacts (Chun et al. 1995).

The projected new intermediate-load and baseload plants with units having more than a 10% change in annual capacity factor from the no-action alternative during 1998 and 2008 are all gas-fired combined cycle units with a unit generating capacity between 13 and 186 MW. The percent changes in annual capacity factor range from -43 to 18% for alternative 5 in 2008 to 43 to 91% for alternative 2 in 1993. Because the air quality impacts of these gas-fired combined cycle units are small even at 100% annual capacity factor, the projected changes in annual capacity factors of these plants are not expected to result in any significant ambient air quality impacts (Chun et al. 1995).

4.1.2.1.2 Regional Air Quality

Differences among alternatives and supply options in the amounts and types of emissions are not intuitively obvious and result from the complex relationships between energy prices, purchases, production, energy source, and associated emission factors. These relationships were accounted for in the power systems model used to project impacts. Differences in emissions among alternatives ultimately reflect differences in the amount of reliance on baseload (with generally high emission factors) and peaking power production sources (with generally low emission factors).

The estimated impacts of commitment-level alternatives and supply options on annual air pollutant emissions from the region's 17 utility systems are presented in Appendix B, Table B.7. In general, the emissions of SO2 and TSP projected for alternative 5 (low capacity-high energy) show slightly higher values than under the no-action alternative, but those for alternatives 2 (high capacity-low energy) and 4 (low capacity-low energy) show slightly lower values than under the no-action alternative. However, no clear trends are observed in the projected emissions of NOx and CO2.

The maximum changes in the regional annual emissions from the baseline (no-action alternative/supply option A) are projected to be a decrease of 8,200 tons in SO2 (alternative 2/supply option C in 1998), an increase of 3,700 tons in NOx (alternative 4/supply option A in 2008), a decrease of 2,400 tons in TSP (alternative 2/supply option C in 1998), and a decrease of 261,000 tons in CO2 (alternative 4/supply option C in 1993). Although these changes in projected regional emissions appear significant in their absolute values, they represent a maximum of about 2% or less of existing emission levels (-2.2%, 0.7%, -1.5% and -0.8% for SO2, NOx, TSP, and CO2, respectively). Provided that these emissions changes occurred at various locations over a very large area, their potential impacts on regional air quality would be small.

4.1.2.2 Noise

Changes in operating levels and the mix of generating units owned by the region's utility systems under Western's various commitment-level alternatives could result in changes in levels and patterns of noise generation at these units. Because baseload units generally have large capacities and operate continuously, a change in power generation from baseload units would mean a change in load factors rather than a shutting down or starting up of units. Thus, noise generation from baseload unit operations should change little as long as the units are in operation.

Peaking units generally have relatively small capacities, so a change in power generation from peaking units usually means starting up additional units or shutting down operating units. Even if the number of operating units were changed, the number of such units would be relatively small at any particular generating facility because the changed peaking power demand would be covered by a number of the region's utility systems. Furthermore, even if all existing peaking units at a particular site were operating, the noise generated would be no higher than the maximum level already experienced at the site. Only the frequency and duration of maximum noise levels might increase. However, because of the timing of peak demand, such potential increases in noise would not occur at night when noise impacts are considered more serious. Thus, changes in commitment-level alternatives would not result in adverse noise impacts in the vicinity of the region's electric power generating facilities whose operations are affected by Western's operations.

4.1.3 Other Resources

Western's commitment-level alternatives would not directly affect water, ecological, cultural, land use, recreation, or visual resources. These resources can be directly affected by the hydropower operations that supply much of the power sold by Western, however. Because there is only a weak link between commitment level and hydropower operations, each of the commitment-level alternatives could produce a wide range of impacts to natural resources that would be dependent on the hydropower operations employed rather than on the commitment level itself. The impacts of hydropower operational scenarios are presented in Section 4.2.

There are some differences among commitment-level alternatives in the need for replacement capacity. This need for additional capacity is small relative to total existing capacity and the need for additional capacity resulting from regional load growth, but could be met by building new power plants, by expanding existing ones, or by methods (e.g., conservation) that have minimal environmental effects. Construction and operation would result in additional impacts to the natural resources in the vicinities of the new or expanded facilities. This section briefly discusses the types of impacts that could occur. A more detailed discussion of specific impacts cannot be presented here because the significance and nature of any such impacts would depend on the specific plans and locations for the new or expanded facilities. An environmental review providing full consideration of environmental impacts would be required before construction of any new facilities or modification of existing facilities.

4.1.3.1 Water Resources

During construction of new thermal power plants or modification of existing ones, water resources could be affected by such processes as site clearing (including dredge or fill activities in water bodies), surface or groundwater withdrawal for construction activities, and discharge or spillage of fluids during the construction process. Indirect impacts also could result from the erosion of construction sites and the runoff of sediment into adjacent water bodies. During power plant operations, impacts to water resources could result from surface or groundwater withdrawal for cooling or moderating during power production, as well as from the discharge of waste fluids during normal operations. Withdrawals or discharges associated with abnormal events (accidents) could also impact nearby water resources.

New hydropower facilities could also be built or existing facilities modified to meet additional capacity needs. As for thermal power plants, the impacts of developing this new capacity would depend on the location, type, and size of the project and the nature of the water resources in the area. Impacts of construction or modification could include alteration of associated reservoirs or riverine systems, changes in flow rates and depths, and modification in sediment loads. Operations would affect downstream flows, water temperature, and sediment loads, as well as reservoir characteristics.

4.1.3.2 Ecological Resources

Construction and operation of new thermal power plants could cause a variety of impacts to ecological resources, including aquatic and terrestrial resources, wetlands, and threatened and endangered species (see USFWS 1978 for review). The types of impacts that could occur would depend on such factors as the location, type, and size of facilities and the nature of the resources in the area. Direct impacts of construction to ecological resources could include dredge or fill activities in wetlands or aquatic habitats, destruction or modification of terrestrial or aquatic habitats during site clearing, displacement of animal populations in construction areas, and disturbance of animals in adjacent habitats by construction activities. Indirect construction impacts could include degradation of adjacent habitats by site erosion and runoff.

Impacts that could result from operations of thermal power plants include (1) degradation of aquatic habitats during withdrawal of cooling water from nearby water bodies; (2) entrainment of aquatic organisms during water withdrawal; (3) degradation of aquatic habitats by discharge of heated cooling water to aquatic systems; (4) disturbance of terrestrial animals in adjacent habitats; and (5) harming vegetation by deposition of salts in cooling tower drift on vegetation.

New or expanded hydropower facilities would also affect ecological resources; the nature and extent of any such impacts would depend on the characteristics of the site and the proposed power plant. Construction of hydropower facilities usually results in the inundation of upstream areas. Such inundation would alter the aquatic ecosystem and would cause the loss of upland and riparian resources. Such inundation often produces localized increases in wildlife, especially waterfowl. Construction and operation of hydropower facilities affects downstream ecological resources as well because of changes in the flow regime (including a reduction in flooding), water temperature, and sediment loads of the stream. Section 3.4 describes the types of impacts that resulted from the construction and operation of Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit; these impacts would be representative of the types of impacts that could occur with any new or expanded hydropower facilities.

4.1.3.3 Cultural Resources

Depending on the specific locations, construction of new or expanded power plants could damage or destroy archaeological sites, historic structures, or Native American cultural resources (as generally defined in Section 3.5). Direct impacts would be from construction- related activities. Indirect impacts would be from visual impacts and erosion at construction sites. Construction of new or expanded hydroelectric facilities could result in the erosion of sites downstream of the facility and the inundation of sites by any associated reservoir.

4.1.3.4 Land Use

The construction of any new power plants could alter land use in the immediate vicinity of the facilities. The magnitude and nature of impacts to land use would depend entirely on the nature of land use before construction. Although most impacts would occur in the immediate vicinity of the power plant, regional impacts could also occur. These regional effects would include those associated with utility corridor construction, maintenance, and operation; mineral extraction if coal was used as a fuel source; ash disposal; and increased pressure on the regional transportation network.

4.1.3.5 Recreation

The construction and operation of new power plants could affect recreation in several ways. Perhaps most important would be the potential for a change in the perception of the quality of recreational experiences available in the vicinities of the new facilities. A negative perception could result in a decline in use rates for those recreational activities that require a relatively pristine environment. Such activities include hiking, scenic viewing, and nature photography. Other impacts could include modification of existing recreational resources (e.g., water bodies used as recreation sites) either during construction (e.g., by dredge, fill, channelization) or operation (e.g., effects on water levels, water temperature, water quality). The magnitude of impacts would be dependent on the nature of the area in which the facilities were built, the level of recreational use, and the nature of the recreational resource. New or expanded hydroelectric facilities could result in changes in recreational activities and could cause a shift from recreation associated with flowing water (e.g., white-water boating) to recreation associated with still water (e.g., flat-water boating).

4.1.3.6 Visual Resources

Visual impacts could occur during construction and operation of any new thermal power plants. Such impacts could include (1) reduction of visibility by fugitive dust generated during site clearing and construction; (2) degradation of views by land disturbance and other construction activities; (3) generation of smoke and steam plumes during operations that could be visible at long distances; and (4) intrusion of industrial-type facilities in previously scenic viewsheds. The magnitude of any such impacts would depend on the size and design of the facilities and the visual quality of the areas in which they were built. New or expanded hydroelectric facilities could produce visible changes in stream flows or changes in visual resources produced by new or expanded reservoirs. The magnitude of these impacts would depend in large part on the nature of existing visual resources.

4.2 CONSEQUENCES OF HYDROPOWER OPERATIONS

This section presents the impacts to resources that would result from operation of the Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit (Blue Mesa and Morrow Point dams) hydropower facilities. All impacts are presented relative to a baseline of existing conditions that have formed since placement and operation of the dams. In general, a continuation of historical operations was considered to have no impact on existing resources. Changes in operations could have adverse impacts or benefits, depending on the resource. At the Glen Canyon and Flaming Gorge facilities, impacts of hydropower operations would be limited primarily to resources downstream of the dams. Fluctuations in water releases to produce power would change flows below the dams but would not be sufficiently large to cause significant changes in water levels in the reservoirs above the dams. The Aspinall Unit, however, has relatively small reservoirs that can fluctuate in depth as a result of releases of water for hydropower operations.

Different operational scenarios that span the range of possible operating modes for each facility (as described in Section 2.3) were formulated to identify the types of impacts that could result from hydropower operations. These operational scenarios were identified to enable an examination of the range of impacts possible under different commitment levels and do not represent alternatives themselves. For purposes of assessment, it was assumed that daily release patterns within an operational scenario would (1) be identical within a season or period; (2) reach the maximum variation possible, as defined by the operational scenario, each day; and (3) use a one-hour period to switch between minimum and maximum releases. In addition, the volume of water released each month would either follow the historical(2) pattern of release or be seasonally adjusted to achieve particular resource objectives (e.g., those established in the Biological Opinion for Flaming Gorge Dam [USFWS 1992b]). In either case, the annual amount of water released from a particular facility would be nearly the same for each operational scenario. As in the past, future monthly and annual release volumes would be determined each year by the Bureau of Reclamation and identified in their Annual Operating Plan. These assumptions are conservative and produce worst-case operational scenarios to bound impacts.

The operational scenarios evaluated in the EIS feature one peak in release each day. In the past, two peaks occasionally occurred within a single day. A single daily peak was evaluated in this EIS because, for most resources, a single, longer peak would result in greater impacts than two shorter peaks. Resources that would be affected more by a single daily peak than two peaks include sediment transport (because of a longer period of peak flows), terrestrial ecology (because of a longer daily period of inundation), and endangered fish (because longer peaks would affect flows farther downstream where these species occur). Resources that would be affected more by two daily peaks than a single peak include trout (because of the effects on energy expenditure) and recreation (because fluctuations are considered to have adverse effects on angling and boating). For all resources, the operational scenarios evaluated in the EIS bound the impacts that would occur. Thus, at Flaming Gorge Dam, the effects on trout of a seasonally adjusted high fluctuation operational scenario with two daily peaks would be greater than the effects of a seasonally adjusted high fluctuation operational scenario with a single daily peak, but less than the effects of a year-round high fluctuation scenario.

For Glen Canyon Dam, the nine alternatives being considered in the Glen Canyon EIS (Reclamation 1995) are considered here as operational scenarios. These scenarios are (1) continuation of historical operations (the no-action alternative of the Glen Canyon EIS), (2) operation at maximum power plant capacity, (3) restricted high fluctuation (the high fluctuation alternative of the Glen Canyon EIS), (4) moderate fluctuation, (5) modified low fluctuation, (6) interim low fluctuation, (7) existing monthly volume steady flow, (8) seasonally adjusted steady flow, and (9) year-round steady flow. The moderate fluctuation, modified low fluctuation, and seasonally adjusted steady flow scenarios would feature occasional habitat- maintenance releases above power plant capacity.

For Flaming Gorge Dam, four hydropower operational scenarios were formulated: (1) year-round high fluctuation (similar to historical hydropower operations), (2) seasonally adjusted high fluctuation, (3) seasonally adjusted moderate fluctuation, and (4) seasonally adjusted steady flow. Seasonal adjustments were made in release patterns for the latter three scenarios to bring them into compliance with the recently issued Biological Opinion for the Flaming Gorge facility. The year-round high fluctuation operational scenario is included to permit comparison with impacts that would result from continuation of past operations. All scenarios would feature releases within power plant capacity. Any releases above power plant capacity are outside of the scope of Western's control of operations.

For the Aspinall Unit, two hydropower operational scenarios are considered: (1) seasonally adjusted high fluctuation and (2) seasonally adjusted steady flows. For both of these scenarios, the seasonal adjustments refer to a shifting of water release patterns from the historical pattern to that which would be considered in the Gunnison River EIS. In addition, both scenarios incorporate steady flows from Crystal Dam, the lowermost dam of the unit. Thus, releases from Crystal Dam would not be altered for hydropower production, and resources below this dam need not be considered in an assessment of hydropower impacts.

4.2.1 Socioeconomics

4.2.1.1 Financial and Regional Economic Variables

Section 4.1.1 summarized the impacts of various combinations of commitment-level alternatives and supply options on a range of socioeconomic variables. Each of the supply options consists of purchases and different combinations of operational scenarios at each of the dams. In addition, each of the supply options was selected in such a manner that the full range of socioeconomic impacts attributable to changes in operational scenarios (for a given commitment-level alternative) would be captured. As was noted in Section 4.1.1, the supply options (including steady flows at all of the affected dams) would have, at most, minimal impacts on each of the regional economies studied. Changing dam operations at one site (e.g, reducing fluctuations at Glen Canyon), while leaving dam operations unchanged at the other sites would result in even smaller impacts to these regional economies. Thus, it can be concluded that there would be little, if any, impact to the regional economies from an isolated change in operation of any one of the dams.

In contrast, the results reported in Section 4.1.1 suggest that the different supply options could have varying impacts on the retail rates paid by the utilities' customers. According to the results presented in Tables 4.1 through 4.4, impacts, as measured by changes in the retail rates charged by the affected utilities, would increase as more restrictions are placed on the operations of each dam. For example, depending upon the commitment-level alternative in question, retail customers of low-reliance utilities could experience rate changes ranging from -7.6% under supply option A to +15.5% under supply option C. In a similar manner, customers of high-reliance utilities could see their rates change by amounts ranging from -10.3% under supply option A to +41.1% under supply option C.

4.2.1.2 Recreation and Nonuse Values

The use values of angling and white-water boating are affected by such factors as the number of recreationists (i.e., the quantity of recreation) and the perceived quality of the recreational experience (see Appendix A, Section A.6, and Carlson [1995] for a more detailed discussion of this relationship). Quality is, in turn, influenced by such factors as river flows, catch rates (in the case of angling), and scenic beauty. A change in the operational scenario at each dam could affect the level of river flows, as well as fluctuations in river flows. In turn, these changes could affect the use value of recreation. The magnitude of this change would depend on the magnitude of the changes in the number of recreationists that visited a site and/or the quality of the recreational experience.

To the extent that there is a change in the quantity of recreation, the local economy would also experience impacts. In particular, at some average level of expenditures per recreationist, a change in use levels would result in a change in total recreation-related expenditures, and, therefore, the total amount of local economic activity attributable to recreation.

As part of its analysis in support of the Glen Canyon Dam EIS, Reclamation is sponsoring a study of nonuse values associated with the riparian environment below Glen Canyon Dam. The preliminary results of focus group sessions conducted for the study suggest that some individuals may attach nonuse values to this environment. Moreover, some evidence suggests that such values may be sensitive to impacts to vegetation and associated wildlife, native fish, Native American Groups, and archeological sites (Reclamation 1995). To the extent that different operational scenarios result in such impacts, a change in dam operations could result in a change in nonuse values as well. However, it is not clear whether some individuals might also attach nonuse values to the hydroelectric power generated at Glen Canyon Dam. If this is the case, the same operational scenario could possibly affect this latter category of nonuse values. Furthermore, it is possible that the potential changes in the nonuse values for hydropower could somewhat offset those for environmental resources. In any event, evidence now available is insufficient to support any definitive conclusions about the magnitude of nonuse values associated with the different operational scenarios. Consequently, changes in nonuse values were not considered further for this EIS.

4.2.1.2.1 Glen Canyon Dam

Following the approach used by Bishop et al. (1987), it was noted that the demand for permits to raft the Colorado River below Glen Canyon Dam far exceeds the available supply. In addition, no evidence suggests that angling use rates would be substantially altered by a change in flow regimes below the dam. Consequently, it was concluded that there would be no change in boating or angler user days as a result of a change in dam operations. Since use rates were assumed to remain constant, it is reasonable to assume that recreation-related expenditures in the local economy would remain unchanged as well. Thus, no estimation was made of regional economic impacts attributable to changes in recreation use rates and expenditures.

In the case of changes in the use value of recreation, however, the study by Bishop et al. (1987) produced strong evidence that such values would change as flows change. According to their results, the use values of white-water rafting and angling increase as the degree of daily fluctuations in flows decreases. In addition, use values for angling reach a maximum at a flow level that is considerably less than the flow level required to maximize the value of white-water boating. However, given the structure of the questions used in the study by Bishop et al., inferences on the effects of fluctuations in flows were limited to fluctuations greater than or less than 10,000 cfs. As a result, it was not possible to distinguish between certain operational scenarios, as indicated below. In addition, recreation values were limited to angling and commercial and private white-water boating, since these were the activities found to be sensitive to changes in flows.

The results of the study by Bishop et al. (1987) were used as the basis for the estimates of the net economic value of recreation for each of the operational scenarios at Glen Canyon Dam. The values reported for each of the operational scenarios discussed below are summarized in Table 4.12. These values were all taken from the Glen Canyon EIS (Reclamation 1995).

TABLE 4.12 Summary of Recreation Use Values Associated with Each Operational Scenario at Glen Canyon Dam

Operational Scenario/ Hydrological Condition[a]	Use Value by Recreational Activity (10^{6} 1994 $)					
	Angling	Commercial White-Water Boating	Private White-Water Boating	White-Water Boating below Diamond Creek	Total[b]	Percent Change[c] from Historical Operations

Continuation of historical operations						
Dry	1.4	5.7	1.2	0.11	8.41	–
Moderate	1.3	6.7	1.3	0.13	9.43	–
Wet	1.2	11.9	1.9	0.26	15.26	–
Maximum power plant capacity flows						
Dry	1.4	5.7	1.2	0.11	8.41	0.00
Moderate	1.3	6.7	1.3	0.13	9.43	0.00
Wet	1.2	11.9	1.9	0.26	15.26	0.00
Restricted high fluctuating flows						
Dry	1.4	5.7	1.2	0.11	8.41	0.00
Moderate	1.3	6.7	1.3	0.13	9.43	0.00
Wet	1.2	11.9	1.9	0.26	15.26	0.00
Moderate fluctuating flows						
Dry	1.6	5.5	0.9	0.10	8.10	-0.04
Moderate	1.3	6.7	1.3	0.13	9.43	0.00
Wet	1.2	11.9	1.9	0.22	15.22	0.00
Modified low fluctuating flows						
Dry	1.9	6.6	1.1	0.12	9.72	15.58
Moderate	1.4	9.6	1.7	0.18	12.88	36.59
Wet	1.2	14.0	2.2	0.26	17.66	15.73
Interim low fluctuating flows						
Dry	1.9	7.0	1.2	0.13	10.23	21.64
Moderate	1.8	9.9	1.8	0.18	13.68	45.07
Wet	1.4	14.1	2.2	0.26	17.96	17.69
Existing monthly volume steady flows						
Dry	1.9	7.0	1.2	0.13	10.23	21.64
Moderate	1.8	9.9	1.8	0.18	13.68	45.07
Wet	1.4	14.1	2.2	0.26	17.96	17.69

Seasonally adjusted steady flows						
Dry	1.8	7.1	1.1	0.13	10.13	20.45
Moderate	1.7	10.4	1.9	0.20	14.20	50.58
Wet	1.4	13.5	2.2	0.26	17.36	13.76
Year-round steady flows						
Dry	2.0	6.1	1.1	0.12	9.32	10.82
Moderate	1.7	10.4	1.9	0.20	14.20	50.58
Wet	1.4	13.6	2.3	0.26	17.56	15.07

[a] The values reported for wet hydrological conditions are a simple arithmetic average of the three values for wet years reported in the Glen Canyon EIS.

[b] Values in rows may not sum to total due to rounding.

[c] Changes are positive except as noted. Source: Reclamation (1995).

[5] 1 The annual capacity factor is the ratio of the energy produced by a power plant during one year compared with the energy it could have produced at maximum capacity under continuous operation during the whole year.

[6] 2 When used to describe flows or operational scenarios, the term *historical* refers to the period in time from construction of the dam to present day or that time when operations were modified to protect downstream natural resources.

Angling

As indicated in Table 4.12, use values for angling decrease as hydrological conditions change from dry to wet under each of the nine operational scenarios. In addition, the continued historical operations, maximum power plant capacity, and restricted high fluctuating flow operational scenarios would yield the same amount of use value to anglers under each hydrological condition. The moderate fluctuating flow scenario would yield similar use values under moderate and wet hydrological conditions and slightly higher angler use values under dry hydrological conditions. All four scenarios would yield angler use values lower than those associated with the other operational scenarios.[7]

The interim low fluctuating flows and existing monthly volume steady flow scenarios would also yield equivalent use values to anglers for each of the three hydrological conditions. In addition, the modified low fluctuating flow and seasonally adjusted steady flow scenarios would yield angler use values approximately equal to those associated with interim low fluctuating flows and existing monthly volume steady flows. Minor differences would arise under moderate and wet hydrological conditions. All four of these operational scenarios would represent an improvement for anglers compared with the four scenarios previously discussed. Under moderate hydrological conditions, the interim low fluctuating flow and existing monthly volume steady flow scenarios would maximize the use value of angling relative to the seven other operational scenarios.

Of the nine operational scenarios, year-round steady flows would yield the maximum use value to anglers under dry and wet hydrological conditions. Under moderate hydrological conditions, this scenario would yield use values equal to those under the seasonally adjusted steady flow scenario, and only slightly less than those under the interim low fluctuating flow and existing monthly volume steady flow scenarios. These results reflect the preference anglers have for constant flows over fluctuating flows, all other variables held constant.

White-Water Boating

As summarized in Table 4.12, use values for white-water boating increase as hydrological conditions change from dry to wet under each of the nine operational scenarios. This reflects the preference boaters have for higher flows, as opposed to lower flows. The continued historical operations, maximum power plant capacity, and restricted high fluctuating flow operational scenarios would yield the same amount of use value to commercial and private white-water boaters and to boaters below Diamond Creek under each hydrological condition. The moderate fluctuating flow scenario would yield similar use values under moderate and wet hydrological conditions, and slightly lower boater use values under dry hydrological conditions. All four scenarios would yield lower boater use values than those associated with the remaining operational scenarios.[8]

The interim low fluctuating flow and existing monthly volume steady flow scenarios would yield equivalent use values to boaters under each hydrological conditions. In addition, boater use values would be higher under either of these scenarios than under the four scenarios discussed above. However, of the nine operational scenarios considered here, seasonally adjusted steady flows would yield the maximum use value to boaters under dry hydrological conditions. Under moderate hydrological conditions, seasonally adjusted steady flows and year-round steady flows would yield the maximum flow volumes to boaters. Under wet hydrological conditions, low fluctuating flows and existing monthly volume steady flows would yield the maximum boater use values. These results reflect the preference boaters have for constant flows over fluctuating flows, all other variables held constant.

4.2.1.2.2 Flaming Gorge Dam

Section 4.2.7 presents the assessment of the impacts of different operational scenarios at Flaming Gorge Dam on angling and day rafting between the dam and the Colorado-Utah border and on white-water rafting in Dinosaur National Monument. Although it is possible to state, qualitatively, the effects of each operational scenario on recreation, there is insufficient data and information on the relationship between flows and use rates to estimate changes in use rates attributable to each scenario. However, it is still possible to gain insights into the potential effects that each operational scenario could have on the level of activity in the local economy.

As was noted in Section 3.1.2.3.1, angling, day floating, and white-water rafting on the Green River between Flaming Gorge Dam and Jensen, Utah, accounted for an estimated $24.8 million (1994 dollars) of output in the local economy[9] in 1991. In addition, these activities resulted in an estimated $12.6 million of personal income and 513 jobs (Rose and Frias 1993).[10] These values amount to 0.22%, 0.22%, and 0.38% of total output, income, and employment in the six-county region in the same year. If all three of these recreational activities were to be eliminated, output, income, and employment would decline by these percentages.[11] However, it is virtually certain that even for the worst-case operational scenario, (year-round high fluctuating flows), use rates would decline by considerably less than 100%. In turn, regional economic impacts would decline compared with the extreme case noted above. Thus, for example, if use rates for each of the three activities fell by 50%, output, income, and employment would fall by 0.1%, 0.1%, and 0.2%. In a similar manner, a 10% decrease in use rates would cause the same three measures of economic activity to decline by 0.02%, 0.02%, and 0.04%.[12]

The effects of each operational scenario on the use value of recreation below Flaming Gorge Dam were calculated on the basis of existing estimates of such use values and the relationship between use values and flows that was developed in the Glen Canyon EIS (Reclamation 1995). The study by Bishop et al. (1987) found no significant relationship between flows and the value of day rafting. Consequently, the value of this activity was not included in the estimates of use values associated with each operational scenario at Glen Canyon Dam. This same approach was used to estimate the use value associated with different operational scenarios at Flaming Gorge Dam. The values reported here (as summarized in Table 4.13) are limited to angling below the dam and commercial and private white-water rafting in Dinosaur National Monument. For a discussion of the methods used to develop the estimates in Table 4.13, see Appendix A and Carlson (1995).

Angling

As indicated in Table 4.13, use values for angling are maximized under moderate hydrological conditions for each of the four operational scenarios. The range of use values associated with year-round high fluctuating flows, seasonally adjusted high fluctuating flows, and moderately fluctuating flows is relatively small. This result is due, in large part, to the constraints on monthly volumes imposed by the Biological Opinion. Use values would vary by less than 6% under all three scenarios and hydrological conditions. Angler use values would be highest under the seasonally adjusted steady flows scenario. This result reflects the preference anglers have for steady flows compared to fluctuating flows.

TABLE 4.13 Summary of Recreation Use Values Associated with Each Operational Scenario at Flaming Gorge Dam

Use Value by Recreational Activity (10^6 1994 $)					
Operational Scenario/ Hydrological Condition	Angling	Commercial White-Water Boating	Private White-Water Boating	Total	Percent Change from Year-Round High Fluctuating Flows
Year-round high fluctuating flows					
Dry	4.019	0.090	0.013	4.122	NA[a]
Moderate	4.027	0.090	0.027	4.144	NA
Wet	2.965	0.546	0.245	3.756	NA
Seasonally adjusted high fluctuating flows					
Dry	3.873	0.211	0.111	4.195	1.77
Moderate	3.974	0.279	0.151	4.404	6.27
Wet	3.118	0.300	0.110	3.528	-6.07
Seasonally adjusted moderate fluctuating flows					
Dry	3.873	0.127	0.030	4.030	-2.23
Moderate	3.953	0.254	0.125	4.332	4.54
Wet	2.958	0.333	0.135	3.426	-8.79
Seasonally adjusted steady flows					
Dry	4.655	0.132	0.032	4.819	16.81

Moderate	4.962	0.189	0.058	5.209	25.70
Wet	3.205	0.290	0.106	3.601	-4.13

[a] NA indicates not applicable.

Source: Carlson (1995).

White-Water Boating

Use values for white-water boating increase as hydrological conditions change from dry to wet under each of the four operational scenarios (Table 4.13). Under moderate hydrological conditions, white-water boater use values would be highest under the seasonally adjusted high fluctuating flow scenario because of the relatively high flows and lack of fluctuations during daylight hours within Dinosaur National Monument under this scenario. Use values would be highest under the combination of year-round high fluctuations and wet hydrological conditions because of the large volumes that would occur in the prime boating months and the absence of fluctuations in flows in Dinosaur National Monument in most months during daylight hours (see Section 4.2.7.2.2).

4.2.1.2.3 Aspinall Unit

As is discussed in Section 4.2.7, neither of the operational scenarios (i.e., seasonally adjusted high fluctuating flows and seasonally adjusted steady flows) would affect recreation use rates or the quality of recreation in the vicinity of the Aspinall Units. Consequently, there would be no economic impacts to recreation.

4.2.2 Air Resources

The potential impacts of Western's hydroelectric generating plant operational scenarios have been assessed with regard to local and regional air quality, regional emissions of greenhouse gases, and the acoustic environment in the vicinity of Western's hydroelectric generating facilities and other electric generating units in the region. Three sets of operational scenarios under each of the commitment-level alternatives were considered in power systems modeling. These scenarios ¾ supply options A, B, and C ¾ provided input data for this assessment (see Section 4.1.1.1 for operational scenarios included in each supply option).

A hydroelectric operational change from high fluctuating flow to lower fluctuating flow means that power production at Western's hydroelectric generating units would be made more uniform throughout the day. Compared with the high fluctuating flows typical of historical operations, hydroelectric power production would be lower during the peak demand period and increased during the off-peak demand period. The hydroelectric energy that was no longer available during the peak demand period would have to be supplied by other peaking units. During the off-peak period, however, electrical generation from baseload units would be reduced to make use of the additional hydroelectric energy. Thus, with reduced fluctuations, a certain amount of the region's baseload electric energy (mostly coal, which has generally higher emission factors) would be replaced by the electric energy generated by the region's nonhydroelectric peaking units (mostly natural gas, which has generally lower emission factors). As a result, a net decrease in air pollutant emissions could occur. Thus, the air pollutant emissions by the region's utility systems would be expected to decrease in general as hydroelectric operations changed from high fluctuating flows to steady flows. The potential impacts on air quality of Western's operational scenarios were assessed on the basis of the same analyses conducted for assessing the potential impacts of Western's commitment-level alternatives (Section 4.1.2.1).

4.2.2.1 Air Quality

4.2.2.1.1 Local Air Quality

Potential effects of Western's commitment-level alternatives on local air quality were analyzed with the data on electric energy produced by the region's individual generating units under selected commitment alternatives, projected by the power systems modeling conducted for this EIS (Section 4.1.2.1.1). Potential effects of Western's operational scenarios on the electric energy produced by individual generating units were estimated by comparing the effects of the various commitment-level alternatives and operational scenarios on the total electric energy produced from nonhydroelectric units. It was assumed that the smaller the effects on total electric energy production from nonhydroelectric units, the smaller the effects on electric energy generation from individual generating units.

Because the projected effects of operational scenarios on total electric energy produced from nonhydroelectric units are less than those projected for the commitment-level alternatives (Chun et al. 1995), differences in electric energy production at individual generating units and associated local air quality impacts under supply options A, B and C would be less than the differences among commitment-level alternatives, which are considered not significant (Section 4.1.2.1.1).

4.2.2.1.2 Regional Air Quality

The estimated impacts of supply options on annual air pollutant emissions from the region's utility systems are presented in Appendix B, Table B.8. The projected regional emissions of SO_2 and TSP show slight but consistent decreases as flow fluctuations at hydroelectric facilities are reduced from supply option A (high fluctuation) to supply option B (low fluctuation), and from supply option B to supply option C (steady flows). However, no clear trends are observed in the emissions of NO_x and CO_2.

The maximum projected changes in the regional annual emissions from the baseline (supply option A/no-action alternative) are a decrease of 8,200 tons of SO_2 (supply option C/alternative 2 in 1998), an increase of 3,700 tons of NO_x (supply option A/alternative 4 in 2008), a decrease of 2,400 tons of TSP (supply option C/alternative 2 in 1998), and a decrease of 261,000 tons of CO_2 (supply option C/alternative 4 in 1993). Although the absolute values of these changes in the projected regional emissions appear significant, they represent only about 2% or less of existing emission levels (-2.2% SO_2, 0.7% NO_x, -1.5% TSP, and -0.8% CO_2). Provided that these emissions changes occurred at various sites over a very large area, as expected, their potential impacts on regional air quality would be small.

4.2.2.2 Noise

Western's operational scenarios could also affect the pattern of noise emissions from various noise-generating equipment at Western's and Reclamation's hydroelectric generating facilities as well as other electric generating units in the region whose operations are affected by Western's operations. Major noise sources at Western's and Reclamation's hydroelectric generating facilities include turbine-generators, step-up transformers, and substation transformers (Section 3.2.3). The number of operating turbine-generators and step-up transformers at multiunit facilities (Glen Canyon and Flaming Gorge) would depend on the level of electric power generated because more units would be turned on as more power generation was desired. However, substation transformers are expected to be in continuous operation as long as some level of hydroelectric power is transmitted to the connected power grid.

Because noise production from a given transformer is independent of load (Gordon et al. 1978, 1980), noise generation from substation transformers would not be affected by changes in the level of hydroelectric generation. Thus, the only changes in noise levels at those facilities would result from changes in the number of operating turbine-generators and step-up transformers. However, turbine-generators and step-up transformers have little effect on noise levels in areas beyond canyon rims because they are located near canyon bottoms and because turbine-generators are also enclosed inside concrete plant buildings (Section 3.2.3). Therefore, the diurnal generating patterns of the units would have little impact on the environmental noise levels in areas above canyon rims.

Changes in diurnal generating patterns of hydroelectric facilities could also change the diurnal patterns of noise generation at the region's baseload and peaking units whose operations are affected by Western's operations. As hydroelectric operations changed from high fluctuating flows to steady flows, more electric energy would have to be generated by the region's peaking units during the peak demand period (daytime) and less electric energy from the region's baseload units during off-peak hours (nighttime). Because changes in the pattern of power plant operations would not result in significant noise impacts in the vicinity of the plant (see discussion in Section 4.1.2.2), changes in hydropower operations would not cause any significant noise impacts in the vicinity of the region's electric power generating facilities whose operations are affected by Western's operations.

4.2.3 Water Resources

Impacts of hydropower operational scenarios on water resources associated with Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit are discussed in Sections 4.2.3.1, 4.2.3.2, and 4.2.3.3, respectively. Areas of concern include flow, stage, sediment, temperature, and floodplains.

4.2.3.1 Glen Canyon Dam

Impact analyses for Glen Canyon Dam were derived from results presented in the Glen Canyon Dam EIS (Reclamation 1995) and its supporting documents. The Glen Canyon Dam EIS examined hydrological impacts for nine alternatives: no action; maximum power plant capacity; high fluctuating flows; moderate fluctuating flows; modified low fluctuating flows; interim low fluctuating flows; existing monthly volume steady flows; seasonally adjusted steady flows; and year-round steady flows. These alternatives are described in detail in the Glen Canyon Dam EIS (Reclamation 1995). The flow alternatives of the Glen Canyon Dam EIS are referred to as hydropower operational scenarios in this Power Marketing EIS. The Glen Canyon Dam EIS no-action alternative is referred to in this document as continuation of historical operations to distinguish it from the no-action commitment-level alternative; and the high fluctuating flow alternative is referred to as restricted high fluctuating flows to distinguish it from other high fluctuation operations.

The impacts of alternatives analyzed in the Glen Canyon Dam EIS include elements unrelated to hydropower operations ¾ for example, impacts caused by the presence of Glen Canyon Dam, annual and monthly releases that are controlled by Reclamation, mitigation strategies, and beach/habitat building flows. The basis for the analysis was 20 years of projected flows for probabilistic, short-term impacts and 50 years of projected flows for long-term effects (Reclamation 1995). Because the time frame of this Power Marketing EIS is 15 years, impacts associated with the operational scenarios are based on the short-term studies (20 years), where possible. If short-term effects were not available, the results of the 50-year studies were used.

4.2.3.1.1 Flow and Stage

Flow

Hydropower operations affect river flows through daily water release patterns, including maximum and minimum releases, maximum daily fluctuations, and ramping rates. A continuation of historical operations would produce the largest amount of daily fluctuation in flow (Table 4.14). Adverse impacts attributed to large daily fluctuations include potential removal of sediment from exposed beaches and other sand deposits, and increased rates of growth of the Lake Mead delta; the larger the fluctuation, the more adverse the impact. For continued historical operations, impacts would be moderate between the Paria River and the Little Colorado River. In Lake Mead and upstream of the Paria River and downstream of the Little Colorado River, the impacts would be slight. Although these adverse impacts would be expected for fluctuating flows, some minor beneficial impacts would also result from high fluctuations ¾ including the reworking of debris fans, the creation of a large active zone (a zone in which changes in water level impact the sand deposit) that would promote the removal of vegetation and maintenance of backwaters and wet marshes, and potential aggradation of deposits downstream of the Little Colorado River.

TABLE 4.14 Summary of Projected Daily Fluctuations and Maximum Releases from Glen Canyon Dam

	Percent in Fluctuation Range								
Operational Scenario	<5,000 cfs	5,000 to 5,999 cfs	6,000 to 7,999 cfs	8,000 to 12,099 cfs	12,100 to 15,999 cfs	16,000 to 20,000 cfs	>20,000 cfs	Maximum Release[a] (cfs)	% Diff.[b]
Continuation of historical operations	2.7	0.6	1.9	8.9	20.4	52.1	13.3	31,500	0
Maximum power plant capacity	2.6	0.5	2.0	8.6	19.2	43.5	23.7	33,200	+5
Restricted high fluctuating flows	3.3	0.9	3.3	15.8	36.4	38.4	1.9	31,500	0
Moderate fluctuating flows	7.2	3.9	47.2	41.8	0	0	0	31,500[c]	0
Modified low fluctuating flows	26.7	19.6	23.5	30.2	0	0	0	25,000[c]	-37
Interim low fluctuating flows	26.7	19.6	23.5	30.2	0	0	0	20,000	-37
Existing monthly volume steady flows	0	0	0	0	0	0	0	14,800	-53
Seasonally adjusted steady flows	0	0	0	0	0	0	0	18,000[c]	-43
Year-round steady flows	0	0	0	0	0	0	0	11,400	-64

[a] May be exceeded during high-water years.

[b] Percent difference compared with continuation of historical operations.

[c] Exceeded during habitat-maintenance flows. Source: Reclamation (1995).

Larger releases would result in higher water levels (stage) which would, in general, produce adverse impacts on sand deposits in the reach between the Paria River to the Little Colorado River, particularly if sediment input from the Paria River were low. Lower releases would result in less reworking of debris fans but also lower rates of erosion from the riverbed, banks, and bars.

Stage

Stage in the Colorado River downstream of Glen Canyon Dam is a function of location, time, and operational scenario. The highest stages would be produced by the highest flows in the narrowest segments of the river; the lowest stages would be associated with the lowest flows and the widest portions of the channel. Maximum stage changes above the minimum water elevation are summarized in Table 4.15. Negative percent changes relative to continued historical operations indicate a decrease in stage, whereas positive values indicate an increase.

Of the operational scenarios analyzed in the Glen Canyon Dam EIS, continued historical operations and maximum power plant capacity flows would produce the highest stages (Table 4.15). Restricted high fluctuating flows would be similar to continued historical operations (1 ft less stage change than continued historical operations [-8%]). Other than year-round steady flows,

TABLE 4.15 Summary of Maximum Daily Stage Change between Glen Canyon Dam and Lake Mead

Operational Scenario	Maximum Stage Change (ft)	% Diff.[a]
Continuation of historical operations	12	0
Maximum power plant capacity	12	0
Restricted high fluctuating flows	11	-8
Moderate fluctuating flows	5	-58
Modified low fluctuating flows	3	-75
Interim low fluctuating flows	3	-75
Existing monthly volume steady flows[b]	5	-58
Seasonally adjusted steady flowsc	7	-42
Year-round steady flows	0	-100

[a] % Diff. is the percent difference from continued historical operations.

[b] Stage change shown is maximum between months with different release volumes.

[c] Stage change shown is maximum between seasons with different release volumes.

Source: Reclamation (1995).

modified low fluctuating flows and interim low fluctuating flows would produce the lowest stage change of any of the scenarios and the largest difference from continued historical operations (up to 9 ft less [-75%]). Year-round steady flows would produce the least change in river stage (essentially zero).

The importance of the difference in stage produced by the hydropower operational scenarios is directly tied to changes in sediment stored in elevated sandbars. Higher flows can either erode or aggrade elevated sandbars ¾ depending on the suspended load in the river, the local geology, and the time of year; they can also produce intermittent flooding of low-elevation river segments, such as backwaters, and impact vegetation.

4.2.3.1.2 Sediment

Impacts to sediment resources were evaluated for the Colorado River between Glen Canyon Dam and Lake Mead. Impacts would occur with changes in flow and stage, including aggradation and erosion of sandbars, changes in sand storage in the riverbed, movement of debris from rapids, changes in the size and pattern of recirculation zones below aggraded fans, and changes in the sediment deposition pattern in the Lake Mead delta (Reclamation 1995). For this evaluation, sand between the Paria River and the Little Colorado River is most important because above the confluence of the Paria River the river channel is armored and, below the confluence with the Little Colorado River, a near-equilibrium condition is established because of sediment from inflowing tributaries. Above or below this reach, impacts of the operational scenarios would be the same as those for continued historical operations. Sand is an important resource because its abundance in the system affects the stability and maintenance of beaches, bank stability, and the number and location of backwaters and channel margin bars.

For the Glen Canyon Dam EIS, the only sources of sand considered in the sediment transport calculations were from the Paria and Little Colorado rivers; sands from ungaged tributaries, flash floods, and debris flows were assumed to be negligible (Reclamation 1995). In addition, sand contributions from the dam to Lees Ferry were assumed to be insignificant because of armoring, and the shapes of the discharge water waves from the dam were assumed to remain constant as the waves travel downstream. These assumptions provide an overestimate of the sand in the river and an underestimate of riverbed sand storage, particularly for fluctuating flows. Impacts to sandbars were correlated with a loss of riverbed sand and determined from the principles of slope stability (Reclamation 1995). Sediment impacts for the operational scenarios are summarized in Table 4.16.

The highest probability of a net gain in sand in the reach between the Paria and Little Colorado rivers over the next 20 years would occur under year-round steady flows (74%; 48% greater than continued historical operations); however, the other steady flow scenarios and the interim low fluctuating flow scenarios would all have probabilities of about 70% (Table 4.16). Continued historical operations and maximum power plant capacity flows would produce the smallest probabilities of a net gain in sand (about 50%). Although a ranking of the scenarios is not warranted because the uncertainty in the sediment transport modeling has not been evaluated, most sediment models have a large degree of uncertainty. On the basis of this anticipated level of uncertainty, all of the scenarios except for continued historical operations and maximum power plant capacity have essentially the same probability of a net gain in sand.

TABLE 4.16 Summary of Sediment Impacts for Glen Canyon Dam

	Probability of Net Gain in Riverbed Sand between Paria and Little Colorado Rivers after 20 Years			**Maximum Active Width of Sandbars**			**Maximum Height of Sandbars**	
Operational Scenario	%	% Diff.[a]		ft	% Diff.[a]		ft	% Diff.[a]

Continuation of historical operations	50	0		74	0		15	0
Maximum power plant capacity	49	-2		77	4		16	7
Restricted high fluctuating flows	-53	6		53	-28		11	-27
Moderate fluctuating flows	61	22		47	-36		10	-33
Modified low fluctuating flows	64	28		53	-28		9	-40
Interim low fluctuating flows	69	38		41	-45		9	-40
Existing monthly volume steady flows	71	42		19	-74		5	-67
Seasonally adjusted steady flows	71	42		29	-61		7	-53
Year-round steady flows	74	48		0	-100		1	-93

[a] % Diff. is the percent difference from continuation of historical operations.

Source: Reclamation (1995).

The maximum power plant capacity scenario would produce the highest elevation sandbars (16 ft; 1 ft higher than continued historical operations) (Table 4.16). The lowest elevation sandbars relative to continued historical operations would be produced by the three steady flow scenarios (-67, -53, and -93%, respectively for existing monthly volume steady flows, seasonally adjusted steady flows, and year-round steady flows). Although higher deposits of sand would normally be considered beneficial, the high percentage of large fluctuations and higher ramping rates of the maximum power plant capacity operational scenario would also produce greater erosion, and, therefore, these elevated deposits would be ephemeral. On the other hand, the deposits produced by steady flows, though at low elevations, would be very stable but easily encroached upon by vegetation and less usable for camping.

In addition to producing the highest elevation sandbars, the maximum power plant capacity scenario would also produce sandbars with the largest active widths (Table 4.16). The predicted width of the active zone for this operational scenario would be 77 ft (4% greater than continued historical operations). Year-round steady flows would produce the smallest active widths (0 ft; 100% less than continued historical operations). Because sandbar stability is inversely related to the width of the active zone, the least stable bars would occur under maximum power plant capacity flows, whereas the most stable bars would occur with year-round steady flows. However, without occasional beach/habitat-building flows, reductions in active width of sandbars would result in vegetation encroachment.

Eddy backwaters, which are important to Colorado River fish, depend on the formation of reattachment bars. With time, the number and size of backwaters would tend to fill with sediment and later reform during flood releases. Operational scenarios with greater seasonal or daily fluctuations (e.g., continued historical operations, maximum power plant capacity flows, and restricted high fluctuating flows) would maintain backwaters longer than scenarios with relatively few fluctuations (e.g., year-round steady flows).

None of the operational scenarios would have maximum discharges that are sufficiently high to move the largest boulders in debris fans (Table 4.14). However, the capability to rework other deposits in the fans would be least for year-round steady flows (maximum flows 64% less than continued historical operations) and greatest for maximum power plant capacity (maximum flows 5% greater than continued historical operations). Eventually, debris fans would be expected to aggrade under all of the operational scenarios and further constrict rapids (Reclamation 1995). Over the 15-year time period for this EIS, impacts of hydropower operations on debris fans would be slight.

In Lake Mead, the rate of growth of the Colorado River delta would vary among operational scenarios (Reclamation 1995). For 20 years of projected operations, sediment delivery to Lake Mead would be higher under fluctuating flows than under steady flows. The highest rates of delta growth would occur for continued historical operations and maximum power plant capacity flows. Year-round steady flows would produce the smallest growth rates in the deltas because this scenario would deliver the least amount of sand to Lake Mead (116% less sand from the reach from the Paria to Little Colorado rivers). The importance of this impact would be very slight because the life expectancy for Lake Mead is more than 500 years (Reclamation 1995).

4.2.3.1.3 Temperature

The temperature of the water released from Glen Canyon Dam would be the same for all scenarios. Once in the Colorado River channel, higher dam releases would travel faster than slow releases and would transport cold water farther downstream. However, the combined effects of mixing with unregulated tributaries and solar heating would minimize the differences in temperature among operational scenarios, especially below the Little Colorado River.

4.2.3.1.4 Floodplains

A floodplain assessment was performed to evaluate the impacts of the hydropower operational scenarios at Glen Canyon Dam on the floodplain of the Colorado River. The approximate 100-year floodplain for the Colorado River below Glen Canyon Dam was assumed to correspond to the water level of a 91,400-cfs release (Section 3.3.1.4). Each of the nine operational scenarios evaluated (Section 4.2.3.1.1) would produce impacts within the 100-year floodplain of the Colorado River below the dam. The maximum water release (Table 4.14) for any of the operational scenarios (33,200 cfs), however, would be less than 40% of the postulated 100-year flood release. Impacts within the 100-year floodplain would range from moderate to slight (Sections 4.2.3.1.1 through 4.2.3.1.3) at low topographical elevations (up to a water surface elevation corresponding to a release of 33,200 cfs) and would be very slight to negligible at higher floodplain elevations.

4.2.3.2 Flaming Gorge Dam

The impacts of hydropower operational scenarios on water resources below Flaming Gorge Dam were assessed for moderate, dry, and wet hydrologic years. On the basis of stream-flow records, the years of 1987, 1989, and 1983 were selected to represent moderate, dry, and wet water years, respectively (see Section 3.3.2.1). (A water year begins on October 1 of the preceding calendar year and ends on September 30 of the current calendar year.) Conditions in 1983 and 1989 represent extreme, worst-case conditions rather than typical wet and dry years.

Four hydropower operational scenarios for Flaming Gorge Dam are evaluated in this EIS ¾ year-round high fluctuating flows, seasonally adjusted high fluctuating flows, seasonally adjusted moderate fluctuating flows, and seasonally adjusted steady flows. The year-round high fluctuating flow scenario assumes that the monthly total reservoir releases would be the same as historical releases. This operational scenario would not comply with the USFWS Biological Opinion (USFWS 1992b). The remaining seasonally adjusted scenarios would comply with the Biological Opinion and would include high flows in the spring and limited hourly fluctuations for much of the year. All of the scenarios would only feature releases that are within power plant capacity and would differ from pre-dam flow regimes in several ways, including greatly reduced peak flows, higher winter and summer flows, and reduced between-year variability.

4.2.3.2.1 Flow and Stage

Reservoir Release Patterns

Reservoir release patterns for an average day in each month, or partial month where necessary to comply with the Biological Opinion, are summarized in Appendix C, Tables C.1 through C.3, for the four operational scenarios. The release patterns for each scenario were developed for the three representative moderate, dry, and wet years (1987, 1989, and 1983, respectively). Each release pattern has a minimum release starting at midnight, ramp up to a maximum release in one hour, hold at the maximum for the on-peak duration, and then ramp down to the minimum release. The on-peak period is assumed to center around 4 p.m. These release patterns are conservative and produce worst-case operational scenarios to bound impacts. The derivation of the release patterns are briefly discussed in Appendix C. Further details on the development of the release patterns are presented in Yin et al. (1995a,b).

Flow

Flows in the Green River resulting from reservoir releases under the four operational scenarios were estimated for five locations below Flaming Gorge Dam for the three representative hydrologic years (Yin et al. 1995a). The five locations are Gates of Lodore, Hells Half Mile, Jones Hole, Rainbow Park, and the Jensen gage (Figure 3.16). Historical releases for power generation ranged from 800 to 4,200 cfs (Figure 3.12).

Year-Round High Fluctuating Flow Scenario. The daily maximum and minimum flows in the moderate hydrologic year (1987) under the year-round high fluctuating flow scenario and the seasonal average inflow of the Yampa River, which joins the Green River 65 mi below the dam between Hells Half Mile and Jones Hole, are given in Appendix C, Table C.6. Under this operational scenario, the maximum daily reservoir release fluctuation would be 3,900 cfs year-round. The fluctuation at Gates of Lodore would be reduced to about 30 to 82% of that below the dam. The difference in the magnitudes of reduction is mainly influenced by the on-peak duration of the reservoir release. A relatively short on-peak period, such as the two-hour duration in March ¾ or a relatively long period, such as the 17-hour duration in November and December (Table C.1) ¾ tends to reduce the flow fluctuation more rapidly. A medium on-peak period, such as the 10-hour duration in October, tends to maintain a high fluctuation for a longer distance down the river. At downstream locations, further reductions in fluctuation would be minor. At Hells Half Mile, the fluctuation still would be 29 to 80% of that at the dam. At the Jensen gage, the fluctuation would be 27 to 77%.

The maximum and minimum flows at Flaming Gorge Dam, Gates of Lodore, and the Jensen gage are shown in Figure 4.4. The flow fluctuations do not change much between Gates of Lodore and the Jensen gage. The flow patterns at the Jensen gage differ from those at Gates of Lodore because of the inflow from the Yampa River.

FIGURE 4.4

Seasonally Adjusted High Fluctuating Flow Scenario. The daily maximum and minimum flows in the moderate hydrologic year (1987) under the seasonally adjusted high fluctuating flow scenario and the seasonal average inflow of the Yampa River are given in Appendix C, Table C.7. Under this operational scenario, the reservoir release fluctuation would be 2,010 to 3,900 cfs, except that no fluctuation would be allowed in February and March (the assumed ice cover period), October would have a steady release of 800 cfs (to compensate for high Yampa River flow), and June 1 through 21 would have a steady release as high as 4,700 cfs (as required by the Biological Opinion). The fluctuation at Gates of Lodore would be reduced to about 19 to 80% of that at the dam. Similar to the year-round high fluctuating flow scenario, further downstream reductions in fluctuation would be minor. At Hells Half Mile, the fluctuation still would be 19 to 80% of that at the dam. At the Jensen gage, the fluctuation would be 17 to 78%.

Figure 4.5 shows the maximum and minimum flows at Flaming Gorge Dam, Gates of Lodore, and Jensen gage. As discussed above, the flow fluctuation does not change much between the Gates of Lodore and Jensen gage.

Seasonally Adjusted Moderate Fluctuating Flow Scenario. The daily maximum and minimum flows in a moderate water year (1987) for the seasonally adjusted moderate fluctuating flow scenario are shown in Appendix C, Table C.8. Under this operational scenario, the daily reservoir release fluctuation would be 1,000 to 1,950 cfs, except that no fluctuation would be allowed in February and March because of ice cover, October would have a steady release of 800 cfs, and June 1 through 21 would have a steady release up to 4,700 cfs (as required by the Biological Opinion). The fluctuation at Gates of Lodore would be reduced to about 0 to 88% of that at the dam. As for the year-round and seasonally adjusted high fluctuating flow scenarios, further downstream reductions in fluctuation would be minor. At Hells Half Mile, the fluctuation still would be 0 to 88% of that at the dam. At Jensen gage, the fluctuation would be 0 to 83%.

Figure 4.6 shows the maximum and minimum flows at Flaming Gorge Dam, Gates of Lodore, and the Jensen gage. As discussed above, the flow fluctuation does not change much between the Gates of Lodore and Jensen gage.

Seasonally Adjusted Steady Flow Scenario. Under the seasonally adjusted steady flow scenario, the reservoir release in each season would be steady (Appendix C, Tables C.1 through C.3). Figure 4.7 shows the flows at the dam, Gates of Lodore, and the Jensen gage. The flows at Gates of Lodore would be the same as reservoir releases, and the flows at the Jensen gage would be the sums of reservoir releases and the Yampa River inflows.

FIGURE 4.5

FIGURE 4.6

FIGURE 4.7

Stage

Maximum and minimum Green River stages resulting from reservoir releases under the four operational scenarios were estimated on the basis of the flows presented in Figures 4.4 to 4.7 and stage-flow relationships presented in Yin et al. (1995a). The river stage at a particular location depends mainly on the river flow and channel geometry in the area. Daily maximum and minimum stages above that for a flow of 800 cfs at Flaming Gorge Dam, Gates of Lodore, and Jensen gage are shown for a moderate year (1987) in Figures 4.8, 4.9, and 4.10 for the year-round high fluctuating flow, seasonally adjusted high fluctuating flow, and seasonally adjusted moderate fluctuating flow scenarios, respectively. River stages for the seasonally adjusted steady flow scenario are shown in Figure 4.11.

Under the year-round high fluctuating flow scenario, the daily stage fluctuations would be about 4.8 ft year-round at Flaming Gorge Dam, about 2.4 to 4.9 ft at the Gates of Lodore, and about 0.6 to 2.0 ft at the Jensen gage. Stage fluctuations in canyon areas (Lodore, Whirlpool, and Split Mountain canyons) would range up to 3 ft. Under the seasonally adjusted high fluctuating flow scenario, the daily stage fluctuations would be about 0 to 4.8 ft at Flaming Gorge Dam, about 0 to 4.9 ft at Gates of Lodore, and about 0 to 2.2 ft at the Jensen gage. Stage fluctuations in canyon areas would range up to 3.4 ft. Under the seasonally adjusted moderate fluctuating flow scenario, the daily stage fluctuations would be about 0 to 2.2 ft at Flaming Gorge Dam, about 0 to 2.1 ft at Gates of Lodore, and about 0 to 0.9 ft at the Jensen gage. Stage fluctuations in canyon areas would range up to 1.4 ft. Under the seasonally adjusted steady flow scenario, no daily stage fluctuations would result from hydropower operations.

For historical operations, when power releases ranged from 800 to 4,200 cfs, the daily stage fluctuation was estimated to be up to 4.2 ft below Flaming Gorge Dam and at Gates of Lodore, and 1.7 ft at the Jensen Gage.

4.2.3.2.2 Sediment

The Green River from Flaming Gorge Dam to Browns Park has been armored by previous flows (Section 3.3.2.2). Because of this armoring, none of the operational scenarios would have a flow sufficiently high to alter this reach.

Net erosion currently occurs from Browns Park to the confluence of the Yampa River; sediment is leaving the reach, but very little is coming in because of the presence of the dam (Section 3.3.2.2). Rates of sediment removal were calculated for the four operational scenarios and for historical operations; the results are summarized in Table 4.17 (see Appendix C, Section C.1.4, for a description of the methodology used). Because the rate of erosion and river meandering in an alluvial stream is proportional to the sediment removed (Leopold et al. 1964), the ratio of the loads relative to those under historical operations are also shown in the table.

FIGURE 4.8

FIGURE 4.9

FIGURE 4.10

FIGURE 4.11

TABLE 4.17 Summary of Sand Load in Browns Park for Different Hydropower Operational Scenarios

Water Year	**Operational Scenario**	**Sand Load[a] (million tons)**		
		Value	% Diff.	Erosion Rate
Moderate (1987)	Year-round high fluctuating flows	1.15	11	1.11
	Seasonally adjusted high fluctuating flows	1.10	6	1.06
	Seasonally adjusted moderate fluctuating flows	0.99	-5	0.95
	Seasonally adjusted steady flows	0.98	-6	0.94
Dry (1989)	Year-round high fluctuating flows	0.17	31	1.31
	Seasonally adjusted high fluctuating flows	0.29	123	2.23
	Seasonally adjusted moderate fluctuating flows	0.28	115	2.15
	Seasonally adjusted steady flows	0.27	108	2.08
Wet (1983)	Year-round high fluctuating flows	3.57	3	1.03
	Seasonally adjusted high fluctuating flows	2.60	-25	0.75
	Seasonally adjusted moderate fluctuating flows	2.58	-25	0.75
	Seasonally adjusted steady flows	2.58	-25	0.75

[a] % Diff. is the percent difference from transport under historical release patterns;
Erosion Rate is the rate of erosion or meandering relative to historical operations.

For a moderate or wet year, year-round high fluctuating flows would have the largest sediment loads (about 3.6 and 1.2 million tons, respectively). For a wet year, all three seasonally adjusted scenarios would produce a comparable load (28% less). For a moderate year, seasonally adjusted steady flows would have the smallest loads (0.98 million tons; 16% less than under historical operations). For a dry year, all loads would be small (Table 4.17) but would be higher than under historical release patterns. In a dry year, any of the seasonally adjusted operational scenarios would have higher loads than the year-round high fluctuating flows due to higher release rates in the spring.

For a moderate or dry year, impacts between the various operational scenarios cannot be differentiated because of uncertainties in the sediment transport model. In a wet year, the seasonally adjusted operational scenarios would transport less sediment than historical release patterns, whereas the year-round high fluctuating flow scenario would be similar to historical releases.

Downstream of the Yampa River, sediment load in the Green River is currently near equilibrium (Section 3.3.2.2). Because the seasonally adjusted operational scenarios would remove less sediment than year-round high fluctuating flows from the Browns Park reach, more sediment could be removed from Lodore Canyon and downstream of the Yampa River. During a dry year, this effect would be minimal because of the low total volumes of sediment involved (0.2 million tons from the Green River). For a moderate year, the effects of the scenarios would be relatively similar, and the net effect of erosion downstream of the Yampa River would be slight. For a wet year, about 1 million less tons of sediment would be delivered by the Green River upstream of the Yampa River. However, for wet conditions, the sediment load in the Yampa River is likely to be high (more than 2 million tons per year). Therefore, conditions below the confluence of the Green and Yampa rivers would not change appreciably, and impacts associated with hydropower operational scenarios for this reach would be slight.

4.2.3.2.3 Temperature

For year-round high fluctuating flows, temperatures would be the same as those measured historically. Hydropower operational scenarios for the Flaming Gorge Dam would not affect water temperatures appreciably. None of the operational scenarios would change the location of water withdrawal from the reservoir (Section 3.3.2.3). Also, changes in water-surface elevation of the reservoir would be small, and the Yampa River would continue to control water temperatures below its confluence. The travel times for water waves to go from the dam to Jensen, Utah, would be similar for all operational scenarios ¾ between 30 and 36 hours (Section 3.3.2.1 and Appendix C) ¾ and the travel time for water to go from the dam to the confluence of the Yampa River would also be similar (29 to 51 hours for releases of 4,000 to 1,000 cfs, respectively, as calculated with the HEC-2 flow model).

4.2.3.2.4 Floodplains

A floodplain assessment was performed to evaluate the impacts of the hydropower operational scenarios at Flaming Gorge Dam on the floodplain of the Green River. The approximate 100-year floodplain below Flaming Gorge Dam was assumed to correspond to the water level of a 12,200-cfs release (Section 3.3.2.4). Each of the four hydropower operational scenarios (Section 4.2.3.2.1) evaluated for this EIS would produce impacts to this floodplain. The maximum water release (Appendix C, Table C.1) for any of the operational scenarios (4,700 cfs), however, would be about 40% of the postulated 100-year flood release. Impacts within the 100-year floodplain would be moderate to slight at low topographical elevations (up to a water surface elevation corresponding to a release of 4,700 cfs) and very slight to negligible at higher floodplain elevations as described in Sections 4.2.3.2.1 through 4.2.3.2.3.

4.2.3.3 Aspinall Unit

Potential impacts of the hydropower operational scenarios on water resources below the Aspinall Unit (i.e., Blue Mesa, Morrow Point, and Crystal reservoirs in downstream order) were assessed for moderate (1987), dry (1989), and wet (1983) years. Two operational scenarios were evaluated ¾ seasonally adjusted high fluctuating flows and steady flows, both of which are based on USFWS research flows for the Aspinall Unit (Harris 1992). The first scenario permits seasonally adjusted high fluctuating flows, whereas the second scenario allows only seasonally adjusted steady flows (no hourly fluctuations within a day) from Blue Mesa and Morrow Point reservoirs. Crystal Reservoir would release a steady flow within each day under both operational scenarios.

4.2.3.3.1 Flow and Stage

The effects on river flow and stage below Crystal Dam would be the same for both operational scenarios because both would have seasonally adjusted steady releases from Crystal Reservoir. For this analysis, the potential effects of the operational scenarios on reservoir surface elevations were compared.

Reservoir Release Patterns

Reservoir release patterns for an average day in each month are summarized for the three Aspinall Unit reservoirs in Appendix C, Tables C.11, C.12, and C.13. The high fluctuating release pattern has a minimum release starting at midnight, ramps up to a maximum release in one hour, holds at the maximum for the on-peak duration, and then ramps down to the minimum release. The on-peak period was assumed to center around 4:00 p.m. The derivation of the release patterns is discussed in Appendix C.

Stage

Maximum daily fluctuations in reservoir surface elevation under the seasonally adjusted high fluctuating flow scenario in a moderate year are shown in Table 4.18. The fluctuations result from both the hourly reservoir release fluctuations and the monthly inflow-outflow imbalance. The maximum surface fluctuations in one day range from 0.1 to 0.5 ft for Blue Mesa and from 0.3 to 1.5 ft for Morrow Point. Because of its relatively small storage capacity, Crystal Reservoir elevations would have larger daily fluctuations, ranging from 2.1 ft in June to 8.4 ft in September. Under the seasonally adjusted steady flow scenario, daily reservoir surface fluctuations would range from 0 to 0.5 ft at Blue Mesa, 0 to 0.2 ft at Morrow Point, and 0 to 0.4 ft at Crystal (Appendix C). Weather-induced daily reservoir surface fluctuations at Blue Mesa and Morrow Point can be greater than those attributable to hydropower operations.

TABLE 4.18 Maximum Daily Surface Fluctuations for a Moderate Year at the Aspinall Unit Reservoirs under the Seasonally Adjusted High Fluctuating Flow Scenario

	Maximum Daily Surface Fluctuation (ft)		
Month	Blue Mesa Reservoir	Morrow Point Reservoir	Crystal Reservoir
Oct	0.3	1.1	8.0
Nov	0.2	0.8	6.9
Dec	0.2	0.8	6.4
Jan	0.1	0.3	4.0
Feb	0.1	0.3	3.8
Mar	0.1	0.4	4.3
Apr	0.2	1.5	3.2
May	0.5	1.3	2.4
Jun	0.3	0.4	2.1

Jul	0.3	0.9	3.4
Aug	0.3	1.3	8.1
Sep	0.3	1.3	8.4

Approximate water surface elevations below Morrow Point Dam are shown in Figure 4.12 for flows ranging from 100 to 5,300 cfs. The river stage just below the dam may fluctuate about 10 ft as the dam releases vary from 0 to 5,300 cfs. At 0.25 mi below the dam, the stage fluctuation would be reduced to about 5.5 ft due to the effect of Crystal Reservoir; at 0.5 mi below the dam, the stage would be largely controlled by Crystal Reservoir. The elevations in Figure 4.12 were estimated by assuming a Crystal Reservoir elevation of 6,750 ft. In a moderate year, Crystal Reservoir end-of-month elevations during the growing season (May through September) could range from about 6,747 to 6,751 ft (Appendix C). A lower Crystal elevation would tend to lower all water surface profiles in the figure, with lesser effects on the profiles for higher flows and lesser effects on locations farther upstream.

4.2.3.3.2 Sediment

Because the operational scenarios for Crystal Dam would not be controlled for the production of hydropower, evaluation of sediment transport in the Gunnison River below Crystal Dam is outside the scope of this Power Marketing EIS. Potential reaches for evaluating sediment transport include Blue Mesa Reservoir, Morrow Point Reservoir, Crystal Dam Reservoir, and short stretches of the Gunnison River that connect the separate hydropower facilities. For downstream reaches of the Gunnison River below and between Blue Mesa Dam, Morrow Point Dam, and Crystal Dam, impacts to sediment would be slight because outflow from the dams would frequently enter directly into the headwaters of the downstream reservoir. In Blue Mesa and Morrow Point reservoirs, impacts to sediment caused by operational scenarios would be slight over the 15-year period of the power marketing program because of the large size of the reservoirs. In Crystal Dam Reservoir, impacts to sediment would also be slight because Blue Mesa and Morrow Point dams would remove most of the upstream sediment.

FIGURE 4.12

4.2.3.3.3 Temperature

Hydropower operational scenarios for the Aspinall Unit would not affect water temperatures in the affected environment. None of the operational scenarios would change the location of water withdrawal from the reservoirs, and, because changes in water-surface elevation of the reservoirs would be small, the resulting changes in water temperature in the reservoir itself would be very slight. Because distances between the dams and the downstream reservoirs are small, travel times would be short and the effects of solar heating would not be detectable.

4.2.3.3.4 Floodplains

A floodplain assessment was performed to evaluate the impacts of the hydropower operational scenarios for the Aspinall Unit on the floodplain of the Gunnison River. The approximate 100-year floodplain for the area below Crystal Dam was assumed to correspond to the water level of a 14,400-cfs release (Section 3.3.3.4). Neither of the two hydropower operational scenarios evaluated for this EIS (Section 4.2.3.3.1) would produce impacts to this 100-year floodplain.

4.2.4 Ecological Resources

This section discusses impacts to ecological resources that would result from hydropower operational scenarios at Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit. Resources include fish, vegetation, wildlife, and threatened and endangered species.

4.2.4.1 Glen Canyon Dam

Impacts of nine operational scenarios on ecological resources below Glen Canyon Dam were derived from results presented in the Glen Canyon Dam EIS (Reclamation 1995). These scenarios include (1) continued historical operations, (2) maximum power plant capacity, (3) restricted high fluctuation, (4) moderate fluctuation, (5) modified low fluctuation, (6) interim low fluctuation, (7) existing monthly volume steady flows, (8) seasonally adjusted steady flows, and (9) year-round steady flows. Three of the scenarios ¾ moderate fluctuation, modified low fluctuation, and seasonally adjusted steady flows ¾ feature annual habitat-maintenance flows of 33,200 cfs.

4.2.4.1.1 Aquatic Ecology

This section addresses the potential impacts of the operational scenarios at Glen Canyon Dam to trout and native fish. These impacts are summarized in Table 4.19. Impacts to Federally listed endangered fish species are addressed in Section 4.2.4.1.3. Impacts to introduced fish species, the aquatic food base, and aquatic habitats below Glen Canyon Dam are also considered because impacts to these resources could directly or indirectly affect trout and native fish in the system. The potential impacts to these resources are presented within the discussions of impacts to trout and native fish when such impacts may result in either beneficial or adverse impacts to those species.

Trout

With continuation of historical operations, or with maximum power plant capacity operations, the status of the trout population below Glen Canyon Dam would not change from existing conditions. Reproduction between the dam and Lees Ferry would continue to be limited by the exposure and dewatering of trout redds. Trout reproduction and recruitment below Lees Ferry would be largely unaffected because these parameters are dependent on tributaries which are unaffected by hydropower operations. During the spawning season, trout would continue to become stranded under continued historical operations during downramping events and when flows fall below 3,000 cfs (Reclamation 1995). The impact of redd exposure and trout stranding on the trout population below Glen Canyon Dam may be unimportant because the current high-quality trout fishery below the dam became established under historical operations and because many trout are stocked (Maddux et al. 1987). Although the growth and condition of trout below the dam has declined since the early 1980s, this decline may not be a result of hydropower operations but instead may reflect changes in nutrient inputs from Lake Powell (which are affecting the aquatic food base) or other factors (e.g., parasites and disease) (Arizona Game and Fish Department 1993) that are not directly associated with hydropower operations.

TABLE 4.19 Summary of Impacts to Trout and Native Fish below Glen Canyon Dam under the Different Operational Scenarios a

Operational Scenarios	Trout	Native Fish
Continuation of historical operations	No change from current conditions; daily flow fluctuations from hydropower operations may limit natural reproduction, via redd dewatering, and adult stranding, above Lees Ferry; population remains stocking- dependent.	No change from current conditions; populations stable to declining; population is limited by cold water temperatures, which are not affected by hydropower operations, and

		possibly by competition and predation from introduced species.
Maximum power plant capacity	Same as above.	Same as above.
Restricted high fluctuating flows	Same as above.	Same as above.
Moderate fluctuating flows	Slight benefit above Lees Ferry from potential increase in spawning habitat and a potential decrease in stranding; potential increase in growth rates; population remains stocking-dependent.	Same as above.
Modified low fluctuating flows	Same as above.	Slight benefit from potential increase in nursery habitat stability and increased food base; benefits may be offset by potential increase in numbers of introduced fish.
Interim low fluctuating flows	Same as above.	Slight benefit; similar to above except no habitat maintenance flow to potentially limit abundance of introduced fish and restore backwater habitats.
Existing monthly volume steady flows	Moderate benefit above Lees Ferry due to potential increase in spawning habitat and the elimination of most redd dewatering and reduction in stranding; potential increase in growth rates; population may become self-sustaining.	Slight to moderate benefit over all fluctuating flow scenarios due to increased nursery habitat stability and food base; benefits may be offset, or adverse impacts may occur from potential increase in numbers of introduced fish.
Seasonally adjusted steady flows	Moderate benefit from an increase in potential spawning habitat and the elimination of most redd dewatering and stranding above Lees Ferry; benefit may be greater than for existing monthly volume steady flows; potential increase in growth rates; population may become self-sustaining.	Moderate benefit; same as above except for increased nursery habitat stability and habitat maintenance.
Year-round steady flows	Moderate benefit above Lees Ferry from increase in potential spawning habitat and the elimination of most redd dewatering and stranding; benefit may be greater than for seasonally adjusted steady flows; potential increase in growth rates; population may become self-sustaining.	Slight to moderate benefit; similar to seasonally adjusted steady flows, but may be more adversely affected by potential increases in numbers of introduced fish and the filling of some backwater habitat with sediment or vegetation.

[a] The terms *slight*, *moderate*, and *large* benefit and *adverse* impacts are used to convey the importance of the impact. These relative terms were not included in the Glen Canyon Dam EIS but have been added

on the basis of a review of the findings presented in that EIS to provide consistency in treatment among facilities.

Source: Reclamation (1995).

None of the other operational scenarios would cause adverse impacts to the trout fishery below the dam. The fluctuating flow scenarios would result in slight benefits from reduced redd exposure and stranding of spawning adults above Lees Ferry (Reclamation 1995). Any of the steady flow operational scenarios would result in moderate benefits to the trout. Steady flow scenarios would greatly reduce stranding of adults and would also eliminate most, if not all, of the exposure and desiccation of trout redds compared with the effects of historical or maximum power plant capacity operations (Reclamation 1995). Because of the reduced stranding and redd exposure, natural recruitment should increase under each of the steady flow scenarios, and the trout population may become self-sustaining.

As minimum flows increased from 1,000 cfs under historical operations to 8,000 cfs under existing monthly volume steady flows, so would the zone for aquatic food production and potential spawning habitat increase. As a result, trout might benefit slightly from the increased food production and increased spawning habitat. If the size of the trout population remains stable, the increase in the aquatic food base could increase growth rates of the trout. Food production and spawning habitat would be greatest under the steady flow scenarios, and little or no difference would occur among these scenarios in their effects on food production and spawning habitat (Reclamation 1995).

Native Fish

Cold water temperature is the most important factor limiting native fish in the Colorado River below the Glen Canyon Dam (Reclamation 1995). The water is cold because it is released from the depths of Lake Powell. Because of the cold water in the main channel, reproduction by native fish is confined primarily to the warmwater tributaries (Reclamation 1995). Conditions in the tributaries are unaffected by hydropower operations.

Under a continuation of historical operations, no change is expected in the status of native fish, some of which are exhibiting declines in abundance. Operational scenarios that maintain backwaters and shallow nearshore habitats may be beneficial to the native fish by promoting increased growth and survival of these species. Under historical operations and maximum power plant capacity flows, daily fluctuations in flow would maintain backwater areas but would periodically drain and inundate the backwater habitats with cold main channel waters, thereby reducing the value of the backwater areas to the native fish (Reclamation 1995).

Native fish could benefit slightly under the moderate, modified low, and interim low fluctuating flow operational scenarios. Nursery habitats would become more stable because of decreases in the allowable daily change in flow and reduced ramp rates. Nursery habitat stability would be greatest with the steady flow scenarios, however, and each of these scenarios could result in a moderate benefit to the native fish. Without occasional flood flows, backwater habitats eventually would fill with sediment and vegetation, thereby eliminating these stable backwater areas as nursery habitats and resulting in an adverse impact to native fish. The yearly habitat-maintenance flow that would occur under the moderate and modified low fluctuating flow and the seasonally adjusted steady flow operational scenarios may provide a slight to moderate benefit for native fish by reforming backwater channels (Reclamation 1995). Similar benefits to native fish could also occur with the beach/habitat-building flows that are common elements of all the restricted fluctuating and steady flow alternatives.

Native fish might also receive slight to moderate benefits from increases in the number of backwater habitats available for use by young fish. The abundance of backwaters has been reported to be lowest at flows below 5,000 cfs and may increase as flows increase (Maddux et al. 1987). Minimum flows below 5,000 cfs would occur under the historical operations, maximum power plant capacity, and restricted high fluctuating flow operational scenarios. Backwater abundance might increase (to the benefit of native fish) with moderate, modified low, and interim low fluctuating flow operational scenarios, each of which would have minimum flows of 5,000 cfs. Under the steady flow scenarios, minimum flows would be at 8,000 cfs or more, and abundance of backwaters could decrease (Reclamation 1995). However, the remaining backwaters would be very stable. Thus, native fish could receive a moderate benefit under the steady flow scenarios.

Potential benefits to native fish could, however, be offset by increased competition with and predation by some introduced species (Minckley 1991; Minckley et al. 1991) because any operational scenario that would benefit native fish populations could also benefit populations of some introduced species. Populations of introduced species may benefit, especially from the reduced fluctuations characteristic of several operational scenarios. Any benefits to these populations could be offset by the proposed periodic habitat-maintenance flows that would occur under the moderate fluctuating flow, modified low fluctuating flow, and seasonally adjusted steady flow scenarios. The beach/habitat-building flows of the restricted fluctuating flow and the steady flow operational scenarios could also control populations of introduced fish. However, because the exact form and magnitude of interaction between native and introduced fish below the dam, as well as the effect of the habitat maintenance and beach/habitat-building flows on introduced species, are not well known, the potential changes in the populations of introduced species cannot be quantified for the various operational scenarios.

4.2.4.1.2 Terrestrial Ecology

Vegetation

Assessments of impacts to riparian vegetation were based on the predicted changes in flow regime that would result from the nine operational scenarios under consideration in the Glen Canyon EIS (Reclamation 1995) (Section 4.2.3.1.1). Flow regime affects riparian vegetation by affecting the soil moisture levels and inundation frequencies to which plant species are adapted. Changes in these conditions could cause shifts in species composition within the riparian zone. Impacts of operational scenarios were assessed for upper and lower riparian zone vegetation. Table 4.20 summarizes these impacts.

The operational scenarios differ considerably in the projected impacts to riparian vegetation. Most of these differences, which are further discussed below, are between the various fluctuating flow scenarios and the steady flow scenarios. A more detailed discussion of impacts to riparian vegetation is provided in Appendix D, Section D.3.1.

Continuation of historical operations would not result in impacts to any riparian vegetation type because the extent and nature of the vegetation in the river corridor is primarily a function of these historical operations. Since construction of the dam, riparian vegetation has increased in abundance due to the elimination or reduction in annual flooding that had occurred naturally (Section 3.4.1.2.1). With this reduction of flooding, riparian vegetation became established at lower elevations ¾ those determined by the maximum flows (32,000 cfs) that have occurred during historical operations.

Except for a continuation of historical operations, operations at maximum power plant capacity, and high fluctuating flows, any of the operational scenarios under consideration could increase the area covered by upper riparian zone vegetation (Table 4.20). The greatest gain would be for year-round steady flows (94% increase in area); existing monthly volume steady flows and interim low fluctuations would each produce increases of at least 30% in the area of this vegetation. Operation at maximum power plant capacity would result in a slight decrease (up to 9%) in upper riparian zone vegetation.

TABLE 4.20 Summary of Impacts of Hydropower Operational Scenarios on Riparian Vegetation below Glen Canyon Dam a

Operational Scenarios	Upper Riparian Zone Vegetation	Lower Riparian Zone Vegetation[b]
Continuation of historical operations	No impact; no net change in area.	No impact; no net change in area.
Maximum power plant capacity	No impact to slight adverse impact (0-9% decrease in area).	Same as above.

Restricted high fluctuating flows	Slight benefit (15-35% increase in area).	Same as above.
Moderate fluctuating flows	No impact to slight benefit (0-12% increase in area with habitat- maintenance flows).	No impact or a slight adverse impact; either no net change or a decrease in area.
Modified low fluctuating flows	Same as above.	Same as above.
Interim low fluctuating flows	Moderate benefit (30-47% increase in area).	Same as above.
Existing monthly volume steady flows	Large benefit (45-65% increase in area).	Slight adverse impact; decrease in area.
Seasonally adjuste steady flows	No impact to slight benefit (0-12% increase in area with habitat- maintenance flows).	Same as above.
Year-round stead flows	Large benefit (63-94% increase in area).	Same as above.

[a] The terms *slight, moderate,* and *large* benefits or *adverse* impacts are used to convey the importance of the impact. These relative terms were not included in the Glen Canyon Dam EIS but have been added on the basis of a review of the findings presented in that EIS to provide consistency in treatment among facilities.

[b] Area coverage cannot be predicted but would likely be similar for all scenarios.

Source: Adapted from Reclamation (1995).

These increases or decreases in riparian vegetation would occur at the lower edge of the riparian zone and would be temporary (i.e., would occur for the next several decades) rather than long term. Any such response at the lower edge of the riparian zone to an increase or decrease in flows eventually would be compensated by an increase or decrease in vegetation at the upper edge of the zone. Thus, if a certain operational pattern was established over the long term, riparian vegetation eventually should reach a new equilibrium along the altered hydrological gradient, and no net increase or decrease in area would occur. In addition, annual high flows for maintenance of fish habitat or periodic floods would remove most upper zone vegetation that became established at lower elevations. These flows would offset any increases in vegetation associated with moderate fluctuations, modified low fluctuations, and seasonally adjusted steady flows (Reclamation 1995).

Changes in lower riparian zone vegetation (including marshes) in response to different operational scenarios would be more complex and are difficult to predict (Reclamation 1995) (Table 4.20). No changes in the area of lower zone vegetation would be expected for continued historical or restricted high fluctuation operational scenarios because wetting of existing vegetation would occur sufficiently often for it to persist. Because of the reduced frequency of inundation, the area of lower zone vegetation could decrease under operational scenarios with reduced fluctuations, especially the steady flow scenarios. Marsh vegetation could initially increase with the decreases in fluctuation associated with the low fluctuation and the steady-flow operational scenarios but eventually could be replaced by upper zone vegetation at higher elevations.

Shifts in flows between months or periods that are characteristic of seasonally adjusted steady flows and existing monthly steady flows would create unvegetated zones below the stage elevation for 11,000- to 13,000-cfs flows, respectively, because these areas would be inundated for extended periods, and vegetation would drown.

Wildlife

Table 4.21 summarizes impacts to nongame wildlife, waterfowl, and game mammals under the nine operational scenarios. Nongame wildlife could be affected by the changes in riparian vegetation expected with the altered flows of different operational scenarios. Most of the expected habitat changes would involve expansion of upper riparian zone vegetation as flow fluctuations were decreased (Section 4.2.4.1.2, Vegetation). Changes in lower zone habitat (including marshes) would not be of major importance to wildlife because of the relatively small amount of such habitat present along the river. Many nongame species inhabiting the corridor would, however, benefit from the increase in upper riparian zone vegetation projected for most operational scenarios, and this increase in vegetation could greatly increase the carrying capacity of the corridor for these species by increasing food supply, nesting sites, or cover.

TABLE 4.21 Summary of Impacts of Hydropower Operational Scenarios on Wildlife below Glen Canyon Dam a

Operational Scenarios	Nongame Species	Waterfowl	Game Mammals
Continuation of historical operations	No impact; riparian habitat unchanged.	No impact; habitat and food supply unaffected.	No impact; habitat unchanged.
Maximum power plant capacity	No impact to slight adverse impact; 0-9% loss of upper riparian zone habitat.	Same as above.	No impact; slight change in habitat but area receives little use.
Restricted high fluctuating flows	No impact; riparian habitat unchanged.	Same as above.	No impact; habitat unchanged.
Moderate fluctuating flows	No impact to slight benefit; 0-12% gain in upper riparian zone habitat with habitat- maintenance flows.	Slight benefit; potential increase in aquatic food base.	No impact; increase in riparian habitat unimportant because area receives limited use.
Modified low fluctuating flows	Same as above.	Same as above.	Same as above.
Interim low fluctuating flows	Moderate benefit; 30-47% increase in area.	Same as above.	Same as above.
Existing monthly volume steady flows	Large benefit; 45-65% gain in upper riparian zone habitat.	Same as above.	Same as above.
Seasonally adjusted	No impact to slight benefit; 0-12% gain in upper riparian zone	Same as above.	Same as above.

steady flows	habitat with habitat- maintenance flows.		
Year-round steady flows	Large benefit; 63-94% gain in upper riparian zone habitat.	Same as above.	Same as above.

[a]The terms *slight, moderate,* and *large* benefits or *adverse* impacts are used to convey the importance of the impact. These relative terms were not included in the Glen Canyon Dam EIS but have been added on the basis of a review of the findings presented in that EIS to provide consistency in treatment among facilities.

Source: Adapted from Reclamation (1995).

Existing monthly volume steady flows, seasonally adjusted steady flows, and year-round steady flows would all result in the loss of some currently vegetated areas as existing marsh and other lower riparian zone vegetation was inundated for extended periods and died. For these operational scenarios, any existing vegetation would be lost between the elevations of the current 8,000-cfs minimum flow and 12,000- to 13,000-cfs flows (Section 4.2.4.1.2, Vegetation). This zone receives little use by most species because the vegetation is relatively sparse and the zone is frequently inundated. Species such as the side-blotched lizard and red-spotted toad that do use this habitat could be adversely affected, but the impact should be minor because those species do not depend exclusively on this habitat for survival. Any adverse impacts to these species resulting from the loss of marsh vegetation would be greatly offset by the benefits of an increase in upper riparian zone vegetation.

The current low level of use of the river by waterfowl reduces the potential impact of any of the operational scenarios on such species. Differences in the degree of flow fluctuation associated with different operational scenarios should have little effect on the suitability of open-water habitats but could affect the aquatic food base (Reclamation 1995). The changes in marsh habitat described above in the Vegetation subsection should not have important impacts to waterfowl because of the current limited availability and use of this habitat. The few species that prefer open shoreline (e.g., killdeer, spotted sandpiper) could be adversely affected by any reductions in this habitat that would occur with existing monthly volume steady flows or year-round steady flows.

The two game mammals that use riparian areas below Glen Canyon Dam ¾ bighorn sheep and mule deer ¾ use riparian habitats only occasionally. The increases in upper riparian zone vegetation expected under all operational scenarios except continuation of historical operations, maximum power plant capacity, and restricted high fluctuations would increase the availability of suitable habitat for these species. Given the current limited use of the river corridor by either of these species and the abundance of these habitats, however, it appears unlikely that either species would respond to any such changes.

4.2.4.1.3 Threatened and Endangered Species

Aquatic Species

Potential impacts to the Federally listed humpback chub, razorback sucker, and flannelmouth sucker under the various operational scenarios are summarized in Table 4.22. Impacts to the Federally listed endangered humpback chub and razorback sucker are discussed in greater detail in the remainder of the section. The assessment presented here is based on the assessment in the EIS for operation of Glen Canyon Dam (Reclamation 1995).

As discussed in Section 3.4.1.3.1, the most important factor adversely affecting the Federally listed fish in the system is water temperature, which is not affected by hydropower operations. The continual release of cold water from Lake Powell appears to be the main factor limiting or preventing successful reproduction, larval growth, survival, and recruitment in the main channel.

Humpback Chub (Endangered). Except for potential adverse impacts from introduced species, impacts of hydropower operations on the humpback chub would be relatively similar among the historical operations, maximum power plant capacity, restricted high fluctuating flow, and moderate fluctuating flow operational scenarios. Under historical operations, the humpback chub population below the dam (including that in the Little Colorado River) should remain at or very near current levels or slowly decline because of natural mortality of adults. The humpback chub would continue to depend almost exclusively on reproduction and recruitment in the Little Colorado River, which would be unaffected by any of the operational scenarios. Similarly, little or no change in the status of the humpback chub would be anticipated under the maximum power plant capacity and restricted high fluctuating flow operational scenarios. The high daily flow fluctuations that would occur under the historical operations, maximum power plant capacity, and restricted high fluctuating flow operational scenarios would reduce the stability of backwater and nursery habitats and thus could result in a slight adverse impact to the potential growth and survival of humpback chub larvae in the Colorado River (Reclamation 1995). Because the greatest flow fluctuations would occur under the maximum power plant operations, nursery habitats would be least stable under this scenario.

TABLE 4.22 Summary of Potential Impacts to, and Overall Population Status of, the Humpback Chub, Razorback Sucker, and Flannelmouth Sucker below Glen Canyon Dam under Different Operational Scenarios a,b

Operational Scenarios	**Humpback Chub (F-E, AZ-E)**	**Razorback Sucker (F-E, AZ-E)**	**Flannelmouth Sucker (F-C2, AZ-NL)**
Continuation of historical operations	No change from current conditions; population stable to declining; reproduction and recruitment in the Colorado River limited by cold water temperature, independent of hydropower operations; large daily flow fluctuations limit nursery habitat stability.	No change from current conditions; population stable to declining; no reproduction because of cold water.	No change from current conditions; population stable to declining; population is limited by cold water temperatures, which are not affected by hydropower operations, and possibly by competition and predation from introduced species.
Maximum power plant capacity	Same as above.	Same as above.	Same as above.
Restricted high fluctuating flows	Same as above.	Same as above.	Same as above.
Moderate fluctuating flows	Same as above.	Same as above.	Same as above.
Modified low fluctuating flows	Slight benefit from increase in nursery habitat stability and possible increase in backwater abundance; benefits may be offset by increased populations of introduced species; habitat maintenance flows may limit abundance of introduced fish.	Same as above (because of absence of spawning, no benefits expected from increased nursery habitat stability and abundance).	Slight benefit from increase in nursery habitat stability and increased food base; benefits may be offset by potential increase in numbers of introduced fish; habitat maintenance flows may limit abundance of introduced fish.
Interim low fluctuating flows	Same as above, except no habitat maintenance flows to limit introduced fish.	Same as above.	Same as above, except no habitat maintenance flows to limit introduced fish.
Existing monthly volume steady flows	Slight benefit; stability of backwater habitats greater than	Same as above.	Slight benefit from increased nursery habitat stability and

	moderate fluctuating flows; benefits may be offset or adverse impacts may occur from potential increase in numbers of introduced fish.		food base; benefits may be offset or adverse impacts may occur from potential increase in numbers of introduced fish.
Seasonally adjusted steady flows	Slight to moderate benefit. Same as above except that habit maintenance flows may limit abundance of introduced fish.	Same as above.	Slight to moderate benefit. Same as above except that habitat maintenance flows may limit abundance of introduced fish.
Year-round steady flows	Slight benefit; habitat stability greater than under other scenarios; potential filling of nursery areas and increased populations of introduced species may negate any benefits and may adversely impact the humpback chub.	Same as above.	Slight benefit; similar to seasonally adjusted steady flows, but may be more adversely affected by potential increases in numbers of introduced fish and potential filling of nursery areas.

[a] Parenthetical coding for species indicates current status. These codes are defined in Table 3.10.

[b] The terms *slight, moderate,* and *large* benefits and *adverse* impacts are used to convey the importance of the impact. These relative terms were not included in the Glen Canyon Dam EIS but have been added on the basis of a review of the findings presented in that EIS to provide consistency in treatment among facilities.

Source: Adapted from Reclamation (1995).

Growth and recruitment of humpback chubs in the Colorado River could be slightly improved with moderate, modified low, and interim low fluctuating flows, primarily because of slightly increased stability in backwater nursery habitats. Additional benefit could be realized under the seasonally adjusted, existing monthly, and year-round steady flows. Under these scenarios, slight increases could occur in survival, growth, and recruitment of humpback chubs in the Colorado River (Reclamation 1995). Because nursery habitats would be most stable under the year-round steady flow operational scenario, this scenario could result in the greatest benefit to the humpback chub. However, main channel water temperatures would remain cold, and the benefit gained by the humpback chub would probably be small (Reclamation 1995). In addition, under year-round steady flows and in the absence of occasional flood flows, backwater habitats eventually would fill with sediment and vegetation, thereby eliminating these stable backwater areas as nursery habitats and resulting in an adverse impact to the chub (Reclamation 1995). The beach/habitat-building flows, which are common to all the restricted fluctuating and steady flow scenarios, could remove accumulated sediment and vegetation from backwater habitat, thus restoring the capacity of these habitats to function as nursery areas.

Any potential benefits to the humpback chub population resulting from lower fluctuations in flow could be offset by a concurrent increase in the number of introduced fish. Introduced fish have been suggested as a major factor responsible for the decline of native fish below Glen Canyon Dam (Minckley 1991; Minckley et al. 1991; see also Section 3.4.1.1). The increased stability of nursery habitats that could occur under many of the operational scenarios could benefit not only endangered and native fish but also could increase survival, growth, and recruitment of introduced fish (Reclamation 1995, see also Section 4.2.4.1.1). This condition could, in turn, result in increased competition with and predation on the endangered and native fish. The steady flow operational scenarios (particularly the year-round steady flow scenario) would have the greatest potential for increasing competition or predation from introduced fish. The beach/habitat building flows that are common elements of all the restricted fluctuation and steady flow scenarios may act to limit the abundance of introduced fish (Reclamation 1995). In addition, the yearly habitat-maintenance flows that would occur under the moderate and modified low fluctuation and the seasonally adjusted steady flow operational scenarios could act to further limit the abundance of introduced fish by flushing them from backwaters.

Razorback Sucker (Endangered). The razorback sucker population in the Colorado River between the dam and Lake Mead consists of only a few, very old (in excess of 25 years old) individuals. Little or no change would be expected in the status of the razorback sucker under any of the operational scenarios. Although some of the scenarios could increase the stability and abundance of nursery habitats that could be used by the razorback sucker larvae, this species does not reproduce in the river or its tributaries below the dam. Spawning is limited by cold water, which is not affected by variations in dam operations. In the absence of reproduction and recruitment, the razorback sucker population will continue to decline, and this species may become extirpated from the river between the Glen Canyon and Hoover dams.

Terrestrial Species

Expected impacts to Federally and state-listed species from hydropower operational scenarios at Glen Canyon Dam are summarized in Table 4.23. Impacts to Federally listed species are discussed in greater detail in the remainder of the section. In general, the various operational scenarios would have only minor (if any) impacts on these species.

Kanab Ambersnail (Endangered). All operational scenarios could adversely affect the Grand Canyon population of the Kanab ambersnail, since ambersnails are now located down to the elevation of 20,000 cfs flows and all operational scenarios would feature at least occasional flows above this level (Reclamation 1995). Consultation between Reclamation and the U.S. Fish and Wildlife Service has begun in order to determine what losses of individuals or habitat could occur without adversely affecting the population (Reclamation 1995).

Bald Eagle (Threatened). None of the operational scenarios under consideration are expected to have important impacts on the bald eagle (Reclamation 1995). Fluctuations in flow could strand trout in isolated pools, a condition that could benefit foraging eagles, but these same fluctuations could limit trout spawning activities and thus offset this benefit. Expected increases in the aquatic food base with moderate, modified low, and interim low fluctuating flows and the steady flow operational scenarios could be of slight benefit to this species.

Peregrine Falcon (Endangered). It is thought that peregrine falcons have benefitted from the increases in aquatic and terrestrial productivity that have resulted from construction of Glen Canyon Dam (Reclamation 1995). Most importantly, falcon prey (mostly birds) may have increased in abundance in response to (1) increases in the abundance of aquatic insects with less turbid water and (2) increases in terrestrial insects in response to the increase in riparian vegetation. However, a quantitative link between these factors has not been firmly established, and, thus, it is difficult to determine what effects (if any) changes in hydropower operations would have on peregrine falcons along the river (Reclamation 1995). It is possible that the expected increases in riparian vegetation associated with reduced fluctuations could result in slight increases in food supply under moderate fluctuation, low fluctuation, and steady flow operational scenarios, but this increase would probably not affect the peregrine falcon population.

TABLE 4.23

Mexican Spotted Owl (Threatened). No impacts to the Mexican spotted owl are likely to occur along the Colorado River as a result of the operational scenarios being considered. The woodland habitats that could be used by the owl are above the level of maximum flows of these scenarios. Projected increases in riparian vegetation under operational scenarios with reduced fluctuations (Section 4.2.4.1.2) would probably not benefit this species because most colonizing vegetation would consist of shrubs rather than trees.

Southwestern Willow Flycatcher (Endangered). Operational scenarios could affect the southwestern willow flycatcher through their effects on woody riparian vegetation, which has been proposed as critical habitat for this species (Reclamation 1995). Only the maximum power plant capacity operational scenario could have an adverse effect on the flycatcher because of the slightly higher maximum flows that would inundate some riparian vegetation. Moderate fluctuation, modified low fluctuation, and interim low fluctuation operational scenarios could result in slight benefits to this species as riparian vegetation increased in response to reductions in maximum flows. Further benefits could accrue with additional increases in riparian vegetation associated with the steady flow scenarios.

4.2.4.2 Flaming Gorge Dam

Impacts of four operational scenarios on ecological resources below Flaming Gorge Dam are evaluated in this EIS. These scenarios include (1) year-round high fluctuation, (2) seasonally adjusted high fluctuation, (3) seasonally adjusted moderate fluctuation, and (4) seasonally adjusted steady flows. Under the year-round high fluctuation scenario, monthly total reservoir releases would be the same as historical releases and operations would be at maximum power plant capacity. This scenario would not comply with the USFWS Biological Opinion (USFWS 1992) and is included here for comparison purposes. The remaining seasonally adjusted scenarios would comply with the Biological Opinion and would include sustained high flows in the spring and limited hourly fluctuations for much of the year. None of the scenarios feature releases outside of power plant capacity and all would differ from pre-dam flow regimes in several ways, including greatly reduced peak flows, higher winter and summer flows, and reduced between-year variability.

4.2.4.2.1 Aquatic Ecology

Potential impacts to trout and native fish are the focus of this discussion of the impacts of hydropower operational scenarios on the aquatic ecology of the Green River below Flaming Gorge Dam. These potential impacts are summarized in Table 4.24. Endangered fish are addressed separately in Section 4.2.4.2.3.

Although concerns may exist regarding impacts to specific aquatic habitats (e.g., backwater areas in the lower portion of the Green River), to the aquatic food base, and to introduced fish species, these concerns are related to potential indirect impacts to endangered fish, native fish, and trout. Therefore, these topics are addressed within the discussions of impacts to fish.

Trout

Important factors relative to trout in the Green River include growth rates, condition factors, overwinter survival of stocked trout, and natural reproduction. Impacts to trout are summarized in Table 4.24.

TABLE 4.24 Summary of Impacts to Trout and Native Fish below Flaming Gorge Dam under Different Hydropower Operational Scenarios a

Operational Scenarios	Trout	Native Fish
Year-round high fluctuating flows	Slight to moderate adverse impact to growth rates and overwinter survival of young; potential reduction in natural reproduction; slight potential decrease in condition.	Slight to moderate adverse impact; populations may be limited by low overwinter survival and recruitment from daily flow fluctuations and introduced fish; use of and reproduction in the Green River above the Yampa River is limited by cold water, independent of hydropower operations.
Seasonally adjusted high fluctuating flows	Either no impact or a slight benefit; potential improvement in summer growth, spawning success, and over-winter survival.	Slight to moderate benefit; recruitment may be enhanced; no change in overwinter survival; high spring flows may limit abundance of introduced species; potential slight increase in use of the Green River above the Yampa River by adults and juveniles, but no change in reproduction.
Seasonally adjusted	Slight benefit; slight	Moderate benefit; recruitment and

moderate fluctuating flows	improvement in condition and potential slight increase in overwinter survival; increase in number of wild-spawned trout.	overwinter survival may be enhanced; high spring flows may limit abundance of introduced species; potential slight increase in the use of the Green River above the Yampa River by adults and juveniles, but no change in reproduction.
Seasonally adjusted steady flows	Moderate benefit; potentially highest level of overwinter survival; slight improvement in condition and slight increase in hatching success over seasonally adjusted moderate fluctuations.	Moderate to large benefit; highest potential recruitment and overwinter survival of all scenarios; high spring flows may limit abundance of introduced species; potential slight increase in use of the Green River above the Yampa River by adults and juveniles, but no change in reproduction.

[a] The terms *slight, moderate,* and *large* are used to convey the importance of the impact. These relative terms were determined after the analysis of the impacts was completed and are based on professional judgment.

Under historical operations and current fishery management practices, the area of the Green River below Flaming Gorge Dam has become one of the premier trout fisheries of the western United States (Modde et al. 1991). Excellent growth rates and condition factors have been documented for this trout fishery (Modde et al. 1991; Johnson et al. 1987). However, the majority of the trout are stocked, and recruitment of naturally reproduced young to the adult populations is typically low. This low recruitment may be due to the substantial daily fluctuations in dam releases that have occurred in the past during the spawning and egg development periods (see Appendix D, Section D.2.1.2 and Hlohowskyj and Hayse 1995 for additional discussion). Daily fluctuations can strand spawning adults, expose eggs, or reduce the quality of spawning sites. One of the trout species present below the dam, the brown trout, relies completely upon natural reproduction of wild stocks to maintain population levels, and reproduction occurs at low levels.

Under the year-round high fluctuating flow operational scenario, maximum releases from the dam would be about 500 cfs greater than under historical operations, and the magnitude of daily flow fluctuations would also be greater. The increase in the magnitude of the daily flow fluctuations could result in slight to moderate adverse impacts to trout. The large daily fluctuations that would occur during spawning and the egg development periods could limit natural reproduction, particularly by the brown trout. The daily fluctuations of the year-round high fluctuating flow scenario could also reduce growth rates, condition, and overwinter survival of trout (Hlohowskyj and Hayse 1995).

The seasonally adjusted high fluctuating flow scenario includes maximum releases and daily fluctuations of the same magnitude as the year-round high fluctuating flow scenario, but these do not occur throughout the year. Under the seasonally adjusted high fluctuating flow scenario, trout would benefit from steady flows or reduced daily fluctuations for seven months of the year. These reductions in daily fluctuations would occur during the summer growing season and for a portion of the overwinter and spawning period. Thus, there is a potential for improvements in growth, spawning success, and overwinter survival by trout under this scenario.

Both the seasonally adjusted moderate fluctuating flow and seasonally adjusted steady flow operational scenarios would increase the amount of potential spawning substrate available for trout that spawn during the fall (brown trout and rainbow trout) or spring (rainbow trout and brook trout), and these areas would remain inundated throughout the period of egg development and hatching. In addition, the reduction or elimination of daily fluctuations could increase populations of aquatic insects such as mayflies, stoneflies, and caddisflies that serve as food for trout. Thus, under these two scenarios, the number of naturally reproduced brown, rainbow, and brook trout could increase. During other times of the year, however, the amount of feeding habitat and shelter available for trout would be similar under all operational scenarios. If trout population levels were maintained near present levels, reduced daily fluctuations in discharge could improve growth and condition of trout, because aquatic food resources could increase slightly. If trout population levels increased, however, growth rates and overall condition of the fish could decrease because of increased competition for food resources. Modde et al. (1991) reported that growth rates of trout in the Green River declined as population levels increased, suggesting that food or habitat is limited. Whether trout population levels increased or remained at current levels would, as in the past, depend primarily on trout stocking and management programs.

Overwinter survival of trout could be improved by the seasonally adjusted moderate fluctuation and seasonally adjusted steady flow operational scenarios because of reduced daily fluctuations in discharge during the winter, with the latter scenario expected to yield the highest overwinter survival.

On the basis of these impact evaluations, the USFWS, in its Fish and Wildlife Coordination Act Report (USFWS 1995), for this Power Marketing EIS, identified the stocking of more or larger trout in the Flaming Gorge Dam tailwaters as a resource enhancement opportunity should Western adopt either the seasonally adjusted high fluctuation or seasonally adjusted moderate fluctuation operational scenario. Stocking was recommended by the USFWS to equalize impacts among scenarios by compensating for the expected lower growth and survival of trout under the seasonally adjusted high and seasonally adjusted moderate fluctuation scenarios relative to the seasonally adjusted steady flow scenario. Less stocking would be required for the seasonally adjusted moderate fluctuation scenario than for the seasonally adjusted high fluctuation scenario. Resource enhancement was not suggested for the year-round high fluctuation operational scenario because it would not comply with the Biological Opinion (USFWS 1992b) and therefore could not be implemented.

Native Fish

The primary issues relative to native fish in the Green River include reproduction, growth, condition, overwinter survival, and recruitment of young fish to the adult populations. Impacts to native fish are summarized in Table 4.24.

Under historical operations, use of the Green River above the Yampa River by adult and juvenile native fish may have been limited by daily flow fluctuations and cold water, which reduce habitat suitability; reproduction was limited by the cold water. Reproduction in this portion of the river would remain limited under all operational scenarios because cold water would be released from the reservoir regardless of the operational scenario implemented. Use of the Green River above the Yampa River confluence by adult and juvenile native fish would continue to be limited under the year-round and seasonally adjusted high fluctuating flow operational scenarios and might be further reduced in winter because the daily flow fluctuations under these scenarios would be greater than during past operations. Use by native fish of the Green River through the Canyon of Lodore in all seasons except winter could increase slightly under the seasonally adjusted moderate fluctuating flow and steady flow operational scenarios, primarily as a result of reduction or elimination of hydropower-generated daily flow fluctuations.

The Yampa River maintains flows in the lower portion of the Green River near pre-dam levels (USFWS 1992b). According to the Biological Opinion issued on the operation of the dam (USFWS 1992b), continuation of historical operations at Flaming Gorge Dam would cause a decline of some native fish populations, primarily because of daily flow fluctuations. These fluctuations limit the abundance and quality of nursery habitats in the Green River below the Yampa River and thus reduce recruitment of young fish to adult populations (USFWS 1992b). Daily flow fluctuations in the Green River below the confluence of the Yampa River would be greater during the nursery period under the year-round high fluctuating flow scenario than under past operations and could reduce recruitment of some native fish. Thus, populations of some native fish species could continue to decline at rates equal to or greater than those occurring in the past. In addition, species with stable populations may begin to decline under year-round high fluctuating flows because of the greater magnitude of the daily fluctuations.

The seasonally adjusted high fluctuating flow operational scenario would control flow fluctuations within specified ranges during the nursery periods for most native and endangered fish species (USFWS 1992b). Under these conditions, growth and recruitment of young fish would be enhanced, and the populations of native fish could increase slightly (see Appendix D, Section D.2.1.2 and Hlohowskyj and Hayse 1995 for a discussion of backwater stability). Little or no change would be expected in overwinter survival.

The seasonally adjusted moderate fluctuating flow operational scenario would produce considerably smaller daily fluctuations in flows in the Green River below the Yampa River during all seasons of the year. The daily flow fluctuations that would occur under the seasonally adjusted moderate fluctuating flow operational scenario are within the range of daily fluctuations allowed under the Biological Opinion and considered protective of backwater nursery habitats for endangered (and native) fish species (USFWS 1992b). Under this scenario, flows at Jensen during the critical nursery habitat period would fluctuate by no more than 200 cfs per day, resulting in fluctuations of less than 2.5 in. per day in surface water elevations of backwaters. Seasonally adjusted steady flow operations would produce no hydropower-generated fluctuations. Under these two scenarios, moderate to high increases in the populations of native fish could occur. These increases could result from increased stability of nursery areas, increased production of the food base, improved growth rates, and improved survival of young and adults; reproduction levels in the Green River are not likely to change.

On the basis of these impact evaluations, the USFWS, in its Fish and Wildlife Coordination Act Report (USFWS 1995) for this Power Marketing EIS, identified restoration of flows to previously flooded bottomlands along the Green River downstream of Jensen, Utah, as a resource enhancement opportunity should Western adopt either the seasonally adjusted high fluctuation or seasonally adjusted moderate fluctuation operational scenario. This action was recommended by the USFWS to equalize impacts among scenarios by offsetting the expected lower growth and survival of native fishes under the seasonally adjusted high fluctuation and seasonally adjusted moderate fluctuation scenarios relative to the seasonally adjusted steady flow scenario. Less stocking would be required for the seasonally adjusted moderate fluctuation scenario than for the seasonally adjusted high fluctuation scenario. Resource enhancement was not suggested for the year-round high fluctuation operational scenario because it would not comply with the Biological Opinion (USFWS 1992b) and therefore could not be implemented. Western, as a member of the Recovery Implementation Program for Colorado River Fishes, is currently involved in efforts to restore bottomland habitats.

The ecological requirements of some of the introduced fish in the Green River below the Yampa River are similar to those of the native fish. Thus, operational scenarios that potentially increase growth and survival of native species could similarly benefit the introduced species. Furthermore, since predation by and competition with introduced species have been suggested as contributing to the decline of native fish (USFWS 1992b; Minckley 1991; Minckley et al. 1991; Tyus and Karp 1991), increased numbers of introduced species could at least partially offset any benefits gained by native species under a particular operational scenario. However, any increase in recruitment of native fishes would be beneficial.

High spring flows may reduce numbers of introduced fish in canyon-bound reaches of western rivers (Minckley and Meffe 1987; McAda and Kaeding 1989; Osmundson and Kaeding 1991). Thus, the high spring flows of the seasonally adjusted operational scenarios could reduce predation and competition on native fish in reaches of the Green River such as the Canyon of Lodore, Whirlpool Canyon, and Split Mountain. Little or no decrease in the abundance or diversity of introduced species is expected in broad floodplain areas, such as Island Park and near Jensen. In these areas, introduced species could probably avoid downstream transport by fast currents. For this reason, the response of introduced fish to operational scenarios and their subsequent effect on native fish cannot be quantified at this time.

4.2.4.2.2 Terrestrial Ecology

Vegetation

Assessments of impacts to riparian vegetation along the Green River below Flaming Gorge Dam were based on the predicted changes in flow regime that would result from the four operational scenarios under consideration for this dam (Section 4.2.3.2.1). Impacts of hydropower operational scenarios were assessed for upper riparian zone vegetation and lower riparian zone vegetation, as described in Appendix D, Section D.2.1.3. Table 4.25 summarizes potential impacts to these riparian zones under the four operational scenarios. A more detailed discussion of these impacts is provided in Appendix D, Section D.3.2, and in LaGory and Van Lonkhuyzen (1995).

TABLE 4.25 Summary of Impacts to Riparian Vegetation below Flaming Gorge Dam under

Different Hydropower Operational Scenarios a

Operational Scenarios	Upper Riparian Zone	Lower Riparian Zone
Year-round high fluctuating flows	Slight adverse impact to existing vegetation; 5% decrease in area.	Slight benefit; 13% increase in area available for lower riparian zone vegetation.
Seasonally adjusted high fluctuating flows	Same as above.	Same as above.
Seasonally adjusted moderate fluctuating flows	Same as above.	Moderate adverse impact; area available for lower zone vegetation decreases by about 40%.
Seasonally adjusted steady flows	Slight benefit; 8% increase in upper zone riparian vegetation as high water line lowered to around 3,400-cfs level.	Large adverse impact; area available for lower zone vegetation decreases by about 74%.

[a] The terms *slight*, *moderate*, and *large* are used to convey the importance of the impact. These relative terms were determined after the analysis of the impacts was completed and are based on professional judgment.

All operational scenarios would result in some impacts to existing riparian vegetation. None would affect pre-dam riparian vegetation because that vegetation is located well above the area affected by releases within power plant capacity. Occasional releases above power plant capacity may be needed to maintain the long-term productivity of this portion of the riparian ecosystem. Upper riparian zone vegetation currently occurs in a band along the edge of the river above the historical maximum operating release of 4,200 cfs. Year-round high fluctuating flows, seasonally adjusted high fluctuating flows, and seasonally adjusted moderate fluctuating flows would all feature extended periods during the growing season when releases would reach 4,700 cfs on a daily basis. This increase in maximum flows represents a stage change of approximately 6 in. and would inundate some existing upper riparian zone vegetation (about 0.7 acre per mile, a 5% decrease). For the seasonally adjusted steady flow operational scenario, flows would be less than historical operational levels for most of the year and could allow an expansion of upper zone vegetation to around the 3,400-cfs level. This expansion would represent an increase in the area of upper zone vegetation of about 8% (1.1 acres per mile).

These increases or decreases in riparian vegetation would occur at the lower edge of the riparian zone and would be temporary (i.e., would occur for the next several decades) rather than long term. Any such response at the lower edge of the riparian zone to an increase or decrease in flows eventually would be compensated by an increase or decrease in vegetation at the upper edge of the zone. Thus, if a certain operational pattern was established over the long term, riparian vegetation eventually should reach a new equilibrium along the altered hydrological gradient, and no net increase or decrease in area would occur. In addition, periodic floods or occasional sustained high releases would remove most upper riparian zone vegetation that became established at lower levels as a result of changes in operations.

With year-round high fluctuating flows, existing lower riparian zone vegetation would be maintained. With daily maximum flows of 4,700 cfs, the area of the lower zone would increase by about 13%. A similar increase in lower zone vegetation is expected with seasonally adjusted high fluctuating flows because this same daily fluctuation zone would be maintained during several months of the growing season.

Lower zone vegetation could decline under both the seasonally adjusted moderate fluctuation and seasonally adjusted steady flow operational scenarios because of decreases in the size of the fluctuation zone. Based on the seasonal and daily patterns of releases, the area available for lower zone vegetation is expected to decrease by about 40% under seasonally adjusted moderate fluctuations and by about 74% for seasonally adjusted steady flows. Under both operational scenarios, the area below the 2,400-cfs level would be largely unvegetated or support only short-lived annual plants because of the extended period of inundation each year. This unvegetated area would occupy about 2.8 acres per mile of river corridor.

On the basis of these impact evaluations, the USFWS, in its Fish and Wildlife Coordination Act Report (USFWS 1995) for this Power Marketing EIS, suggested that if Western adopted either the seasonally adjusted high fluctuation or seasonally adjusted moderate fluctuation operational scenario, Western should manage approximately 100 acres of riparian habitat to increase the representation of native plant species below Flaming Gorge Dam and discourage the invasion of weedy species, such as tamarisk and giant whitetop. Management of these areas would increase biodiversity in riparian areas and increase the value to native wildlife. This action was recommended by the USFWS to equalize impacts among scenarios by compensating for the smaller amount of upper riparian zone vegetation expected under the seasonally adjusted high and seasonally adjusted moderate fluctuation scenarios relative to the seasonally adjusted steady flow scenario. Resource enhancement was not suggested for the year-round high fluctuation operational scenario because it would not comply with the Biological Opinion (USFWS 1992b) and therefore could not be implemented.

Wildlife

Table 4.26 summarizes impacts to nongame wildlife, waterfowl, and game mammals under the four operational scenarios for Flaming Gorge Dam. Most of the impacts would be attributable to changes in riparian vegetation that serves as wildlife habitat (Section 4.2.4.2.2, Vegetation). These impacts are discussed below.

TABLE 4.26 Summary of Impacts of Hydropower Operational Scenarios on Wildlife below Flaming Gorge Dam a

Operational Scenarios	Nongame Species	Waterfowl	Game Mammals
Year-round high fluctuating flows	Slight adverse impact associated with 5% decrease in area of upper riparian zone vegetation.	Slight benefit; 13% increase in lower riparian zone vegetation; open water maintained in winter.	Slight adverse impact associated with 5% decrease in upper riparian zone vegetation.
Seasonally adjusted high fluctuating flows	Same as above.	Slight adverse impact; 13% increase in lower zone vegetation, but less ice-free water in winter.	Same as above.
Seasonally adjusted moderate fluctuating flows	Slight adverse impact associated with 5% decrease in area of upper riparian zone vegetation and 40% decrease in lower riparian zone.	Slight adverse impact; 40% reduction in lower zone vegetation and less ice-free water in winter.	Same as above.
Seasonally adjusted steady flows	Slight benefit from 8% increase in upper riparian zone vegetation.	Slight adverse impact; 74% decrease in lower zone vegetation and less ice-free water in	Slight benefit from 8% increase in upper riparian zone vegetation.

		winter.	

[a] The terms *slight, moderate,* and *large* are used to convey the importance of the impact. These relative terms were determined after the analysis of the impacts was completed and are based on professional judgment.

Nongame wildlife could be adversely affected by the year-round high fluctuation, seasonally adjusted high fluctuation, or seasonally adjusted moderate fluctuation scenarios. These species are most dependent on the woody species common in the upper riparian zone of the Green River corridor, and the area occupied by this vegetation would be reduced by about 5% under these scenarios. Seasonally adjusted steady flows could, on the other hand, cause an 8% increase in upper zone vegetation, thus providing a slight benefit to most nongame species. Expected reductions in the area of the lower riparian zone (and the marsh habitat it contains) as a result of seasonally adjusted moderate fluctuating flow and steady flow operational scenarios could adversely affect some nongame species, but these impacts should be relatively minor given the relative abundance of marsh vegetation in nearby Browns Park wildlife refuges.

Differences in the degree of flow fluctuation associated with different operational scenarios should have little effect on the open-water habitats or aquatic food supply used by waterfowl in the spring, summer, and autumn. In addition, nesting areas currently used by species such as Canada geese should not be adversely affected because the slight increase in maximum flows would result in only a 6-in. increase in maximum stage. On the other hand, none of the operational scenarios would increase nesting habitat either. The reduced maximum flows of all the seasonally adjusted flow scenarios, which could increase the availability of nesting substrates, occur between July and September, after the nesting season.

Reductions in lower zone (including marsh) vegetation under seasonally adjusted moderate fluctuating flows and seasonally adjusted steady flows should have only slight adverse effects on waterfowl because the amount of marsh available in riparian areas along the river is small compared with the thousands of acres of managed wet marsh in the nearby Browns Park wildlife refuges. The few species that prefer open shoreline habitats (e.g., killdeer, spotted sandpiper) could benefit from the increase in unvegetated shoreline that would occur with seasonally adjusted moderate fluctuations or seasonally adjusted steady flows.

Wintering waterfowl could be adversely affected by a reduction in the availability of open, ice-free water with any of the seasonally adjusted flow scenarios. These scenarios have been developed to discourage ice breakup once an ice cap has formed, thus fluctuations would be reduced after February 1 for each scenario. Open, ice-free water would be maintained for all operational scenarios, however, from the dam to the Gates of Lodore because of the relatively warm dam releases. Use of this river reach by waterfowl in the winter would likely increase.

Riparian habitats below Flaming Gorge Dam receive various levels of use from mule deer, elk, moose, pronghorn, and bighorn sheep. The 8% increase in upper riparian zone vegetation projected under the seasonally adjusted steady flow scenario could benefit these species by increasing the carrying capacity of the river corridor. All but moose use a variety of nonriparian habitats, and, therefore, the importance of an increase in riparian vegetation is probably minor. While moose would potentially benefit most from increases in riparian vegetation (especially willow, a preferred forage), their current low numbers in the area would limit the importance of this habitat increase.

As described in Section 4.2.4.2.2, Vegetation, the USFWS, in its Fish and Wildlife Coordination Act Report (USFWS 1995) for this Power Marketing EIS, identified resource enhancement opportunities for riparian habitats to offset differences in impacts among operational scenarios. Any such actions could provide benefits to wildlife using these habitats.

4.2.4.2.3 Threatened and Endangered Species

Aquatic Species

Except for the year-round high fluctuating flow operational scenario, the scenarios evaluated for Flaming Gorge Dam were developed to comply with the Biological Opinion on the operation of Flaming Gorge Dam (USFWS 1992b), and each would be expected to be protective of the endangered fish (and presumably all native fish) in the Green River downstream of Jensen, Utah. Therefore, this analysis evaluates the effects of the operational scenarios on endangered fish only for that reach of the Green River between the dam and Jensen. The year-round high fluctuating flow operational scenario would not comply with the Biological Opinion and is discussed here only to provide a point of comparison between conditions under maximum power plant operations and those that would prevail under the operational scenarios that would comply with the opinion. Impacts to Federally and state-listed aquatic species between the dam and Jensen are summarized in the following subsections and in Table 4.27. Impacts to the Federally endangered fish are discussed in greater detail in the following sections.

On the basis of the impact evaluations presented in Table 4.27, the USFWS, in its Fish and Wildlife Coordination Act Report (USFWS 1995) for this Power Marketing EIS, identified restoration of flows to previous flooded bottomlands along the Green River downstream of Jensen, Utah, as a resource enhancement opportunity should Western adopt either the seasonally adjusted high fluctuation or seasonally adjusted moderate fluctuation operational scenario. Restoration of these areas could increase recruitment of endangered fish by providing nursery habitat in areas that have been affected by flow modification, filling, and construction of dikes. This action was recommended by the USFWS to equalize impacts among scenarios by compensating for the expected lower growth and survival of endangered fish and the decreased stability of nursery habitats under the seasonally adjusted high fluctuation and seasonally adjusted moderate fluctuation scenarios relative to the seasonally adjusted steady flow scenario. Less extensive restoration would be required for the seasonally adjusted moderate fluctuation scenario than for the seasonally adjusted high fluctuation scenario. Resource enhancement was not suggested for the year-round high fluctuation operational scenario because it would not comply with the Biological Opinion (USFWS 1992b) and therefore could not be implemented. Western, as a member of the Recovery Implementation Program for Colorado River Fishes, is currently involved in efforts to restore bottomland habitats.

TABLE 4.27

It should be noted that competition with and predation by introduced fish species have been suggested as factors contributing to the decline of native fish, including threatened and endangered species (Minckley 1991; USFWS 1992b), and conditions that benefit native fish could also benefit introduced ones (see Section D.2.1.2.2 in Appendix D). Therefore, any benefits realized by threatened and endangered fish species under the various operational scenarios might be at least partially offset by concomitant benefits to introduced species. The high spring flows of the seasonally adjusted operational scenarios could reduce the distribution and abundance of some introduced fish species, particularly in the canyon-bound reaches of the Green River (Minckley and Meffe 1987). However, the increased stability of backwater and nursery habitats in summer and autumn under the seasonally adjusted operational scenarios might benefit not only endangered fish, but also introduced fish (Section 4.2.4.2.1, Native Fish), potentially offsetting any benefits to endangered fish (Kaeding and Osmundson 1988; Tyus and Beard 1990; Haines and Tyus 1990; Karp and Tyus 1990a; Reclamation 1995). The potential for increased production and growth of introduced fish during the summer and autumn would be greatest under seasonally adjusted steady flows because this scenario would provide the most stable conditions in backwaters and other nursery areas. Although it is not possible at this time to quantify the balance between negative and positive influences of the various operational scenarios to introduced fish species, any increase in recruitment of endangered fish would be considered beneficial, especially for the razorback sucker, which has had little or no successful recruitment for at least 25 years. Annual surveys of backwaters to determine the abundance of introduced fishes in these habitats and the influence of hydropower operations on population levels is warranted.

Humpback Chub (Endangered). Reproduction by humpback chub in the Green River above the confluence with the Yampa River would remain limited under all operational scenarios because of the cold water released from the reservoir. Within the Green River Basin, the humpback chub spawns primarily in the Yampa River, which is not influenced by Flaming Gorge Dam. None of the operational scenarios would affect spawning in this reach. Some humpback chub may spawn in Whirlpool Canyon of the Green River, and spawning in this reach could be adversely affected by daily fluctuations in flow and stage. Fluctuations in spring and early summer could affect spawning by stressing adults and degrading the suitability of spawning habitat. Only the year-round high fluctuating flow scenario would feature marked fluctuations during this period. Impacts to the humpback chub are summarized in Table 4.27.

In the Green River, hydropower-induced fluctuations in flow and stage in spring and summer may stress adults and limit reproduction and recruitment (USFWS 1992b) by destabilizing adult, juvenile, and nursery habitats. Fluctuations in winter may stress adults and reduce condition and survival (Valdez and Masslich 1989). Under year-round high fluctuating flows, daily fluctuations in flow and stage would be greater than under past operations, resulting in greater adverse impacts to adult, juvenile, and nursery habitats than occurred in the past. Adult and juvenile growth, recruitment, and overwinter survival could be reduced, and the population could decline at a rate equal to or slightly greater than in the past.

The humpback chub might receive slight benefits under seasonally adjusted high fluctuating flows. Daily fluctuations in flow and stage in winter and early spring (April and May) would be the same as under year-round high fluctuating flows, and there would be no difference in stress to fish in winter or spring. However, daily fluctuations in nursery habitats in summer and autumn would be reduced, possibly increasing recruitment by increasing survival and growth of young fish.

The potential benefit to the humpback chub would be even greater under the seasonally adjusted moderate fluctuating flows and seasonally adjusted steady flows. Daily fluctuations in flow and stage in summer and autumn would be very small, and nursery habitat stability would be similar under the two scenarios. As a result, a moderate to high potential increase in recruitment could occur. The difference in habitat stability between these two scenarios would be small and within the range of natural fluctuations resulting from variations in Yampa River flow. Fluctuations in flow and stage in winter due to hydropower operations would be reduced or eliminated under seasonally adjusted moderate fluctuating or steady flows, and fluctuation-induced stress would be reduced or eliminated. Use of the Green River through the Canyon of Lodore by adult and juvenile humpback chub could increase slightly under the seasonally adjusted moderate fluctuation and steady flow operational scenarios, primarily as a result of reduced hydropower-generated daily flow fluctuations.

Bonytail Chub (Endangered). Without specific information on the status and ecology of the bonytail chub in the Green River between the dam and Jensen, it is difficult to assess impacts to this species. However, because of the similarity between the bonytail and humpback chubs (Kaeding et al. 1986) and the general similarity in adult and juvenile habitats among other endangered and native Colorado River fish, it is assumed that conditions meeting the habitat and life history requirements of the humpback chub, Colorado squawfish, and razorback sucker would benefit the bonytail chub. Thus, the assessment prepared for the humpback chub is presumed to apply to the bonytail chub as well (Table 4.27).

Colorado Squawfish (Endangered). Impacts of each of the hydropower operational scenarios on the Colorado squawfish would be very similar to the impacts identified for the humpback chub (Table 4.27). None of the operational scenarios is expected to affect the two known spawning areas for this species located in the lower Yampa River and Desolation Canyon of the lower Green River. Under year-round high fluctuating flows, daily fluctuations in flow and stage would be greater than under past operations and thus could adversely affect adult, juvenile, and nursery habitats. Adult and juvenile growth, recruitment, and overwinter survival could be reduced, and the population could decline.

Increased backwater habitat stability under the seasonally adjusted and steady flow scenarios might increase growth, survival, and recruitment of this species. Habitat stability would be greatest under seasonally adjusted steady flows. Decreased fluctuations in winter under the seasonally adjusted moderate fluctuation and steady flow scenarios could enhance overwinter survival of Colorado squawfish. Use of the Green River through the Canyon of Lodore by adult and juvenile Colorado squawfish could increase slightly in response to the reduced daily flow fluctuations that would occur under the seasonally adjusted moderate fluctuation and steady flow scenarios.

Razorback Sucker (Endangered). Potential impacts of each of the operational scenarios to the razorback sucker would be similar to the impacts identified for the humpback chub and the Colorado squawfish (Table 4.27). None of the operational scenarios is expected to affect access to spawning areas in the Yampa River or in the Green River below Jensen. Flow fluctuations in winter may stress razorback suckers (USFWS 1992b), and thus could reduce survival.

The daily flow fluctuations to which the razorback sucker would be subject under the year-round and seasonally adjusted high fluctuating flow scenarios would be greater than the daily fluctuations that occurred under past operations. Thus, overwinter survival could be less than occurred in the past, and the population could decline more rapidly under these scenarios.

Fluctuations would be reduced or eliminated under seasonally adjusted moderate fluctuating or steady flows, respectively, and overwinter survival could be enhanced under either of these operational scenarios. Use of the Green River through the Canyon of Lodore by adult razorback suckers could increase slightly under the seasonally adjusted moderate fluctuation and steady flow operational scenarios, primarily as a result of reduced or eliminated hydropower-generated flow fluctuations.

Flooded bottomland nursery habitats, because of their warmer temperatures and high production of food resources, are thought to play a critical role in the survival and recruitment of young razorback suckers into the adult population (USFWS 1992b). Under each of the seasonally adjusted operational scenarios, flow and daily fluctuations would fall within the target flows and fluctuations identified in the Biological Opinion that would produce and maintain nursery habitats for the razorback sucker and other native fish (USFWS 1992b). Thus, recruitment could be enhanced under each of the seasonally adjusted flow operational scenarios as a result of nursery habitats stability; nursery habitats would be most stable under the seasonally adjusted steady flow scenario.

Terrestrial Species

Impacts of hydropower operational scenarios on Federally and state-listed terrestrial plant and animal species below Flaming Gorge Dam are summarized in Table 4.28. Impacts to animal species were determined from predicted changes in riparian habitats (see Section 4.2.4.2.2 Vegetation) or aquatic ecology (see Section 4.2.4.3.1). Impacts to Federally listed species are discussed in greater detail in the following subsections. No resource enhancement opportunities for terrestrial threatened or endangered species were suggested by the USFWS in its Fish and Wildlife Coordination Act Report (USFWS 1995) for this Power Marketing EIS.

TABLE 4.28

Ute Ladies'-Tresses (Threatened). No operational scenario is expected to cause inundation of any existing Ute ladies'-tresses because these individuals are all located several feet above the height of maximum hydropower releases. Soil-moisture levels in these locations would be maintained under year-round high fluctuations throughout the growing season. The operational scenarios with seasonally adjusted flows, however, could result in lower soil-moisture levels during most of the summer and thus could adversely affect these individuals; seasonally adjusted steady flows would have the greatest effect and could result in a moderate adverse impact to existing individuals.

Although existing Ute ladies'-tresses could be adversely affected by seasonally adjusted flows, these operational scenarios could favor the establishment of additional individuals closer to the river and thus provide greater overall benefit to the species. These operational scenarios follow more closely the natural seasonal pattern of river flow to which this species is adapted (however, spring peaks in flow would be much lower than the annual floods that occurred before the dam was built). The spring peak of the seasonally adjusted flows could benefit the species by periodically removing competing plants and accumulations of dead plant material. The greatest potential benefit would result from seasonally adjusted steady flows.

The USFWS, in its Fish and Wildlife Coordination Act Report (USFWS 1995) for this Power Marketing EIS, suggested that Western perform annual surveys of Ute ladies'-tresses populations in riparian areas of Browns Park to determine the influence of seasonal adjustment of operations on soil moisture levels during the summer. The USFWS suggested that any observation of adverse effects should prompt actions such as providing supplemental water or transplanting affected individual plants to areas of suitable habitat.

Whooping Crane (Endangered). Hydropower operations at Flaming Gorge Dam are not likely to impact the whooping crane because the probability that habitat along the river would be used by migrating cranes appears low. The expected reduction in the amount of lower zone vegetation (including marshes) under seasonally adjusted moderate fluctuations or seasonally adjusted steady flows could represent a slight adverse impact to this species if migrating birds began to use this portion of the river corridor regularly during migration. This habitat could serve as a potential foraging area for the species.

Bald Eagle (Threatened). Operational scenarios at Flaming Gorge Dam would differ in the amount of open, ice-free water available during the winter for foraging eagles. All but the year-round high fluctuation scenario incorporate flows that are intended to maintain a solid ice cover during the winter to protect endangered fish. Thus, seasonally adjusted high fluctuation, moderate fluctuation, and steady flows would reduce the availability of open water in important foraging areas such as Island and Rainbow parks. Much of the river above the Gates of Lodore would remain open under all operational scenarios because the temperature of water released from the dam is sufficiently high to prevent freezing. Eagles would concentrate their use in this section of the river during the winter under seasonally adjusted flow scenarios. No other impacts to this species are anticipated.

Peregrine Falcon (Endangered). Given the expected magnitude of impacts to riparian vegetation and aquatic ecology along the Green River associated with various operational scenarios (Section 4.2.4.2.2, Vegetation), it is unlikely that the peregrine falcon population would be affected regardless of the operational scenario employed. A slight adverse effect could occur if prey populations declined as a result of the decrease in upper riparian zone vegetation expected under year-round high fluctuations, seasonally adjusted high fluctuations, and seasonally adjusted moderate fluctuations. A slight benefit could occur if prey populations increased in response to the increase in upper riparian zone vegetation expected under seasonally adjusted steady flows.

Mexican Spotted Owl (Threatened). No impact to the Mexican spotted owl is likely to occur along the Green River under any of the operational scenarios at Flaming Gorge Dam; the woodland habitats that could be used by the owl are above the level of maximum flows of these scenarios. The 8% increase in upper riparian zone vegetation expected with seasonally adjusted steady flows would probably not benefit this species because most colonizing vegetation would consist of shrubs rather than trees.

4.2.4.3 Aspinall Unit

The impacts of two operational scenarios on ecological resources in the vicinity of the Aspinall Unit are evaluated in this EIS. These scenarios include seasonally adjusted high fluctuation and seasonally adjusted steady flows. Both of these scenarios are based on USFWS research flows for the Aspinall Unit (Harris 1992). The seasonal pattern of release from Crystal Reservoir would be identical and would be steady within each day. The seasonally adjusted high fluctuation scenario features maximum power plant capacity releases from Blue Mesa and Morrow Point reservoirs while meeting the needs for seasonal releases from Crystal Reservoir. No fluctuations in release from any of the reservoirs would occur under the seasonally adjusted steady flow scenario. The USFWS did not identify resource enhancement opportunities for either aquatic or terrestrial resources at the Aspinall Unit in its Fish and Wildlife Coordination Act Report (USFWS 1995) for this Power Marketing EIS.

4.2.4.3.1 Aquatic Ecology

Under the seasonally adjusted steady flows operational scenario, releases of water from the Aspinall Unit dams would not be controlled to produce hydropower. Daily changes in reservoir elevations would result solely from Bureau of Reclamation operations, and no adverse impacts would be expected from hydropower generation at any of the three dams. Under the seasonally adjusted high fluctuating flow scenario, the kokanee salmon would be the aquatic resource of principal concern. Potential impacts to this salmon could include increased mortality from entrainment and passage through the penstocks and hydropower turbines, reduced growth and condition as a result of a reduction in the aquatic food base, and loss of habitat. However, as discussed below, hydropower operations are not expected to produce any such impacts that would seriously affect the population.

Entrainment of kokanee salmon typically occurs in summer when adults seek cold temperatures in deep water. During this period, kokanee concentrate at depths of 50 to 100 ft below the surface of Blue Mesa Reservoir and from the surface to a depth of about 40 ft at Morrow Point Reservoir (Van Buren and Burkhard 1981). Under seasonally adjusted steady flows, these depths would be about 25-120 ft above the depths of the penstock intake structures. Thus, very little entrainment of kokanee salmon at the penstocks would be expected under this scenario.

The similarity of the estimated use values for these four operational scenarios results from the inability of the model developed by Bishop et al. (1987) to distinguish among the flow regimes associated with each of these scenarios.

[8] The similarity of the estimated the values for these four operational scenarios results from the inability of the model developed by Bishop et al. (1987) to distinguish among the flow regimes associated with each of these scenarios.

[9] The local economy around the Green River below Flaming Gorge Dam was defined to include Uintah and Daggett counties in Utah, Sweetwater and Uinta counties in Wyoming, and Moffat and Rio Blanco counties in Colorado.

[10] The data reported in Rose and Frias (1993) had to be adjusted for the use rates below Flaming Gorge Dam reported in Carlson (1995).

[11] This assumes that use rates are relatively stable over time. This assumption is supported by recent data (see Table 3.18).

[12] Note that an increase in use rates would result in an increase in output, income, and employment. The amount of change in each variable would depend on the change in each of the three use rates.

Under seasonally adjusted high fluctuating flows, surface elevations in Blue Mesa Reservoir would vary by no more than 0.5 ft per day, and Morrow Point Reservoir would vary by no more than 1.5 ft per day. These variations are insufficient to bring the fish within the influence of the penstocks. Thus, no impacts to adult kokanee salmon are anticipated from entrainment in summer months. Entrainment is known to occur in Crystal Reservoir. Although releases from Crystal Dam would be identical under both operational scenarios, the surface water elevation in Crystal Reservoir may vary by more than 8 ft per day, depending on releases from Morrow Point Dam. At minimum reservoir elevations, the surface of Crystal Reservoir would be within about 40 ft of the intake structure. Nothing is known about the depth distribution of kokanee salmon in Crystal Reservoir, nor of the temperature profile of this reservoir (see Section 3.3.3.3). If adult kokanee salmon use Crystal Reservoir to depths of 40 ft below the surface as they do in Morrow Point Reservoir, the salmon could be entrained at minimum reservoir elevations. This would be a slight adverse impact, since the kokanee salmon population in Crystal Reservoir is incidental to operations of upstream facilities and constitutes a very small portion of the kokanee salmon fishery in the Aspinall Unit reservoirs.

Kokanee salmon (as well as trout in the reservoirs) would not be affected by any daily fluctuations in surface water elevation and nearshore areas under the high fluctuating flows. Daily fluctuations along the shores of Blue Mesa and Morrow Point reservoirs would be comparable to the fluctuations produced by wind and watercraft. Although daily fluctuations in the surface elevation at Crystal Reservoir could exceed 8 ft, the nearshore habitats are of limited quality because of the very steep, vertical contours of the shoreline areas. Thus, fluctuations in this reservoir should not adversely affect kokanee salmon.

Little or no information is available on the aquatic food base in the Aspinall Unit reservoirs. Because these reservoirs are nutrient-poor, primary and secondary productivity is not high. The primary food base for kokanee salmon is plankton. Although the relationship between daily fluctuation in surface water elevation and plankton production is not known, the productivity of this resource would be limited by nutrient input to the reservoirs and largely unaffected by hydropower operations. Because the volume of water released monthly from Blue Mesa and Morrow Point reservoirs would be identical under both operational scenarios, there would be no differences between the scenarios in monthly nutrient inputs to Morrow Point and Crystal reservoirs.

4.2.4.3.2 Terrestrial Ecology

Vegetation

The limited amount of riparian vegetation along any of the reservoirs of the Aspinall Unit greatly reduces the potential for impact from the two operational scenarios being considered. Table 4.29 and the following paragraphs summarize these potential impacts; additional details are presented in Appendix D.3.3.

TABLE 4.29 Summary of Impacts of Hydropower Operational Scenarios on Vegetation along the Aspinall Unit Reservoirs a

Operational Scenarios	Upper Riparian Zone	Lower Riparian Zone
Seasonally adjusted high fluctuating flows		
Blue Mesa Reservoir	No impact on existing vegetation (including marsh in upper end) because fluctuations would be within historical range.	No impact; little vegetation exists in zone along reservoir.
Morrow Point Reservoir	Same as above.	Same as above.
Crystal Reservoir	Slight benefit; expansion of zone in headwaters down to 3,800-cfs level represents increase of about 0.1 acre.	Slight adverse impact; about 0.4 acre of the zone lost.
Seasonally adjusted steady flows		
Blue Mesa Reservoir	No impact because fluctuations would be within historical range.	No impact; little vegetation exists in zone along reservoir.
Morrow Point Reservoir	Same as above.	Same as above.
Crystal Reservoir	Slight benefit; expansion of zone in headwaters down to 3,325-cfs level represents increase of about 0.2 acre.	Slight adverse impact; about 0.6 acre of lower zone vegetation lost.

[a] The terms *slight*, *moderate,* and *large* are used to convey the importance of the impact. These relative terms were determined after the analysis of the impacts was completed and are based on professional judgment.

No adverse impacts to existing upper riparian zone vegetation are expected to result from either hydropower operational scenario. Even under the seasonally adjusted high fluctuation scenario, daily fluctuations in Blue Mesa Reservoir water levels attributable to hydropower generation would be only about 0.5 ft and this would occur when reservoir levels would be more than 0.5 ft lower than historical levels (Section 4.2.3.3.1). Consequently, no impacts to the marsh in the upper reach of the reservoir are expected to result from hydropower operations. Although fluctuations in water levels due to hydropower operations would be greater in Morrow Point and Crystal reservoirs (up to about 1 ft or 8 ft, respectively), these fluctuations would be within the range of historical fluctuations and therefore should not affect upper riparian zone vegetation, which is established above this range.

For both operational scenarios, some expansion of upper riparian zone vegetation could occur in the half-mile riverine reach between Morrow Point Dam and the headwaters of Crystal Reservoir because of the seasonal adjustment in flows. Fluctuations in flow would be reduced from historical levels, and this reduction would lower the high-water line by about 1 ft during most of the growing season (1.0 ft lower for high fluctuations and 1.3 ft lower for steady releases). An increase of about 0.2 acre or less is expected in the upper riparian zone under these scenarios.

Reduction in the fluctuation zone in this half-mile reach below Morrow Point Dam under both operational scenarios would cause some reduction in the area of the lower zone. Under the seasonally adjusted high fluctuating flow scenario, the lower riparian zone would be limited to a vertical range of about 1.6 ft above the minimum flow level.

This represents a loss of about 0.4 acre. Any vegetation below the elevation of 1,800-cfs flows would be eliminated because of extended periods of inundation. Under seasonally adjusted steady flows, the fluctuation zone would be eliminated. Vegetation below the elevation of 3,325-cfs flows would be eliminated because of monthly changes in inundation and exposure. These impacts are considered slight because of the small area of the existing lower riparian zone (about 0.6 acre).

Wildlife

Potential impacts to nongame wildlife, waterfowl, and game mammals that would result from the operational scenarios being considered for the Aspinall Unit are summarized in Table 4.30. Little potential exists for impacts to nongame wildlife along the Aspinall Unit reservoirs. No change is expected to the limited amount of riparian vegetation that exists along either Blue Mesa or Morrow Point reservoirs. The increase in riparian vegetation (less than 0.2 acre) in the headwaters of Crystal Reservoir for both operational scenarios could result in a slight benefit to nongame species dependent on this half-mile section of habitat.

TABLE 4.30 Summary of Impacts of Hydropower Operational Scenarios on Wildlife at the Aspinall Unit Reservoirs a

Operational Scenarios	Nongame Species	Waterfowl	Game Mammals
Seasonally adjusted high fluctuating flows			
Blue Mesa Reservoir	No impact; existing habitat unchanged.	No impact; existing habitat unchanged.	No impact; existing habitat unchanged.
Morrow Point Reservoir	Same as above.	Same as above.	Same as above.
Crystal Reservoir	Slight benefit; increase in upper riparian zone habitat along headwaters.	Same as above.	Slight benefit; increase in upper riparian zone habitat along headwaters.
Seasonally adjusted steady flows			
Blue Mesa Reservoir	No impact; existing habitat unchanged.	Slight adverse impact; reservoir freezes earlier in winter.	No impact; existing habitat unchanged.
Morrow Point Reservoir	Same as above.	Same as above.	Same as above.
Crystal Reservoir	Slight benefit; increase in upper riparian zone habitat along headwaters.	Same as above.	Slight benefit; increase in upper riparian zone habitat along headwaters.

[a] The terms *slight, moderate*, and *large* are used to convey the importance of the impact. These relative terms were determined after the analysis of the impacts was completed and are based on professional judgment.

Waterfowl are not expected to be affected by either of the operational scenarios at the Aspinall Unit. These reservoirs receive little use by waterfowl, presumably because of the limited amount of suitable riparian habitat along the shorelines and the low productivity of the aquatic ecosystem (Section 4.2.4.3.1). Operational scenarios would have little effect on riparian vegetation or aquatic productivity. The 10-acre marsh at the upstream end of Blue Mesa Reservoir, which could be used by waterfowl, would not be affected by the small fluctuations in reservoir levels attributable to hydropower operations (Section 4.2.4.3.2, *Vegetation*).

Seasonally adjusted steady flows could increase the rate at which the Aspinall reservoirs freeze in the winter. Wintering waterfowl dependent on open, ice-free water would be forced to leave once the reservoirs froze. Since these reservoirs freeze over completely each year anyway, the increase in the rate of freezing should not be important.

Elk and mule deer, which occur along Blue Mesa and Morrow Point reservoirs, would not be affected by either operational scenario. No impact is expected to riparian habitat along these reservoirs, and these species utilize a wide variety of other habitats. The minor increase in riparian vegetation expected along the half-mile section above Crystal Reservoir could provide some additional forage for the bighorn sheep that use this area, but any beneficial effect would be limited by the small size of the area affected.

4.2.4.3.3 Threatened and Endangered Species

Aquatic Species

No Federally listed threatened or endangered aquatic species are known to occur in the Aspinall Unit reservoirs. Thus, no impact to Federally listed species are anticipated from either of the two operational scenarios considered. The flannelmouth sucker, a Federal Category 2 species is present in Blue Mesa Reservoir, but its status in the other reservoirs is unknown. No impacts to this species in Blue Mesa Reservoir are anticipated under either of the operational scenarios. The flannelmouth sucker is a bottom-dwelling species and thus should not become entrained under either operational scenario or be affected by the small (less than 0.5 ft) daily changes in the elevation of Blue Mesa Reservoir.

Terrestrial Species

Expected impacts to Federally and state-listed terrestrial species from the two hydropower operational scenarios considered for the Aspinall Unit are summarized in Table 4.31. Impacts to animal species were determined from predicted changes in riparian habitats (see Section 4.2.4.3.2 *Vegetation*) or aquatic ecology (see Section 4.2.4.3.1). Potential impacts to Federally listed species are discussed in greater detail below.

TABLE 4.31

Whooping Crane (Endangered). The whooping crane would not be affected by operational scenarios at the Aspinall Unit. The 10-acre marsh at the upstream end of Blue Mesa Reservoir and the shallow open-water areas of the reservoir are the only habitats suitable for this species in the vicinity of the unit. No impacts to these habitats are anticipated because hydropower-induced changes in reservoir levels would be very small (Section 4.2.4.3.2, *Vegetation*).

Bald Eagle (Threatened). Operational scenarios at the Aspinall Unit could differ in the amount of available open, ice-free water, which serves as foraging areas for the bald eagle during the winter. The steady flows under the seasonally adjusted steady flow operational scenario would tend to increase the rate of ice formation and result in a more rapid reduction in area available for foraging eagles. However, even with fluctuating releases, the reservoirs freeze over completely each year, so any impacts from hydropower operations would be negligible. For both operational scenarios, ice-free foraging areas would be available in the waters immediately downstream of each dam throughout the winter.

Peregrine Falcon (Endangered). No adverse impacts to the peregrine falcon would occur at the Aspinall Unit as a result of either operational scenario considered here. The area receives limited use by this species and the negligible habitat changes expected to occur only with seasonally adjusted steady flows should not affect bird populations on which the falcon feeds. Earlier freezing of the reservoirs in winter also should not affect this species. Although waterfowl, which serve as prey, may leave sooner under steady flows, eventual freezing would force them to leave anyway. Overwintering peregrines would switch to alternate prey sources (e.g., songbirds) once waterfowl left the area.

4.2.5 Cultural Resources

4.2.5.1 Glen Canyon Dam

4.2.5.1.1 Archaeological Sites and Historic Structures

All of the hydropower operational scenarios under consideration in this EIS could have adverse effects on archaeological sites (Reclamation 1995). A Class I survey determined that a total of 336 archaeological sites either have already been adversely affected or exhibit the potential to be adversely affected (directly or indirectly) by the river; 323 of these sites have been determined eligible for the *National Register of Historic Places* (NRHP) (Fairley et al. 1994). Some sites reflect effects or potential effects from more than one agent of impact. Fairley et al. (1994) observed direct impacts from inundation or bank erosion at 33 sites (10%); indirect effects from bank failure or slope movement at 101 sites (30%); and indirect effects from accelerated arroyo cutting at 123 sites (37%). Potential impacts were identified at 238 sites (71%) on the basis of their geomorphic setting (riverine deposits), and potential impacts were identified at an additional 73 sites (22%) on the basis of their location below the 300,000-cfs level (Fairley et al. 1994).

Currently, no adverse effects to specific sites have been explicitly linked to hydropower operations (all operational scenarios), although some sites were affected by the 1983 flood flows. Other factors likely to cause or to contribute to impacts to archaeological sites include [1] long-term downcutting action of the Colorado River in Glen Canyon; [2] effect of Glen Canyon Dam as a sediment trap, resulting in a reduction in sediment replenishment; [3] erosion due to wind and surface water runoff; and [4] regulated flows unrelated to hydropower operations at Glen Canyon Dam. The effects of these factors must be accounted for in order to assess the impacts of the hydropower operational scenarios.

Although not all impacts to specific archaeological sites can be linked to the hydropower operational scenarios, levels of potential impacts of the scenarios can be compared in general terms. The historical, maximum power plant capacity, and possibly the restricted high fluctuating flow scenarios would probably adversely affect more archaeological sites than would the other scenarios. These operational scenarios would probably accelerate sediment loss and bank erosion relative to the moderate fluctuation, low fluctuation, and the steady flow scenarios (Reclamation 1995).

4.2.5.1.2 Native American Cultural Resources

The hydropower operational scenarios could adversely affect Native American cultural resources, including archaeological sites of traditional or religious significance, sacred locations or areas (e.g., Honga Springs), and biotic and abiotic resources of cultural significance (e.g., riparian plants, birds with yellow feathers) (Reclamation 1995). Currently, the effects of each hydropower operational scenario on specific archaeological sites have not been determined, although, in general, the continued historical, maximum power plant capacity, and possibly restricted high fluctuating flow scenarios would probably adversely affect more archaeological sites than would the other scenarios. The continued historical, maximum power plant capacity, and possibly the restricted high fluctuating flow scenarios would also probably have greater adverse effects on locations, areas, and resources of cultural significance because of accelerated erosion of sediment and greater impact to plants and animals. However, some types of Native American cultural resources (e.g., springs, side-valley canyons) will likely be unaffected by any of the operational scenarios. As in the case of archaeological sites, sufficient information is not now available to project the impact of the operational scenarios on specific cultural resources.

4.2.5.2 Flaming Gorge Dam

4.2.5.2.1 Archaeological Sites and Historic Structures

Six archaeological sites and two historic structures downstream of Flaming Gorge Dam could be affected through erosion by the hydropower operational scenarios evaluated. These sites and structures are located on or near the margins of the first or second terrace in Browns Park (Table 4.32). Although all of these sites would eventually be eroded in the course of the natural evolution of the river, rates of erosion would vary among the four hydropower operational scenarios. The year-round high fluctuating flows and seasonally adjusted high fluctuating flows would generate the highest erosion rates. The seasonally adjusted moderate fluctuating flows and seasonally adjusted steady flows scenarios would generate lower erosion rates (14-15% less than the year-round high fluctuating flows scenario) (Table 4.33).

TABLE 4.32 Archaeological Sites and Historic Structures Downstream of Flaming Gorge Dam that Could Be Affected by Hydropower Operational Scenarios

Site Description	Location	Erosion Potential
Jarvie Ranch; historic structure listed on the NRHP; riprap present	First terrace; extends to the river.	High, but protected.
Former historic bridge	Floodplain and second terrace on outer meander of river; 5 ft above mean water level; 50-100 ft from channel.	High, actively eroding, but may not be eligible for NRHP.
Prehistoric lithic scatter with hearths	Second terrace on vertical bank; 15-20 ft above mean water level.	Very high, actively eroding.
Prehistoric lithic scatter	First terrace; 10 ft above mean water level; 3 ft from channel.	High.
Fort Davy Crockett; historic site; listed on the NRHP; has been excavated	First terrace; extends to cutbank.	High, actively eroding, but mitigated.
Protohistoric campsite; potentially eligible for NRHP	First terrace; 100 ft from channel; may extend to cutbank at edge of terrace.	High, if site extends to cutbank; more data needed.
James Warren Cabin; historic log cabin; potentially eligible for the NRHP	First terrace; may extend to edge of terrace.	High, more data needed.
Historic scatter; eligible for the NRHP	First terrace; 10 ft above mean water level; extends to cutbank.	Very high, actively eroding.

TABLE 4.33 Summary of Impacts of Hydropower Operational Scenarios on Cultural Resources below Flaming Gorge Dam

Operational Scenario	Archaeological Sites	Historic Structures
Year-round high fluctuating flows	Six sites potentially impacted by erosion.	Two structures potentially impacted by erosion.
Seasonally	Six sites potentially	Two structures potentially

adjusted high fluctuating flows	impacted by erosion at a rate of 4% less than year-round high fluctuations.[a]	impacted by erosion at a rate of 4% less than year-round high fluctuations.
Seasonally adjusted moderate fluctuating flows	Six sites potentially impacted by erosion at a rate of 14% less than year-round high fluctuations.	Two structures potentially impacted by erosion at a rate of 14% less than year-round high fluctuations.
Seasonally adjusted steady flows	Six sites potentially impacted by erosion at a rate of 15% less than year-round high fluctuations.	Two structures potentially impacted by erosion at a rate of 15% less than year-round high fluctuations.

[a] The erosion rate for a moderate water year is used (Table 4.17); little difference is noted between the erosion rates for the seasonally adjusted operational scenarios for wet and dry years.

Potential impacts to archaeological sites and historic structures were assessed by applying the projected erosion rates of the various hydropower operational scenarios (Section 4.2.3.2) to the geomorphic context of individual sites. Information on individual sites was collected during a field study undertaken for this EIS. Variables examined included relationship to active channels (distance and elevation), sedimentary context, slope, vegetation, and others (Moeller et al. 1995). Some information on current erosion rates is available for the first terrace, which has been subject to measurable attrition at historic site Fort Davy Crockett in lower Browns Park since 1980 (Eddy et al. 1982).

No sites upstream of Browns Park (Red Canyon, Little Hole, and Devil's Hole) would be affected by the hydropower operational scenarios evaluated. No sites are recorded in areas of Red Canyon that would be affected by dam flows. At least 20 archaeological sites have been recorded within the boundaries of the river corridor in Little Hole and Devil's Hole (Section 3.5.2.2). However, these sites are located in areas that would not be subject to river erosion in the near future, such as on bedrock surfaces or the second (about 20-ft) terrace (composed of cobbles and gravels in a sandy matrix) (Moeller et al. 1993, 1995).

One prehistoric archaeological site and two historic structures in upper Browns Park (between Red Canyon and Swallow Canyon) would be exposed to potential river erosion (Table 4.32). Although 26 sites and structures have been recorded within the boundaries of the river corridor (Section 3.5.2.2), most sites are located in geomorphic settings that would not be affected by dam flows in the near future (e.g., alluvial fans overlying the first terrace, bedrock outcrops). The potentially affected sites include John Jarvie Ranch, a historic structure complex listed on the NRHP. The ranch occupies an area extending to the margin of the first terrace. A riprap barrier has been constructed by the Bureau of Land Management (BLM) to protect the site from erosion. The other potentially affected sites include the remains of a historic bridge and a prehistoric lithic scatter. These sites are located on concave meander banks near active channels. Both sites occupy sparsely vegetated sand and gravel surfaces on the second terrace (15-20 ft), the historic site extending onto the floodplain. With respect to NRHP status, the integrity of the historic bridge has been compromised by past disturbance, and it appears unlikely to meet eligibility criteria. The prehistoric site, which contains several former hearths, may be eligible, but requires further field study.

Four prehistoric and historic archaeological sites and one historic structure in lower Browns Park (between Swallow Canyon and Gates of Lodore) would be potentially exposed to river erosion (Table 4.32). As in the case of upper Browns Park, many sites and structures (a total of 29) occur within the boundaries of the river corridor, but most occupy geomorphic settings that would not be subject to river erosion within the near future. The potentially affected sites include two prehistoric lithic scatters, two historic archaeological sites (Fort Davy Crockett and another unnamed site), and one historic structure (James Warren Cabin). These sites are located on or near the margin of the first terrace (10 ft), which is composed of sand (Moeller et al. 1995). Although they are not situated on concave meander banks, these sites are adjacent to vertical cut banks, and recent erosion has occurred at Fort Davy Crockett, and two unnamed sites (Moeller et al. 1995). The effects of erosion at Fort Davy Crockett, which is listed on the NRHP, have been mitigated by data recovery (excavation) undertaken by the USFWS (Eddy et al. 1982). The two remaining historic sites and at least one of the prehistoric sites appear to be potentially eligible for the NRHP (Norman and Merrill 1981) but require additional field study.

Areas of Browns Park that have not been subject to adequate field survey are likely to contain additional archaeological sites. Some of these sites are likely to be found on or near the margins of the first and second terrace and could also be adversely affected through erosion by the hydropower operational scenarios evaluated.

Adverse effects to sites or structures that are eligible for the NRHP require mitigative measures developed in consultation with the appropriate State Historic Preservation Officer (SHPO) (36 CFR 800). This EIS addresses the impacts of power marketing and hydropower operations, which must be considered separately from the effects of natural river action and the presence of the dam (which increases the erosive power of the river by reducing sediment load). The higher rates of erosion generated by the high fluctuation scenarios could have adverse effects (in addition to erosion caused by natural river action and the presence of the dam) to sites and structures that are listed on, eligible for, or potentially eligible for the NRHP. Additional studies must be undertaken to complete the inventory and evaluation of affected sites and structures. Protection, where feasible, is the preferred mitigation and could entail construction of protective features (e.g., riprap) to reduce erosion rates. Alternatively, impacts to sites could be mitigated through data recovery, entailing collection, mapping, and (if appropriate) excavation within the framework of a problem-oriented research design.

4.2.5.2.2 Native American Cultural Resources

No sites, areas, or resources of Native American religious or cultural significance have been identified to date in areas that would be affected by the hydropower operational scenarios considered in this EIS. Consultation with potentially affected Native Americans is in progress.

4.2.5.3 Aspinall Unit

4.2.5.3.1 Archaeological Sites and Historic Structures

None of the hydropower operational scenarios considered in this EIS would affect archaeological sites or historic structures in the vicinity of the Aspinall Unit. Many archaeological sites are located along the margins of Blue Mesa Reservoir (Section 3.5.3.2), and some of these have been subject to erosion damage from shifting reservoir levels (Jones 1986, 1992). However, the maximum contribution of hydropower operations to changes in reservoir level would not exceed 0.1 ft and would have no significant effect on these archaeological sites. One archaeological site and one historic structure complex are located near the margins of Morrow Point Reservoir, but they are situated at elevations (in excess of 7,200 ft above sea level) that would not be affected by reservoir-level changes caused by hydropower operations. (These operations-related reservoir changes would not exceed 1.3 ft). No sites or structures are recorded in the remaining areas that would be affected by the hydropower operational scenarios (Section 3.5.3.2).

4.2.5.3.2 Native American Cultural Resources

To date, no sites, areas, or resources of Native American religious or cultural significance have been identified in areas that would be affected by the hydropower operational scenarios considered in this EIS. Consultation with potentially affected Native Americans is in progress.

4.2.6 Land Use

Impacts to land use were evaluated against standard assessment criteria. Factors examined included conversion, development potential, legal conflict, and disruption. Conversion refers to the potential of an action to result in the conversion of land from one type of use to another. Development potential refers to the likelihood that an action will change a parcel's potential for future development. Legal conflict refers to the potential of an action to cause conflicts with zoning or other legal controls. Finally, disruption refers to the potential for an action to disrupt activities associated with a particular land use.

Each criterion was applied to the affected areas associated with hydroelectric facilities for the stream flow changes under each operational scenario. Stream flow changes were found to have no influence on the conversion potential, development potential, or zoning designation of any of the affected areas for any of the operational scenarios. Changes in stream flow could, however, disrupt recreational activities on or along the Colorado and Green rivers and on the reservoirs of the Aspinall Unit. Impacts to recreational activities and facilities resulting from operational scenarios are discussed in Section 4.2.7.

NPS lands are to be managed in a manner that leaves them unimpaired for the enjoyment of future generations. To meet this objective, the NPS attempts to maintain conditions as near to pristine as possible, and any departure from natural conditions is viewed as an adverse impact. Thus, to evaluate impacts to land use within NPS areas, each of the operational scenarios is evaluated against pre-dam conditions rather than existing conditions as for other evaluations.

4.2.6.1 Glen Canyon Dam

Hydropower operational scenarios would not affect land use below Glen Canyon Dam. Virtually the entire river corridor consists of public lands under the jurisdiction of the National Park Service (NPS), and little or no potential exists for private acquisition, conversion, or development of the land. Operational scenarios would not result in the removal or modification of any existing NPS facilities.

Operational scenarios that featured reduced fluctuations (e.g., modified low fluctuation, interim low fluctuation, any of the steady flow scenarios) would be most in keeping with NPS values (i.e., most similar to natural, pre-dam conditions) and, therefore, in NPS's view would minimize impacts within Grand Canyon National Park.

4.2.6.2 Flaming Gorge Dam

Hydropower operational scenarios would not affect land use below Flaming Gorge Dam. With the exception of a few privately owned ranches, the entire affected area consists of public lands under the jurisdiction of the state of Utah and several Federal agencies. Consequently, little or no potential exists for private acquisition, conversion, or development of the land. Operational scenarios would not result in any conflicts with existing land use regulations or controls. Special land uses, as identified in Section 3.6.2, would remain unaffected. No existing facilities in the affected area would be removed or altered. Private lands within the affected area would not be impacted.

Releases would more closely resemble the natural flow regime under any of the seasonally adjusted operational scenarios than under historical operations. All of these scenarios would represent some level of benefit to the NPS within Dinosaur National Monument. Of these, the seasonally adjusted steady flow scenario would have the greatest level of benefit because daily fluctuations would be eliminated.

4.2.6.3 Aspinall Unit

Land use would not be affected by either operational scenario for the Aspinall Unit. The affected environment consists of public lands under the jurisdiction of the NPS, and little or no potential exists for private acquisition, conversion, or development of the land. Operational scenarios would not alter the NPS zoning designation (natural) that governs Curecanti National Recreation Area. Modification of existing facilities would not be necessary under either scenario.

Both of the operational scenarios under consideration feature a seasonal pattern of release that is more closely aligned to a natural flow regime than were historical operations. Thus, both scenarios would represent a benefit to the NPS, which administers Curecanti National Recreation Area. The seasonally adjusted steady flow scenario would have the greatest level of benefit because hydropower-induced daily fluctuations in reservoir elevation would be eliminated.

4.2.7 Recreation

A variety of recreational activities and resources occur in the areas of Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit. To assess the impacts of the hydropower operational scenarios on these recreational activities, it was assumed that boating (angling and nonangling), fishing, and riverside camping would be the most likely to be affected by stream flows. Activities such as hiking and hunting should not be affected by changing stream flows.

A number of studies have examined the relationship between flow and the quality of recreational experiences (Shelby et al. 1992), including a study by Bishop et al. (1987) of the effects of Glen Canyon Dam releases on recreation in the Grand Canyon. In general, anglers in the Grand Canyon (both boating and nonboating) tend to prefer constant flows over fluctuating flows, as do nonangling boaters (e.g., rafters, canoeists, and kayakers). However, nonangling boaters prefer high flows (up to a threshold where safety becomes a factor) to low flows. Anglers, especially those who fish from shore, tend to prefer lower steady flows (for wading into the river). Thus, the levels of stream flow considered best for angling are lower than the levels associated with high-quality rafting experiences, so a change in stream flow that constitutes an improvement for anglers may adversely affect rafters, and vice versa (Walsh et al. 1980; Bishop et al. 1987; Reclamation 1990b).

The assessment in this EIS assumed that both anglers and white-water boaters prefer constant flows to fluctuating flows. Anglers prefer constant flows because they believe sudden fluctuations in stream flow can cause fish to scatter, making them more difficult to locate and catch. White-water boaters prefer constant flows because they believe that fluctuations in stream flow result in a setting that is unnatural. In contrast, Bishop et al. (1987) concluded that day floaters (i.e, those who float downstream for all or part of a single day only) are indifferent to flow regimes, so changes in stream flow resulting from hydropower operations were assumed to have no impact on day floaters.

4.2.7.1 Glen Canyon Dam

The analysis of potential impacts to recreation at Glen Canyon Dam is based on the Glen Canyon Dam EIS (Reclamation 1995), which focused on the principal recreational users, including boat and shore anglers and white-water boaters. The impacts to beaches along the Colorado River are included in the discussion of impacts to white-water boaters because they are the primary users of riverside beaches. A moderate water year was assumed. Table 4.34 summarizes the assessment of impacts to recreation below Glen Canyon Dam under the nine operational scenarios presented in the Glen Canyon Dam EIS (Reclamation 1995).

4.2.7.1.1 Angling

Shore anglers, most of whom cluster around Lees Ferry, prefer moderate, constant flows. Operational scenarios with unrestricted, rapid upramping can result in a river stage increase that can potentially endanger a wading angler (Reclamation 1995). During summer, upramping episodes typically begin at 7 a.m. Angling boaters between Glen Canyon Dam and Lees Ferry prefer minimum flows of 5,000 cfs. At lower flows, most boats have difficulty navigating past 3-Mile Bar and can sustain damage from hitting rocks (Reclamation 1995). Motorized rafts that are used primarily for day floating can navigate upstream from Lees Ferry in low flows (below 3,000 cfs) that restrict other boats. Flows above 8,000 cfs appear to mitigate the majority of navigational problems. Because most boaters using this segment of the river do so to fish, it was assumed that they would prefer moderate, constant flows.

Current use levels for angling below Glen Canyon Dam have developed under flow conditions similar to those for the continued historical operations scenario. Thus, this operational scenario should result in no impacts to current use levels or values. Under the maximum power plant capacity scenario, slight adverse impacts from larger fluctuations and higher maximum flows could occur to anglers using the river between Glen Canyon Dam and Lees Ferry. For the restricted high fluctuating flow scenario, minimum flows between Labor Day and Easter would be set at 3,000 cfs and increased to 5,000 cfs after Labor Day. These minimum flows would be higher than the minimum flows under the continued historical flow scenario. Slight beneficial impacts to fishing would occur because higher minimum flows would provide some relief to those fishing from boats between the dam and Lees Ferry.

The year-round minimum flow of 5,000 cfs under the moderate fluctuating flow scenario would be slightly beneficial to angling boaters between the dam and Lees Ferry.

TABLE 4.34 Summary of Impacts to Recreational Activities below Glen Canyon Dam under Nine Hydropower Operational Scenarios a

Operational Scenario	Angling	Day Floating	White-Water Boating	Beaches
Continuation of historical operations	No change from current conditions, which feature daily fluctuations.	Slight adverse impact; navigation difficult at low flows.	No change from current conditions, which feature daily fluctuations and low flows.	No change from current conditions.
Maximum power plant capacity	Slight adverse impact to shore and boat anglers because of larger fluctuations and higher maximum flows.	Same as above.	Same as above.	Same as above.
Restricted high fluctuating flows	Slight benefit to anglers because of increase in minimum flows.	Same as above.	Slight benefit from reduced fluctuations.	Same as above.
Moderate fluctuating flows	Slight benefit to boat anglers from higher minimum flows in fall; slight benefit to shore anglers from restricted upramping.	Slight benefit; navigation improved.	Moderate benefit from reduced fluctuations.	Slight benefit; greater area and improved mooring quality.
Modified low fluctuating flows	Moderate benefit to boat anglers from higher minimum flows; moderate benefit to shore anglers from reduced fluctuations and ramp rates.	Same as above.	Moderate to large benefit; sustained minimum flows of 8,000 cfs and moderate reduction in fluctuations and ramping.	Slight benefit; increase in area over moderate fluctuating flows.
Interim low fluctuating flows	Same as above.	Same as above.	Same as above.	Same as above.
Existing monthly volume steady flows	Large benefit; flows closest to those preferred by anglers.	Same as above.	Large benefit; flows close to those preferred by river guides and passengers.	Large benefit; improved mooring and increase in number and area over continued historical operations and all fluctuating flow scenarios.
Seasonally adjusted steady flows	Moderate benefit; minimum releases during spring peak higher than preferred flows.	Same as above.	Same as above.	Same as above.
Year-round steady flows	Large benefit; flows close to those preferred by anglers.	Same as above.	Same as above.	Same as above.

[a] The terms *slight, moderate,* and *large* benefits and *adverse* impacts are used to convey the importance of the impact. These relative terms were not included in the Glen Canyon Dam EIS but have been added on the basis of a review of the findings presented in that EIS to provide consistency in treatment among facilities.

Source: Adapted from Reclamation (1995).

The lower upramping rate under this scenario (4,000 cfs/h) would be more attractive to shore anglers than the unrestricted rates under scenarios of continued historical operations, maximum power plant capacity, and restricted high fluctuating flows.

The modified low fluctuating flow and interim low fluctuating flow operational scenarios would result in moderate benefits to boat or shore anglers relative to continued historical operations and scenarios with larger fluctuations. Higher minimum flows (8,000 cfs between 7 a.m. and 7 p.m.), moderate maximum releases (20,000 cfs), and relatively low daily fluctuations (5,000-8,000 cfs) would be available during the summer.

Beneficial impacts to angling activities would be expected under the steady flow operational scenarios. Relatively high minimum flows (8,000 cfs year-round), low upramping rates (2,000 cfs/d), and limited daily fluctuations would create conditions close to those that most anglers prefer.

4.2.7.1.2 White-Water Boating

White-water boaters running the Colorado River from Lees Ferry prefer constant flows with moderate fluctuations, ramping restrictions, and minimum flows of 5,000 cfs (Reclamation 1995). Under such conditions, trip schedules are not threatened, the character of most rapids remains dynamic, and most beach campsites are accessible and provide good mooring for boats and rafts.

Current use levels for white-water boating developed under flow conditions similar to those for the continued historical operations scenario. Thus, a continuation of that scenario should result in no impacts to current use levels or values. The larger fluctuations that would occur under the maximum power plant capacity scenario would result in slight adverse impacts relative to continued historical operations. Under the restricted high fluctuating flow scenario, minimum flows would be 5,000 cfs during the peak season. This flow level would result in a slight benefit to white-water boaters relative to continued historical operations and maximum power plant capacity because these scenarios would have peak season minimum flows of only 3,000 cfs.

Daily releases exceeding 25,000 cfs would submerge certain beaches and result in a decrease in size and number of beach campsites and diminished mooring quality. Such releases would occur most often under scenarios of continued historical operations, maximum power plant capacity, and restricted high fluctuating flows. Usable beach areas would be smallest and mooring quality poorest under the maximum power plant capacity scenario.

Conditions under the moderate fluctuating flow scenario would be moderately improved over scenarios of continued historical operations, maximum power plant capacity, and high fluctuating flows. Mooring quality, as well as area and number of beach campsites, would increase only slightly compared with higher fluctuating flow scenarios. Under the modified low fluctuating flow and interim low fluctuating flow scenarios, conditions for white-water boating would be close to those preferred by river guides and would represent an improvement compared with scenarios of continued historical operations, maximum power plant capacity, and restricted high and moderate fluctuating flows. Beach campsite area would increase slightly compared with the moderate fluctuating flow scenario.

All three steady flow operational scenarios would result in conditions most preferred by white-water boaters. Beach campsite area and number and mooring quality are highest under the steady flow scenarios. However, reduced fluctuations would also result in an increase in the amount of vegetation on these beaches (see Section 4.2.4.1.3) and a concurrent decrease in their quality as campsites over time.

4.2.7.2 Flaming Gorge Dam

In the reach immediately below Flaming Gorge Dam, shore anglers tend to prefer flows ranging from 800 to 1,100 cfs (Section 3.7.2.1), and boat anglers tend to prefer flows ranging from 800 to 1,500 cfs, with the upper end of this range considered ideal. The relatively low flows preferred by shore anglers allow them to wade into the river to cast and gives them greater overall access to the river. For boat anglers, low flows mean slower currents and more time to hit "holes" containing fish. Because motorized boats are prohibited between the dam and Browns Park, lower flows give anglers optimal control of their boats.

According to Bishop et al. (1987), anglers prefer constant flows over fluctuating flows. White-water boaters in Dinosaur National Monument were also assumed to prefer constant flows over fluctuating flows. However, they prefer higher flows and can safely operate in flows well above maximum power plant capacity.

The assessment in this EIS focused on flow conditions between dawn and dusk when boat angling, shore angling, and white-water boating would occur. For anglers, flows that were within 100 cfs of preferred flows were considered beneficial, whereas flows that exceeded the upper limit of angler preferences by more than a factor of two were considered adverse. For white-water boaters in Dinosaur National Monument, flows were considered constant as long as fluctuations did not occur between 7 a.m. and 3 p.m. at the Gates of Lodore. A moderate water year was assumed. The assessment of impacts on recreation below Flaming Gorge Dam is summarized in Table 4.35.

4.2.7.2.1 Angling

Current use levels for angling below Flaming Gorge Dam developed under flow conditions in which actual fluctuations were smaller than would occur under the year-round high fluctuating flow scenario. Thus, year-round high fluctuating flows could have some adverse impacts on angling. Seasonal adjustments in flow (e.g., the spring peak in flows from June 1 through 21 and low summer flows) are required by the Biological Opinion to meet the needs of endangered fish species in the lower Green River (USFWS 1992b). Such flow patterns would occur under the seasonally adjusted high fluctuating flow, moderate fluctuating flow, and steady flow scenarios but not under the year-round high fluctuating flow scenario.

TABLE 4.35 Summary of Impacts to Recreational Activities on the Green River below Flaming Gorge Dam under Moderate Hydrological Conditions a

Operational Scenario	Angling	White-Water Boating	Day Floating
Year-round high fluctuating flows	Slight adverse impact due to larger daily fluctuations.	No change from current conditions; current use rates continue.	No impacts attributable to hydropower operations.
Seasonally adjusted high fluctuating flows	Slight adverse impact overall; large adverse impact due to high flows from April 1 through July 9; slight benefit after July 9. More periods of adverse flows from April 1 to July 9 than under year-round high fluctuating flows.	Moderate benefit; high flows in May and June. Minimum flows higher than those under year-round high fluctuating flows.	No impacts attributable to hydropower operations.
Seasonally adjusted moderate fluctuating flows	Slight adverse impact overall; slight adverse impact from high minimum flows in April; moderate adverse impact in May; large adverse impact from high flows in June; and moderate benefit after July 9.	Moderate benefit; conditions improved because of less fluctuation and higher minimum flows.	No impacts attributable to hydropower operations.
Seasonally adjusted steady flows	Slight benefit overall; large adverse impact from high flows in May and June; moderate benefit from July 10 through October.	Moderate benefit; sustained steady flows and high flows during May and June and minimum flows slightly higher than those under seasonally adjusted moderate fluctuating flows. No daily fluctuations.	No impacts attributable to hydropower operations.

[a] The terms *slight, moderate,* and *large* are used to convey the importance of the impact. These relative terms were

determined after the analysis of the impacts was completed and are based on professional judgment.

Overall, adverse impacts to angling would be greater under the seasonally adjusted high fluctuating flow scenario than under the year-round high fluctuating flow scenario. From April 1 to July 9, the seasonally adjusted high fluctuating flow scenario would result in conditions more adverse for shore and boat anglers. This scenario would have extended periods of constant flows from April 1 to July 9, but most of these flows would be held at 4,700 cfs between dawn and dusk to meet requirements of the Biological Opinion. The 4,700-cfs threshold is far higher than the flows preferred by shore and boat anglers. Consequently, even though constant flows are preferred by anglers, constant flows of 4,700 cfs would be largely adverse rather than beneficial. Before July 9, the only times that anglers would experience flows below 4,700 cfs would be from dawn until 10 a.m. in April and from dawn until 12 p.m. from July 1 through 9.

After July 9, seasonally adjusted high fluctuating flows would result in slightly improved conditions for anglers compared with year-round high fluctuating flows because fluctuations from July 10 to October 31 would be smaller (about 3,000 cfs) and of shorter duration (two hours). However, more anglers fish between April 1 and June 15 than after July 10. Therefore, the potential benefits to anglers after July 9 might not offset the adverse effects present between April 1 and June 15.

Under the seasonally adjusted moderate fluctuating flow scenario, impacts to angling would be mixed. Overall, impacts would be similar to those associated with the seasonally adjusted high fluctuating flow scenario. Except for June 1 through 21, the moderate fluctuating flow scenario would have fewer sustained flows of 4,700 cfs and a lower range of fluctuations than the high fluctuating flow scenario. However, moderate fluctuations would be achieved by increasing the minimum flows over those occurring under the high fluctuating flow scenarios (from 800 cfs in April and May to 2,400 in April and 2,700 in May). These minimum flows would generate slight to moderate adverse impacts for shore anglers from April through May because they could severely restrict wading and would be well above the upper limit of flows that shore anglers prefer.

Boat anglers would experience better conditions in April and May under the seasonally adjusted moderate fluctuating flow scenario. Although the minimum flows would be above the upper range considered ideal by boating anglers, they would not be high enough to be considered adverse. After July 9, flows associated with the moderate fluctuating flow scenario would be beneficial to all anglers from dawn until 2 p.m. and from 5 p.m. until dusk. Minimum flows after July 9 would slightly improve conditions for boat anglers.

The seasonally adjusted steady flow scenario would also result in mixed impacts compared with year-round high fluctuations. Like the moderate and high fluctuating flow scenarios, the steady flow scenario would generate large adverse impacts for shore anglers during the sustained spring peak in June (4,700 cfs). However, in months before and after this peak, flows would also be relatively high (3,400 cfs in May and 3,700 cfs for the rest of June). Any beneficial aspect of constant flows would be overridden by these high flows, which far exceed those preferred by anglers, particularly shore anglers. Any benefits derived by constant flows for boat anglers would also be canceled out by relatively high flows in May and June. The constant flows of April (2,600 cfs) would create conditions more stable for all anglers than would exist under the seasonally adjusted moderate or high fluctuating flows. Although flows after July 9 would be similar in impact (beneficial for all anglers) to the fluctuating flow scenarios, the steady flow scenario would not result in the daily fluctuations that would occur under all the fluctuating flow scenarios. Consequently, it would have more beneficial impacts on angling during this period than any of the other scenarios.

4.2.7.2.2 White-Water Boating

The impacts of hydropower operations on white-water boating in Dinosaur National Monument depend on the degree of attenuation affecting daily maximum releases and the timing of their arrival in the monument. Maximum releases of relatively short (two hours) or long (17 hours) duration tend to attenuate more quickly (Section 4.2.3.2.1) than releases of medium duration (e.g., 10 hours). The minimum and maximum flows expected at Gates of Lodore under each scenario are presented in Appendix C. The average travel time for water released from the dam has been estimated at approximately 3 mph for releases of 4,000 cfs and 2.6 mph for releases of 1,000 cfs (Section 3.3.2.1). Thus, it would take a change (i.e., increase or decrease) in flow at the dam approximately 15 to 17 hours to be detectable at the Gates of Lodore. Because dam releases spread out as they travel downstream, the effects of a dam release episode would be detectable at Gates of Lodore for a longer period of time than the duration of the release itself.

The impacts of hydropower operations on flows below the confluence of the Green and Yampa rivers are greatly reduced by flows of the Yampa River, particularly in spring (Appendix C, Table C.8). Current use levels for white-water boating in Dinosaur National Monument developed under flow conditions similar to those that would occur under the year-round high fluctuating flow scenario. Although large fluctuations would occur under this scenario, the timing of fluctuations at Flaming Gorge Dam would result in nearly constant, low flows through Dinosaur National Monument during daylight hours (after 9:00 a.m.) when conditions for white-water boaters are most important. Therefore, year-round high fluctuating flows should have no impact on current levels of use.

The seasonally adjusted high fluctuating flow scenario would result in moderately improved conditions for white-water boating compared with year-round high fluctuating flows because it would have longer periods of high sustained flows, higher minimum and maximum flows at Gates of Lodore (Table C.7), and daily fluctuations of less magnitude and shorter duration after July 9. On the basis of travel time estimates, relatively high steady flows would occur during the night until approximately early afternoon in April and May, for the entire day from June 1 through 21 (as required by the Biological Opinion), and from 9 p.m. until 2 p.m. for the rest of June. Even though a large fluctuation (4,300 cfs down to 1,200 cfs) would occur after 12 p.m. in April, few white-water boaters would be using the river at this time of year, so no adverse impact is expected.

Flows occurring after July 1 would be similar for both the seasonally adjusted high and the year-round high fluctuating flow scenarios. Minimum flows from July 10 through September would be slightly higher (100 to 200 cfs) compared with year-round high fluctuations.

Conditions for white-water boating would improve further under the seasonally adjusted moderate fluctuating flow scenario. Although relatively high flows would be of shorter duration than under the seasonally adjusted high fluctuating flow scenario, minimum flows would be higher under the moderate fluctuating flow scenario (100 to 1,000 cfs), and fluctuations would be less severe than under either high fluctuating flow scenario (Table C.8). After July 9, maximum flows would be lower at Gates of Lodore than under the high fluctuating flow scenarios. The high constant flows required by the Biological Opinion would provide beneficial impacts during the spring peak (June 1 through 21).

The seasonally adjusted steady flow scenario has the constant flows preferred by white-water boaters. It also has high flows in May and June and the highest minimum flows of any operational scenario. Compared with the other scenarios, the steady flow scenario would appear to result in improved conditions for white-water boating during most months. However, during May and the last nine days of June, there may be a trade-off between the benefits of higher flows associated with the seasonally adjusted high and moderate fluctuating flow scenarios and the beneficial effect of constant flows under the seasonally adjusted steady flows scenario.[1]

4.2.7.3 Aspinall Unit

The range of daily fluctuations under the seasonally adjusted high fluctuating flow scenario is slightly larger than under the steady flow scenario, but virtually no adverse impacts to recreational resources or use rates are expected. Daily fluctuations on Blue Mesa Reservoir resulting from hydropower operations would be less than 0.1 ft throughout a moderate water year. Morrow Point Reservoir would experience hydropower-induced daily fluctuations of between 0.3 and 1.5 ft, with the highest daily fluctuations occurring during April, May, August, and September (Table 4.18). Impacts to recreational facilities or use rates would be negligible. Morrow Point has no boat ramps (all boats must be carried in), but none of its potential boaters or shore anglers would be affected by such a slight fluctuation in daily water level. Adequate space would be available for those fishing from shore. The reservoir's campgrounds (Pioneer Point and Hermits Rest) are located above full pool level (elevation 7,160 ft) and would not be affected.

Under the seasonally adjusted high fluctuating flow scenario, water levels in Morrow Point Reservoir would drop below the minimum threshold (elevation 7,147 ft) required for the reservoir's floating dock and pontoon tour boat for part of the day during the month of August. The tour boat could become stranded during these low-water periods, resulting in adverse impacts to users. Although the tour boat has been stranded in the past, such occurrences are rare. Overall, slight impacts to users of the tour boat could be expected. Like Morrow Point, Crystal Reservoir has no boat ramps, and all boats must be carried in. Daily fluctuations in water levels could be more extreme (over 8 ft in August and September) at Crystal than at Morrow Point, and boaters could encounter gravel bars at low flows under the seasonally adjusted high fluctuation scenario. Because the number of boaters potentially affected represents less than 1% of total users, impacts are expected to be slight. The reservoir's single campground (Crystal Creek) is located high enough above the full pool threshold to remain unaffected by changing water levels.

Hydropower operations under the seasonally adjusted steady flow operational scenario would result in no adverse impacts to recreational users or facilities on the Aspinall Unit's reservoirs. Steady flows would result in minimum water levels that would not adversely affect the boat dock or tour boat on Morrow Point Reservoir.

4.2.8 Visual Resources

In riverine environments, the relationship between scenic value and stream flow is not well understood. In general, a river and its environs has the least scenic value at both flood tide and lowest flows. At flood stage, features such as riffles, small rapids, beaches, bars, and islands are submerged. At very low flows, certain unattractive visual elements ¾ such as debris, mud flats, rotting vegetation, and the "bathtub ring"[2] that stains rock surfaces ¾ can be exposed. Brown and Daniel (1991) recently examined the relationship between scenic value and flow and concluded that perception of the scenic value of a river increases with increased flow to a point but then decreases with further increases in flows; also, frequent visitors to a particular river corridor prefer a variety of flows across successive visits. Landform and vegetation are two of the visual elements most likely to be affected by releases from the dams examined in this EIS.

The impact analysis for visual resources in the affected areas of Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit (Section 3.8) relied on subjective criteria. The conclusions were not empirically based. The analysis included several assumptions concerning viewers, viewing times, and viewing zones. Because a vast majority of viewers (recreationists) are present between March 15 and October 31, winter months were not included in the discussion of impacts. Viewing times were assumed to be from 7 a.m. to 7 p.m. daily.[3] Only foreground and middle-ground viewing zones were included in the analysis. Dam operations are not expected to impact views from points beyond the outer edge of the middle-ground viewing zone. The foreground zone contains the beaches and shore vegetation and would contain most of the viewers. Middle-ground viewing zones contain many of the road and trail viewpoints.

4.2.8.1 Glen Canyon Dam

The Colorado River provides high-quality landscapes at any flow and from all viewing proximity zones. Each operational scenario has the potential to change the visual character of the river, but such changes have positive aspects that balance out potentially negative impacts. For example, under steady flow operational scenarios, the areal extent and number of white-water effects could decrease and a bathtub ring would be visible, but the size of the areas supporting riparian vegetation would be expected to increase (Section 4.2.4.1). A positive visual impact could result because increased amounts of vegetation would add color and contrast to existing inner-canyon landscapes. Under fluctuating flow operational scenarios, a wider range of river effects (rapids) and shoreline landscapes would be available for viewers, and any effects that would diminish visual quality (e.g., inundated beaches, bathtub ring, submerged geologic features) would be temporary.

Views of the river from the mesas above Glen Canyon Dam or from the rims of the Grand Canyon would not be affected by flows associated with any of the operational scenarios. Distances from the viewer to the river are too great, and the surrounding landscapes offer high visual diversity.

4.2.8.2 Flaming Gorge Dam

Under the year-round high fluctuating flow operational scenario, low flows (less than 1,100 cfs) that result in exposed debris and a prominent bathtub ring would occur for most of the viewing day during spring and summer. However, these low flows would also result in visually diverse views that include numerous beach areas, islands, bars, and riffles. Existing riparian vegetation would not be adversely affected. No change in status would occur on the stretches of the Green River that are classified under the U.S. Forest Service (USFS) and BLM visual resource management systems (Section 3.8.2). Overall, impacts are expected to be negligible.

The seasonally adjusted high fluctuating flow operational scenario would generate flows below 1,100 cfs less often than the year-round high fluctuating flow scenario. High flows (4,700 cfs) would be maintained continuously for several days during June. The seasonally adjusted high fluctuating flow scenario would also have longer daily periods of sustained high flows between March and early July than the year-round high fluctuating flow operational scenario. These higher sustained flows would result in conflicting visual impacts; although the visible debris and bathtub ring effects would be reduced, the high flows would also tend to submerge some of the beach areas, riffles, and small rapids for most of the viewing day between April 1 and July 1. The seasonally adjusted high fluctuating flow operational scenario would result in some changes in riparian vegetation but in no net loss (Section 4.2.4.2). Overall, impacts are expected to be negligible.

The relatively high minimum releases of the seasonally adjusted moderate fluctuating flow operational scenario would result in impacts to riparian vegetation and in less bathtub ring effects than the year-round high fluctuating flow scenario. Between March 1 and July 10, unattractive visual effects associated with the lowest flows would be absent because minimum flows would never fall below 1,100 cfs. No vegetation would grow in the zone between flows of 2,700 and 800 cfs (Section 4.2.4.2). This barren strip would be most visible from July 10 through 31 and throughout October, when minimum flows would be 1,000 and 800 cfs, respectively. However, because this strip would add more visual diversity than either of the high fluctuation scenarios, it would not be considered an adverse impact. No adverse impacts are anticipated under this operational scenario.

The seasonally adjusted steady flow scenario would result in more consistent daily viewing than any of the fluctuating flow scenarios. Views would change from month to month during the season and during June and July. The greatest visual diversity would occur from the spring peak (June 1 through 21) to the middle of July. During this period, flows would drop from 4,700 cfs on June 21 to 3,700 cfs on June 22 to 2,100 cfs on July 1 and 1,100 cfs on July 10. The steady flow operational scenario would have the highest minimum flows of any scenario, and higher minimum flows would reduce unattractive debris effects. Overall, no adverse impacts are anticipated.

4.2.8.3 Aspinall Unit

The aesthetic values of the Aspinall reservoirs vary with lake levels. Because the Morrow Point and Crystal reservoirs are less accessible to visitors, changes in the visual quality of these reservoirs were considered less important than changes at Blue Mesa Reservoir.

No adverse impacts to visual resources on Blue Mesa Reservoir would occur under either operational scenario. Although water levels on the reservoir could vary considerably, little of the change would be attributable to operational scenarios. The resulting barren shoreline would be relatively small in area and would blend in with the existing landscape. A bathtub ring would be visible when the reservoir level dropped below full pool, but this condition would not be a consequence of hydropower operations.

No impacts to visual resources on Morrow Point or Crystal reservoirs would be expected under either operational scenario. Although daily fluctuations attributable to hydropower operations could reach 1.5 ft on Morrow Point Reservoir and more than 8 ft on Crystal Reservoir, the surrounding area's uniform topography (canyon walls) and relatively sparse vegetation limit visual diversity for those standing in the foreground viewing zone. Although a bathtub ring would be visible in the foreground zone of both reservoirs, it would not drastically detract from the overall view because most of the surrounding rock and canyon walls are dark and provide little visual contrast. The impacts to views from the middle-ground zone would be negligible.

4.3 SUMMARY OF IMPACTS OF COMMITMENT-LEVEL ALTERNATIVES AND HYDROPOWER OPERATIONAL SCENARIOS

This section summarizes the potential impacts of the commitment-level alternatives and hydropower operational scenarios addressed in this EIS.

4.3.1 Commitment-Level Alternatives

Table 4.36 presents a detailed summary of the estimated impacts that each of the commitment-level alternatives would have on various socioeconomic variables, air resources, and other natural and cultural resources. Impacts are further disaggregated on the basis of the various supply options that were assumed as part of the analysis. These supply options were defined as follows:

- *Supply Option A:* Continuation of historical operations at Glen Canyon, year-round high fluctuations at Flaming Gorge, and seasonally adjusted high fluctuations at the Aspinall Unit combined with necessary power purchases;
- *Supply Option B:* Low fluctuations at Glen Canyon, year-round high fluctuations at Flaming Gorge, and seasonally adjusted high fluctuations at the Aspinall Unit combined with necessary power purchases; and
- *Supply Option C:* Seasonally adjusted steady flows at Glen Canyon, Flaming Gorge, and the Aspinall Unit combined with necessary power purchases.

Table 4.36 indicates that the largest economic impacts would be on retail rates paid by the end-users served by Western's utility customers. The financial condition of some of Western's customers might also be impacted. Under the combination of commitment-level alternative 4 and supply option C, less than 12% of the utilities included in the financial analysis would experience a decrease in financial viability. All of the other alternatives and operational scenarios would result in smaller impacts on financial viability. As indicated in Table 4.36, the predicted impacts on regional socioeconomic variables ¾ population, employment, disposable income, and gross regional product ¾ are not statistically different from zero. Consequently, those factors are not considered further here. For similar reasons, impacts on air resources, noise, conservation and renewable energy programs (consumption efficiency and load management), and agricultural production are not considered further.

The no-action alternative combined with supply options B and C illustrates the effects that restrictions on hydropower operations would have on the costs of electricity in the affected regions. Moving from supply option A to supply option C, rates tend to increase. This result reflects, in part, the fact that under supply option C, Western would be unable to take advantage of the rate differential that arises in the case of spot market sales. As such, the rates Western charged its long-term firm customers would have to be increased to ensure that Western could meet its repayment obligation. Under supply option C and the no-action alternative, the average rate charged by Western's utility customers would increase 8%. In addition, supply option C would result in a moderate increase in the number of utilities with a coverage ratio of less than 1.1. However, the number of utilities with a coverage ratio of at least 2.0 would remain unchanged under both supply options B and C.

TABLE 4.36

The combination of commitment-level alternative 1 and supply option A would leave retail rates relatively unchanged. In some cases, such as for high-reliance municipal utilities in Utah, rates are predicted to decline by a moderate amount. In other cases, rates would decrease slightly, remain unchanged, or increase by a very slight amount. Under supply option B, rates would decrease slightly or increase by a small amount. However, as in the case of supply option A, the overall impact would be slight. Supply option C would result in the largest impacts, as illustrated in Table 4.4. The financial viability of Western's utility customers would be unaffected by the combination of commitment-level alternative 1 and any of the three supply options.

All of the other alternative/supply option combinations would result in retail rate and financial viability impacts of varying amounts. Overall, rate increases would be largest under commitment-level alternative 4 combined with supply option C. In this case, customers of high-reliance municipals in Utah would see their rates increase by an estimated 41%, while customers of high-reliance cooperatives in Utah would see their rates rise by 32%. These changes represent significant increases in the amount paid for electrical energy by these customers. Customers of high-reliance cooperatives in New Mexico would also experience a significant increase in rates relative to the baseline; it is predicted that rates would increase by 28%. This alternative would also result in the largest number of firms (five) experiencing a decline in financial viability. Alternative 5 would result in similar impacts on rates and financial viability. The largest rate increases would occur in Utah and New Mexico, where rates would be expected to increase by 31% and 23% under supply option C. Financial viability impacts under alternative/option combination 5C would be comparable to those under combinations 4A, 4B, and 4C, while impacts associated with combinations 5A and 5B would be somewhat smaller.

Commitment-level alternatives 2 and 3 would have comparable impacts on retail rates and the financial viability of affected utilities. Impacts are predicted to be slightly larger under alternative 3, but the distribution of impacts across states and utility categories would be generally similar to the largest rate impacts occurring in Utah under both alternatives. Rate and financial impacts associated with alternative 6 would be generally comparable to those occurring under alternatives 2 and 3. Once again, the largest impacts would occur under supply option C. However, the largest rate impacts would occur in New Mexico.

Overall, high-reliance utilities in Utah and New Mexico would experience the largest rate impacts under each of the commitment-level alternatives. This result reflects the fact that a large share of the power these utilities sell comes from Western. As such, changes in the rate Western charged for its power would have a larger absolute impact on the rates charged by these utilities to their end-users.

The impacts of commitment-level alternatives to water resources, ecological resources, cultural resources, land use, recreation, and visual resources are dependent on the operational scenarios implemented at the hydropower facilities under consideration in this EIS. In addition to the direct impacts of hydropower operations, indirect impacts could result from fulfilling the need for additional generating capacity under each commitment-level alternative. This need for additional capacity could be met by building new power plants, expanding existing ones, or by other methods. Construction and operation of power plants to meet additional capacity needs could result in additional impacts to natural and cultural resources in the vicinities of any new or expanded facilities. A detailed assessment of specific impacts is not presented here because the significance and nature of any such impacts would depend on the specific plans and locations for the new expanded facilities ¾ information that is not available at this time.

4.3.2 Hydropower Operational Scenarios

This section summarizes the impacts to natural and cultural resources that would occur under the various hydropower operational scenarios considered for Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit. Each facility is considered separately to emphasize the differences among operational scenarios at the individual facilities.

To determine the impacts to socioeconomics and air resources associated with a specific operational scenario, it is necessary to specify both an operational scenario and a commitment-level alternative (Section 4.1). In the assessment of socioeconomic and air resource impacts, commitment-level alternatives were paired with specific supply options that consisted of combinations of operational scenarios at each of the three hydropower facilities.

On the basis of an analysis conducted by Palmer and Ancrile (1995), the socioeconomic and air resource impacts projected for the supply options capture the full range of impacts that could occur for any possible combination of operational scenarios. The impacts of any combination of operational scenarios that included a continuation of historical operations, maximum power plant capacity, or restricted high fluctuations at Glen Canyon Dam; any of the four operational scenarios at Flaming Gorge Dam; and either of the operational scenarios at the Aspinall Unit would correspond to the impacts identified for supply option A. The impacts of any combination that included moderate fluctuations or low fluctuations at Glen Canyon Dam; any of the four operational scenarios at Flaming Gorge Dam; and either of the operational scenarios at the Aspinall Unit would correspond to the impacts of supply option B. Finally, the impacts of any combination consisting of seasonally adjusted steady flows, existing monthly steady flows, or year-round steady flows at Glen Canyon Dam; any one of the four operational scenarios at Flaming Gorge Dam; and either of the operational scenarios at the Aspinall Unit would correspond to the impacts of supply option C. The impacts of these supply options on socioeconomics and air resources are summarized in Section 4.3.1.

4.3.2.1 Glen Canyon Dam

Table 4.37 summarizes impacts to natural and cultural resources in and along the Colorado River downstream of Glen Canyon Dam.[4]

Continuation of historical operations and maximum power plant capacity operational scenarios would have impacts on most natural resources similar to those that have occurred since the dam was completed in 1963 and that have determined existing conditions for water resources, ecological resources, and recreational activities (as described in Sections 3.3.1, 3.4.1, and 3.7.1). The increase in fluctuations under maximum power plant capacity operations would result in some additional adverse impacts to water resources, riparian vegetation, humpback chub, the Kanab ambersnail, southwestern willow flycatcher, and recreation.

Restricted high fluctuations would result in slight benefits to water resources, most ecological resources, and recreation. For this scenario, slight adverse impacts were identified for the humpback chub. Adverse impacts could also occur to cultural resources (because of erosion) and to the Kanab ambersnail.

Moderate and low fluctuation operational scenarios would produce moderate benefits for water resources (moderate increases in the probability of a net gain in riverbed sand), cultural resources, and white-water boating. These operational scenarios could result in slight benefits for aquatic ecology (trout and native fish), some endangered species (bald eagle, peregrine falcon, and southwestern willow flycatcher), and angling. Slight adverse impacts could occur to the humpback chub, and adverse impacts could occur to the Kanab ambersnail.

Although steady flow scenarios could result in benefits to a number of resources, some benefits may require the proposed annual high habitat-maintenance flows to build beaches and maintain fish habitats. Moderate benefits could occur for water resources (moderate increase in the probability of a net gain in riverbed sand), aquatic ecology (trout and native fish), terrestrial ecology (large increase in upper riparian zone vegetation without habitat-maintenance flows), endangered species (humpback chub, bald eagle, peregrine falcon, and southwestern willow flycatcher), cultural resources, and recreation (angling and white-water boating). Adverse impacts to the Kanab ambersnail could occur under any of the steady flow scenarios because of the occasional high flows required for beach and habitat maintenance.

TABLE 4.37

4.3.2.2 Flaming Gorge Dam

Table 4.38 summarizes impacts to natural and cultural resources in and along the Green River downstream of Flaming Gorge Dam.

The year-round high fluctuation operational scenario features maximum flows and daily flow fluctuations that are slightly higher than historical operations. Consequently, this scenario could result in adverse impacts to native and endangered fish, trout, riparian vegetation, and cultural resources.

The remaining three operational scenarios are seasonally adjusted; that is, they feature shifts in monthly volumes to meet requirements of the USFWS Biological Opinion (USFWS 1992b). All of these scenarios exhibit a high sustained flow in May or June, reduced fluctuations and lower flows in summer and autumn, and steady flows when an ice cover is present on the river (February and March). These flow patterns are intended to be protective of endangered fish in the system and could result in benefits to these species, as well as other resources. Some adverse impacts could result from this seasonal adjustment, however. The spring peak in flows would result in large adverse impacts to anglers. In addition, the bald eagle and waterfowl could be adversely affected by steady flows in February and March. With steady flows, less open ice-free water would be available for these species.

TABLE 4.38

Seasonally adjusted high fluctuations would have moderate effects on flow and stage, but would have erosion rates similar to year-round high fluctuations. Slight to moderate benefits are expected to native fish (including the endangered humpback chub, bonytail chub, razorback sucker, and Colorado squawfish) because of improved nursery habitat conditions, but fluctuations could adversely affect trout. Slight adverse impacts to Ute ladies'-tresses could occur with a reduction in soil moisture in the summer. This scenario would result in large benefits to angling from mid-summer through autumn (when lower flows are maintained) and moderate benefits to white-water boating during the spring peak. Slight adverse impacts are expected to terrestrial ecology because of the inundation of some upper riparian zone vegetation. Because erosion rates would be similar to the year-round high fluctuation scenario, cultural resources could be adversely affected by this operational scenario.

Seasonally adjusted moderate and steady flows are relatively similar in their projected impacts to most natural and cultural resources, but seasonally adjusted steady flows generally would produce the greatest level of benefit. Both scenarios would have moderately reduced erosion rates and thus would benefit water and cultural resources. Slight or moderate benefits to trout and moderate to large benefits to native and endangered fish, angling, and white-water boating are also expected under these scenarios because of reduced daily fluctuations. Slight to moderate adverse impacts to existing Ute ladies'-tresses could occur if these scenarios resulted in lower soil moisture levels in the alluvial meadows where the plant species occurs. These impacts could be offset, however, if the more natural flow patterns of these scenarios resulted in the establishment of new individuals of this species.

Slight adverse impacts under seasonally adjusted moderate fluctuations are expected to terrestrial resources because decreases in upper and lower riparian zones could occur. The steady flow scenario would result in benefits to terrestrial resources by allowing a slight increase in upper riparian zone vegetation.

4.3.2.3 Aspinall Unit

Table 4.39 summarizes impacts to natural and cultural resources in the vicinity of the Aspinall Unit. Because Crystal Dam reregulates flows from the Aspinall Unit, flows in the Gunnison River below the unit and the resources dependent on those flows would not be affected by hydropower operations.

Slight to moderate impacts to flow and stage in Blue Mesa and Morrow Point reservoirs would occur because of seasonal adjustments in releases and daily fluctuations. Despite this, neither operational scenario is expected to result in impacts to sediment, most ecological resources (aquatic ecology, threatened and endangered species), cultural resources, land use, or visual resources. Both scenarios could result in slight benefits to terrestrial resources in the headwaters of Crystal Reservoir because of an increase in the size of the upper riparian zone. Slight adverse impacts to the bald eagle are expected under the seasonally adjusted steady flow scenario because the reservoirs would freeze earlier in the winter with reduced fluctuations. Slight adverse impacts to boaters on Morrow Point and Crystal reservoirs could occur at low water under the seasonally adjusted high fluctuation scenario.

TABLE 4.39

[1] This trade-off accounts for the drop in use values between the seasonally adjusted moderate fluctuating flow and the seasonally adjusted steady flow scenarios, as shown in Table 4.13.

[2] Although a "bathtub ring" effect can be visible at most sustained flows, it is most pronounced at the lowest flows.

[3] Most users of the rivers and reservoirs examined in this EIS typically leave the environs of the water by 7 p.m.

[4] The assessment presented here for Glen Canyon Dam was based on the analysis presented in a separate EIS for that facility (Reclamation 1995). Relative levels of benefit or adverse impacts have been added to provide consistency of treatment among facilities.

5 CUMULATIVE IMPACTS OF COMMITMENT-LEVEL ALTERNATIVES AND OPERATIONAL SCENARIOS

Cumulative impact, as defined by the Council on Environmental Quality (40 CFR 1508.7), is "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time." This section discusses potential cumulative impacts of the commitment-level alternatives for the SLCA/IP and the hydropower operational scenarios for Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit.

As discussed below, commitment-level alternatives have the potential to contribute directly to cumulative impacts on regional socioeconomics and air quality, as well as indirectly (through required capacity expansion) on water, ecological, cultural, land use, recreation, and visual resources. Hydropower operations also have the potential to contribute to cumulative impacts to this latter group of resources. The fact that the three hydropower facilities under consideration are all within the Colorado River Basin increases the potential for cumulative impacts to resources that are affected by hydropower operations. In addition, other SLCA/IP hydropower facilities within the basin could contribute to cumulative impacts by altering the hydrology of the basin and affecting the resources dependent on this hydrology.

Past actions relevant to the cumulative impacts of commitment-level alternatives and hydropower operations include the construction and operation of existing hydropower facilities and thermal power plants, as well as development activities (e.g., housing, agriculture, mining, forestry) within the region that could affect the hydrology of the basin. These past impacts are discussed implicitly or explicitly as part of the description of the affected environment (Chapter 3). For example, the discussion of water resources in Section 3.3 presents flows and sediment balance within the Colorado River before completion of Glen Canyon Dam and the changes in these parameters that have occurred since then. The description of current flows and sediment balance integrates all factors, including ongoing activities, that affect existing (baseline) conditions. Because these past and ongoing activities are incorporated into baseline conditions, the assessment of impacts of commitment-level alternatives and hydropower operational scenarios presented in Sections 4.1 and 4.2 already considers these aspects of cumulative impacts.

Similarly, reasonably foreseeable future actions have been considered in the impact assessment wherever possible. Thus, the EIS for continued operation of Glen Canyon Dam (Reclamation 1995) is considered here by examining, as operational scenarios, all eight of the alternatives being considered in that EIS. Flow regimes stipulated in the Biological Opinion for Flaming Gorge Dam, recently issued by the USFWS (1992b), were incorporated into the development of operational scenarios for this facility. The impacts of possible future changes in release patterns from the Aspinall Unit are also considered here by assessment of the impacts of hydropower operations with the seasonally adjusted releases that are being considered by Reclamation. No other future Federal, state, local, or private actions that could contribute to cumulative impacts are known at this time.

5.1 SOCIOECONOMICS

The cumulative economic effects that could be attributed to a change in Western's commitment levels have already been addressed. The economic analysis of a change in Western's commitment levels was designed to provide estimates of both the short- and long-term impacts of each alternative. In particular, the analysis considered how changes in commitment levels and supply options would affect each utility's capacity expansion path. The results of this part of the analysis, combined with estimates of the effects of each alternative on the rates charged by Western (as well as other factors), were used to estimate the short- and long-term effects on the rates charged by each utility and the financial condition of each utility. The changes in rates were then used to estimate the short- and long-term effects on such regional economic variables as employment, income, and output.

Other factors that could influence cumulative impacts include the implementation of the Final Biological Opinions at Flaming Gorge Dam and Glen Canyon Dam and changes in the operations at the Aspinall Unit. However, the selection of operational scenarios and corresponding supply options for this analysis was designed to capture the range of effects that any such changes could have on the economic analysis of the commitment-level alternatives (Section 4.1.1).

5.2 AIR RESOURCES

No significant variations in regional emissions of criteria air pollutants or CO2 (used as the surrogate for all types of greenhouse gases emitted from fossil-fuel combustion) are expected under Western's commitment-level alternatives or operational scenarios (Sections 4.1.2.1.2 and 4.2.2.1.2). Therefore, no significant variations in cumulative impacts are expected.

5.3 WATER RESOURCES

Cumulative hydrological impacts for operational scenarios at any of the hydroelectric power plants considered in this EIS would range from slight to moderate (Section 4.2.3). This conclusion is based on a number of findings. First, impacts of the operational scenarios would range from slight to moderate for each of the individual power plants considered in this EIS (Section 4.2.3). Next, incremental increases in impacts to the hydrological environment from such external activities as new construction, increased agricultural usage, or other activities in the associated basins would also be small relative to current environmental conditions. Finally, impacts due to other operational constraints on the dams (e.g., the Glen Canyon Dam EIS [Reclamation 1995], the Glen Canyon Dam Biological Opinion [USFWS 1994a], and changes in the operation of the Aspinall Unit) would fall within the bounds of the analyses reported in this EIS.

In addition to slight to moderate cumulative impacts for each of the facilities, the cumulative impact of the hydropower operational scenarios considered in this EIS on operations of other SLCA/IP power plants would be small. This conclusion is based primarily on the large physical distances separating the power plants and the independence of the operational scenarios from annual and monthly water releases, which would remain under the control of Reclamation.

Flaming Gorge Dam is the most northern of the power plants considered. It is located on the Green River, a major tributary that joins the Colorado River about 35 mi southwest of Moab, Utah. The next most northern power plant is the Aspinall Unit, which is located on the Gunnison River about 100 mi upstream of the confluence with the Colorado River near Grand Junction, Colorado (approximately 125 mi northeast of the confluence of the Green and Colorado rivers). The southernmost power plant is Glen Canyon Dam, which is located on the Colorado River near Page, Arizona, about 70 mi southwest of Grand Junction, Colorado. Water release patterns from Flaming Gorge Dam or the Aspinall Unit would be indistinguishable by the time the released water reached the vicinity of Lake Powell because of physical attenuation and mixing with numerous tributaries that join the main stem of the Colorado River between Lake Powell and the upstream power plants. Upstream of Flaming Gorge Dam and the Aspinall Unit, Flaming Gorge Reservoir and Blue Mesa Reservoir would effectively buffer Fontenelle Dam and any units upstream of Blue Mesa Dam from impacts of hydropower operations. As with flow, cumulative impacts of sediment transport, beyond what is already included in the individual assessments for facilities, would be small because of the large distances between the units and the large number of tributaries and alluvial stretches of river that supply sediment to the main stem of the Colorado River.

5.4 ECOLOGICAL RESOURCES

In Section 4.2.4, the assessment of ecological impacts of each operational scenario at the Glen Canyon, Flaming Gorge, and Aspinall Unit dams incorporated impacts to the ecological resources that resulted from construction and historical operations of the dams (as summarized in Section 3.4) as part of the affected environment at each facility. Therefore, the impacts identified represent the cumulative impacts of each operational scenario combined with the impacts of past dam construction and operation activities in the Colorado, Green, and Gunnison rivers.

No additional cumulative impacts are anticipated to the ecological resources below Glen Canyon Dam beyond those impacts already identified in Section 4.2.4.1. The only major Federal action currently being planned for the area is modification of Glen Canyon Dam operations. An EIS for that action was prepared by Reclamation, and the operational scenarios evaluated in Section 4.2.4.1 of this EIS are the same as the operational alternatives evaluated by Reclamation. The operational scenario ultimately implemented at Glen Canyon Dam will be selected by Reclamation and will be subject to adaptive management as further studies are completed.

The river corridor below Flaming Gorge Dam is almost exclusively under the control of Federal agencies, such as the USFS and the NPS. As a result, few (if any) private or state actions are expected in or along the river between the dam and Jensen, Utah. The only known action currently planned in the river corridor below the dam is the modification of Flaming Gorge Dam operations by Reclamation to comply with the Biological Opinion issued by the USFWS for that facility (USFWS 1992b). That Biological Opinion considered the cumulative effects of operations in developing its reasonable and prudent alternative for operation of Flaming Gorge Dam. With the exception of the year-round high fluctuating flow operational scenario, which was evaluated only for comparison with the other operational scenarios, all of the operational scenarios for Flaming Gorge Dam evaluated in this EIS would be in compliance with the Biological Opinion and, therefore, would be expected to cause an improvement to, rather than degradation of, ecological resources.

The reservoirs of the Aspinall Unit are all under the control of Federal agencies. Thus, no private or state actions would be expected to occur at the reservoirs unless specifically authorized by the controlling agency. Water releases from Crystal Reservoir are currently being changed by Reclamation to provide flows downstream of Crystal Dam requested by the USFWS and the NPS. This change in releases from Crystal Dam will affect the storage and release patterns for the other reservoirs in the Aspinall Unit. The operational scenarios evaluated in this EIS were developed to provide the requested releases from Crystal Dam. Because the impacts of hydropower operations at the Aspinall Unit would be limited to the reservoirs themselves and not extend below Crystal Dam, no cumulative impacts would be expected to the ecological resources in the Gunnison River below that dam.

The location of Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit within the Colorado River Basin increases the potential for interactive effects that could contribute to cumulative impacts to ecological resources. Such interactions could occur if (1) a facility affected downstream areas that were also affected by another facility or (2) a resource (e.g., a population of endangered fish) occurred in a sufficiently large area that this resource incurred impacts from several facilities. Impacts of Fontenelle Dam (60 mi upstream of the headwaters of Flaming Gorge Dam Reservoir) would not contribute to impacts on ecological resources below Flaming Gorge Dam because Flaming Gorge Reservoir serves as a buffer to any water resource impacts (e.g., flow, sediment, water temperature) of Fontenelle Dam. Similarly, hydropower operations at Flaming Gorge Dam would not contribute to ecological impacts below Glen Canyon Dam because of the moderating effects of Lake Powell and the influence of tributaries on water quality between the two facilities (Section 5.3). The impacts of hydropower operations at the Aspinall Unit would be limited to the area of the reservoirs themselves (Section 4.2.4), thus precluding the potential for interactions between either Flaming Gorge Dam or Glen Canyon Dam.

The dams and reservoirs of the facilities effectively isolate most downstream aquatic resources. Thus, the population of humpback chubs below Glen Canyon Dam is separate from that below Flaming Gorge Dam, and impacts on one population cannot have interactive effects with any impacts on the other population. The fact that no hydropower operational scenario impacts are anticipated below the Aspinall Unit precludes any interactive effects between this facility and Flaming Gorge and Glen Canyon dams.

The great distances between facilities limits the potential for cumulative impacts to terrestrial resources.

5.5 CULTURAL RESOURCES

No cumulative impacts to cultural resources have been identified that have not already been discussed in Sections 4.1.3 and 4.2.5. The great distances between facilities prevents interactive effects on flow and sediment transport that would have been unaccounted for in the assessments presented for the individual facilities. The predominantly Federal control of the affected areas reduces the uncertainty of future actions that could affect cultural resources in the area.

5.6 LAND USE

Adoption of certain commitment-level alternatives might require the construction of new power-generating facilities to meet requirements for firm capacity and energy. However, the location, size, and type of any new facilities are unknown at this time. The range and magnitude of impacts to land use resulting from construction and operation of such facilities cannot be determined without site-specific information. Because such information is not available, the potential cumulative impacts to land use associated with the various commitment-level alternatives cannot be thoroughly analyzed at this time.

No cumulative impacts to land use in the Colorado River Basin would result from any of the operational scenarios. No land use interactions would occur among the three facilities examined in this EIS.

5.7 RECREATION

The commitment-level alternatives may require construction of new power-generating facilities to compensate for the loss of hydropower resources; however, the location, size, and type of potential facilities are unknown at this time. The range and magnitude of impacts (including cumulative impacts) to recreational facilities and activities resulting from the construction and operation of such facilities would vary and cannot be analyzed until site-specific information is available.

In Section 4.2.7, the assessment of recreational impacts of each operational scenario at Glen Canyon and Flaming Gorge dams incorporated impacts to recreation that resulted from construction and historical operations of the dams (summarized in Section 3.7) as part of the affected environment at each facility. Therefore, the impacts identified represent the cumulative impacts of each operational scenario combined with the impacts of dam construction and operational activities in the Colorado and Green rivers. No additional cumulative impacts to recreation are anticipated under the operational scenarios beyond those identified in Section 4.2.7. Reclamation has prepared an EIS examining operations at Glen Canyon Dam, and the alternatives assessed by Reclamation are the same as the operational scenarios examined in this EIS. On the Green River, Reclamation is operating Flaming Gorge Dam to comply with the USFWS Biological Opinion (USFWS 1992b). Impacts from the operational scenarios examined in this EIS would not exceed those resulting from compliance with the Biological Opinion. Except for a few parcels of privately owned land, the segment of the Green River examined in this EIS is under Federal jurisdiction. No other action by any of the participating agencies is expected. The reservoirs of the Aspinall Unit are completely under the jurisdiction of the Federal Government, and no cumulative impacts with other actions are anticipated.

The relationship of recreational activities occurring at the three facilities examined in this EIS is limited because of the distance between them. Consequently, action at one facility would cause little if any shift of use rates to any of the other two.

5.8 VISUAL RESOURCES

Although commitment-level alternatives may require construction of new power-generating facilities to compensate for the loss of hydropower resources, the location, size, and type of potential facilities are unknown at this time. Site-specific information would be needed to determine the range and magnitude of impacts to visual resources associated with the construction and operation of such facilities. Because that information is not available, a thorough analysis of the cumulative impacts generated by commitment-level alternatives cannot be presented at this time. No cumulative impacts to visual resources would be generated under the operational scenarios. No relationship exists between the visual resources of the three hydropower facilities examined in this EIS. Visual resources in the Colorado River Basin would not be affected by flows from Glen Canyon Dam, Flaming Gorge Dam, or the Aspinall Unit dams.

6 UNAVOIDABLE ADVERSE IMPACTS

The impacts of commitment-level alternatives are presented in Section 4.1, and the impacts of hydropower operations at Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit are presented in Section 4.2. This chapter summarizes the impacts of commitment-level alternatives and hydropower operations that cannot be avoided.

Unavoidable adverse impacts to socioeconomics from implementation of any of the commitment-level alternatives would be relatively limited. Compared with the no-action alternative, commitment-level alternatives 2, 3, 4, 5, and 6 would in most cases result in increased costs for Western's customers and a corresponding increase in the retail rates charged by those customers. As was discussed in Section 4.1, the magnitude of these increases would vary across the affected utilities. Some utilities, especially small, high-reliance cooperatives, could see their financial condition worsen. In addition, some end-users, especially those in Utah, could see the rates they pay for electricity increase by as much as 41% (under commitment-level alternative 4, supply option C). Over the forecast period, each of the alternatives could result in a short-term decrease in output, employment, income, and agricultural output in the majority of the affected subregions. However, any impacts that might occur are predicted to be extremely small and would gradually diminish over time. Nonetheless, the initial decrease for all but the no-action alternative does represent a potential unavoidable adverse impact to the levels of output, employment, and income.

Because of the small change in variables affecting air quality and noise, there would be no unavoidable adverse impacts to these attributes of the environment.

It is likely that under each commitment-level alternative and supply option combination, new or replacement power plants would be required to replace generating capacity currently provided by Western. The amount of additional capacity constructed as a direct result of any of the alternatives would likely be small, however, compared with additional capacity required to meet overall load growth in the area in which Western power is sold. Construction and operation of new power plants could affect water resources, ecological resources, cultural resources, land use, recreation, and visual resources. Because the impacts of constructing and operating new power plants depend on plant characteristics and location (which are not known at this time), these impacts are assessed in a qualitative sense in this EIS (Section 4.1.3). Unavoidable adverse impacts associated with new power plants cannot be determined at this time, but any such impacts would be assessed in the environmental review that would be required for any proposed new facility.

Commitment levels could also affect natural and cultural resources through the hydropower operations employed to produce marketed power. Since the relationship between commitment levels and specific operational modes is dependent on many factors, the assessment in the EIS directly examined the effects of hydropower operations to bound the possible impacts (Section 4.2). Because the hydropower facilities examined in the EIS have been operating for the past 30 years, the existing condition of the natural environment associated with these facilities is a product of the presence of the dams and past operations. For the most part, hydropower operations similar to historical operations would not produce further changes in environmental conditions downstream of facilities. Thus, impacts associated with those scenarios similar to historical operations (continued historical operations, maximum power plant capacity, and restricted high fluctuation scenarios at Glen Canyon Dam; year-round high fluctuations at Flaming Gorge Dam; and seasonally adjusted high fluctuations at the Aspinall Unit) would be limited. The high fluctuations characteristic of these operational scenarios at Glen Canyon and Flaming Gorge dams would result in slightly to moderately higher erosion rates than other operational scenarios and could erode cultural resource sites near the river. These adverse impacts to cultural resources could be avoided with mitigation (e.g., protecting sites with riprap, or data recovery). Potential unavoidable adverse impacts to other resources for these operational scenarios would be slight but could include impacts to the humpback chub, riparian vegetation, and terrestrial wildlife.

Operational scenarios with fluctuations lower than historical levels would benefit most resources, including water resources (sediment), ecological resources (trout, native fish, riparian vegetation, most wildlife, and most threatened and endangered species), cultural resources, and recreation (all activities). Exceptions to this general trend include slight to moderate adverse impacts under operational scenarios with reduced fluctuations to (1) lower riparian zone vegetation at Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit, (2) waterfowl at Flaming Gorge Dam and the Aspinall Unit, (3) bald eagles at Flaming Gorge Dam and the Aspinall Unit, and (4) Ute ladies-tresses at Flaming Gorge Dam. These trade-offs between operational scenarios with fluctuations and those with steady flows would result in some unavoidable adverse impacts, depending on the scenario actually implemented.

7 RELATIONSHIP BETWEEN SHORT-TERM USE OF THE ENVIRONMENT AND LONG-TERM PRODUCTIVITY

The commitment-level alternatives examined in this EIS consist of potential changes in the way hydroelectric capacity and energy produced at SLCA/IP facilities are marketed. In particular, Western is proposing to change the amount of firm capacity and energy that it would commit to for a specified period of time. In contrast, the total amount of capacity and energy produced on an annual basis would be unaffected by any of the commitment-level alternatives or hydropower operational scenarios. Thus, short-term uses are limited to the manner in which power is marketed and hydropower facilities are operated (especially with regard to the amount of daily flow fluctuation), not the total capacity and amount of energy produced.

With respect to socioeconomic impacts, the analysis indicates any impacts that might occur in the short-term would gradually disappear. Long-term productivity, as measured by economic variables such as employment, output, income, and agricultural production, would be unaffected by any of the commitment-level alternatives considered.

Long-term productivity of downstream environments has been affected by the reduction in sediment load resulting from the presence of the dams. Although this impact is not a hydropower operations issue, per se, hydropower-induced fluctuations affect the amount of sediment transported downstream, the amount of erosion, and ultimately the area available for riparian vegetation, wildlife populations, and shoreline recreational use (e.g., beaches). Thus, any operational scenario that features high flow fluctuations affecting sediment transport would also affect the long-term productivity of the area. These operational scenarios are continued historical operations, maximum power plant capacity, and restricted high fluctuations at Glen Canyon Dam and year-round high fluctuations and seasonally adjusted high fluctuations at Flaming Gorge Dam. Neither of the operational scenarios at the Aspinall Unit would influence the long-term productivity of the affected area. It is important to note that for long-term productivity to be affected, high fluctuating flow operational scenarios would have to be in place for a long, as yet undetermined, period of time. Switching to a reduced fluctuation operational mode could slow or halt declines in long-term productivity.

Although reduced fluctuations would generally have positive effects on long-term productivity, backwater areas that are important to the long-term productivity of the aquatic ecosystem could eventually fill in with sediment and upper elevation riparian vegetation could be lost without occasional high flows. Some of the reduced fluctuation operational scenarios at Glen Canyon Dam (moderate fluctuation, low fluctuation, and the steady flow scenarios) feature periodic high flows intended to flush accumulated sediments, deposit sediments at higher elevations, and provide conditions suitable for upper elevation riparian vegetation. Periodic flows above power plant capacity may also be required at Flaming Gorge Dam to maintain long-term productivity of the ecological system.

8 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

Neither the capacity and energy produced from water stored behind each of the dams nor the natural resources as printout:mcr:11/15/95 8 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES Neither the capacity and energy produced from water stored behind each of the dams nor the natural resources associated with each facility would be irreversibly or irretrievably committed by implementation of any commitment-level alternative or hydropower operational scenario. This conclusion is based on the capability of facility operators and/or Western to modify hydropower operations or aspects of the power marketing program such as energy purchases and exchanges. Thus, changes in operations or elements of the marketing program could be made at any time to reverse or reduce impacts to resources.

The USFWS issued a Biological Opinion (USFWS 1992b) concluding that continuation of historical operations of Flaming Gorge Dam would jeopardize the continued existence of endangered fish in the Green River. Consequently, the USFWS proposed, as a reasonable and prudent alternative, reoperation of the dam to provide flows they believed would be protective of these fish (see Section 4.2.4.2.3). Of the operational scenarios for Flaming Gorge Dam considered in this EIS, only the year-round high fluctuating flows scenario would not comply with the Biological Opinion and thus, according to that opinion, is the only operational scenario considered in this EIS that could result in the decline or irreversible loss of these species.

Similarly, a Biological Opinion has been issued for operation of Glen Canyon Dam (USFWS 1994a) that states that implementation of Reclamation's preferred alternative for that facility (modified low fluctuating flows) would jeopardize the continued existence of the humpback chub and razorback sucker but not the bald eagle, peregrine falcon, or Kanab ambersnail. The opinion presented a reasonable and prudent alternative that included (1) examination of the effects of high steady flows in the spring and low steady flows in the summer and fall in low water years, and of operations according to the modified low fluctuating flow alternative in moderate and high release years; (2) evaluation of the effects of a selective withdrawal structure; (3) determination of the response of native fish to various temperature regimes; (4) protection of the humpback chub spawning population and habitat in the Little Colorado River; (5) development of recommendations that would help ensure the continued existence of the razorback sucker; and (6) development of a program to establish a second spawning aggregation of humpback chub downstream of Glen Canyon Dam. According to the USFWS, this reasonable and prudent alternative would avoid jeopardizing the continued existence of those species.

9 ENVIRONMENTAL STATUTES, REGULATIONS, EXECUTIVE ORDERS, AND PERMIT REQUIREMENTS

This chapter identifies the major laws, regulations, Executive Orders, U.S. Department of Energy (DOE) orders, and other instruments that impose environmental protection and compliance requirements upon Western's activities in the affected areas. Also addressed are applicable measures for which Federal law delegates enforcement or implementation authority to state or local agencies.

The Department of Energy Authorization Act created Western as a separate and distinct entity within the DOE [42 USC §7152(a)(3)]. The act transferred the power marketing and transmission functions from the Secretary of the Interior (Bureau of Reclamation) to the Secretary of Energy, acting through Western. Therefore, Western, as an administration within the DOE, is governed as a Federal agency and must comply with all Federal facility requirements and DOE regulations and orders.

Executive Order 12088, Federal Compliance with Pollution Control Standards, requires Federal agencies, including Western, to comply with applicable administrative and procedural pollution control standards established by, but not limited to, the Clean Air Act (Section 9.1), the Noise Control Act (Section 9.2), the Clean Water Act (Section 9.3.1), the Safe Drinking Water Act (Section 9.3.3), the Toxic Substances Control Act, and the Resource Conservation and Recovery Act (RCRA) (Section 9.6).

9.1 CLEAN AIR ACT (42 USC §§7401 et seq.)

Development and implementation of power marketing criteria by Western will not directly result in the release of air pollutants to the atmosphere. The hydroelectric power generating units are not major stationary sources as defined under the Clean Air Act1 and, therefore, hold no permits and need no approvals from the U.S. Environmental Protection Agency (EPA) or the delegated state agency.

Sections 4.2 and 5.2 discuss estimated potential effects of various operational scenarios of changes in Western's hydroelectric generation on local and regional air quality. These sections assume air pollutant emissions from local and regional public utility generating facilities are tied to the amount of peak power generated by the hydroelectric generating units included in this EIS. Therefore, air pollutant emissions eliminated by hydroelectric energy would increase as the operational scenarios under the various alternatives change from high to low flexibility.

Increases in power generation from local or regional public utility generating units may result in additional regulatory compliance burdens on these utilities if air pollutant emissions also increase, either through modification of existing fossil-fuel-fired facilities, or construction of a new major source of air pollutants. Such modification or construction would require the utility to obtain approval and a permit to operate from either the EPA or the appropriate state agency. All such modifications and construction must meet the requirements of the Clean Air Act. However, examination of the regulatory compliance of other than Western is beyond the scope of this section.

9.2 NOISE CONTROL ACT OF 1972 (42 USC §§4901 et seq.)

Section 4 of the Noise Control Act of 1972, as amended, directs all Federal agencies to conduct their programs in a manner that furthers a national policy of promoting an environment free from noise that jeopardizes health or welfare. Noise impacts of commitment-level alternatives and hydropower operational scenarios are analyzed in Sections 4.1.2 and 4.2.2.

The Noise Control Act leaves regulation of environmental noise to the states (42 USC §4913). However, of the six states within the affected region, only Colorado has quantitative noise-limit regulations. The Colorado Noise Abatement Law (Colorado Revised Statutes 1973, Title 25, Article 12) establishes noise level limits (see Appendix B, Table B.6). Noise above those limits is deemed to constitute a public nuisance.

Analyses indicate that hydropower facilities make little contribution to the environmental noise levels beyond their immediate environs. The acoustic emissions from the Curecanti substation do not raise the residual background environmental noise levels above the Colorado limits at the nearest residential area. Hydropower facilities at Glen Canyon do not increase ambient noise levels beyond the rim of the canyon, and hydropower facilities at Flaming Gorge Dam contribute little to the ambient noise level in the area.

The acoustic emissions from the Federal hydropower plants considered here do not increase residual background environmental noise levels in residential areas above the Federal guideline of 55 dBA (EPA 1974).

9.3 WATER QUALITY AND WATER RESOURCE REQUIREMENTS

Water quality and water resource requirements to which Federal hydropower generating facilities and activities would be subject are discussed in this section.

9.3.1 Clean Water Act (33 USC §§1251 et seq.)

The Clean Water Act (CWA) makes it illegal to discharge pollutants from a point source into navigable waters of the United States except in compliance with a National Pollutant Discharge Elimination System (NPDES) permit. Section 402 of the CWA (33 USC §1342), provides for the issuance of a permit for the discharge of any pollutant or combination of pollutants within the applicable requirements of the act.

The EPA, however, does not consider dam-induced water quality changes to constitute the discharge of a pollutant under Section 401 of the CWA, and therefore no permit is necessary. This interpretation was upheld by the court in National Wildlife Federation, et al v. Anne Gorsuch, 693 F.2d 156 (D.C. Cir. 1982). In addition, in United States of America ex rel. Tennessee Valley Authority v. Tennessee Water Quality Control Board, 717 F.2d 992 (6th Cir. 1983), the court found that a state may not subject a Federal agency to a state-enacted permit program when, under the CWA, the pollutant at issue is not considered a discharge from a point source requiring a permit under Section 402. These rulings do not, however, mean that operations at a dam never require an NPDES permit. Permits may be required for operational wastewater discharges, as distinguishable from turbine generating water discharges. The wastewater discharges contain pollutants from outside the hydroelectric power generation system (e.g., noncontact cooling water, oil/water separator discharge, or turbine pit dewatering discharge) that would have to meet the limits of an NPDES permit.

9.3.1.1 Clean Water Act Requirements for Arizona

Arizona has not received full authority under the CWA to implement an NPDES permitting program for Federal facilities. Although the Arizona Department of Environmental Quality, Office of Waste and Water Quality Management, performs processing and monitoring functions, the Federal EPA (Region IX) retains responsibility for issuing permits and conducting enforcement functions within the state. The surface water segment of the Colorado River from Lake Powell to Topock is designated as protected for aquatic and wildlife (including coldwater fishery), domestic water source, full-body contact, agricultural irrigation, and livestock watering. Specific parameters have been set for each designation.

Reclamation holds a permit issued by EPA Region IX for discharge of domestic wastewater to the Colorado River from the treatment plant serving the Glen Canyon Dam and power plant. Western does not hold any permits for these facilities. Implementation of the proposed action, any alternative, or any of the hydropower operational scenarios under consideration would not result in changes in domestic wastewater discharges from the treatment plant because wastewater production at the facility is independent of dam operations.

9.3.1.2 Clean Water Act Requirements for Colorado

Colorado has full authority to implement an NPDES permitting program in the state under its Water Quality Control Act (Colorado Revised Statutes, Title 25, Article 8). However, under Section 25-8-503 of the act, activities in exercise of water rights, such as diversion, storage, or release of water, shall not be considered to be point-source discharges of pollution, provided such discharge does not generate wastewater effluent. No permits have been required or issued by the Colorado Department of Health for the Aspinall Unit. The classifications and numeric standards applicable to the Gunnison River Basin are specified in the Code of Colorado Regulations, Title 5, Chapter 1002, Article 8, Section 3.5.0.

9.3.1.3 Clean Water Act Requirements for Utah

In Utah, the state does not have authority to administer the Federal NPDES permit program or pretreatment programs. Therefore, all NPDES permits issued in Utah under the CWA are issued by the EPA, Region IX. Utah may, however, issue a discharge permit under state-enacted water quality laws and regulations (Utah Water Quality Act, Title 19, Chapter 5, Section 19-5-104). The Green River is designated as protected for domestic drinking water purposes (Class 1C); for in-stream boating, water skiing, and similar uses, excluding recreational bathing (swimming) (2B); for warmwater species of game fish and other warmwater aquatic life (3B); and for agricultural uses, including watering stock and irrigating crops (4).

Reclamation holds a state permit to discharge domestic wastewater to the Green River downstream of Flaming Gorge Dam. Western does not hold any permits for these facilities. It is unlikely that implementation of the proposed action, any alternative, or any hydropower operational scenario under consideration would result in changes in domestic wastewater discharges from the treatment plant.

9.3.2 Rivers and Harbors Appropriations Act of 1899 (33 USC\n§§401et seq.)

Section 10 of the Rivers and Harbors Appropriations Act of 1899 prohibits the unauthorized obstruction or alteration of any navigable water of the United States. The construction of any structure in or over navigable water; the excavation from or depositing of material in such waters; or the accomplishment of any such work affecting the course, location, condition or capacity of such waters is unlawful unless the work has been recommended by the Corps of Engineers and authorized by the Secretary of the Army. The implementation of the proposed action, any alternative, or any hydropower operational scenario under consideration would not result in the construction of any structure or the excavation or deposit of any material into such waters, so no approval under the act would be necessary.

9.3.3 Safe Drinking Water Act (42 USC §§300(f) et seq.)

The primary objective of the Safe Drinking Water Act is to protect the quality of public water supplies, water supply and distribution systems, and all sources of drinking water. Sections of the act address public water systems, protection of underground sources of drinking water, and requirements to regulate underground injection wells. The National Primary Drinking Water Regulations (40 CFR Part 141), administered by the EPA, establish standards applicable to public water systems. The implementation of the proposed action, any alternative, or any hydropower operational scenario under consideration would not affect drinking water supplies or systems at or near SLCA/IP facilities, so no provisions of this act will be applicable.

9.3.4 Wild and Scenic Rivers Act (16 USC §§1274 et seq.)

The Wild and Scenic Rivers Act provides for protection of the outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values of rivers designated as components or potential components of the National Wild and Scenic Rivers System. No license, permit, or other authorization can be issued for a Federally assisted water resources project that could have a direct or adverse impact on the values for which a river was designated as a wild and scenic river or a study river. Within the affected area, the entire segment of the Green River within Colorado and the segment of the Gunnison River from the upstream southern boundary of the Black Canyon of the Gunnison National Monument to its confluence with the North Fork were listed as rivers designated for potential addition to the National Wild and Scenic Rivers Systems [16 USC §§1276(a)(38) and (39)].

The Department of the Interior published a final environmental impact statement finding that the Secretary of the Interior would submit recommendations to the President for transmittal to Congress for inclusion in the National Wild and Scenic Rivers System of a 91-mi segment of the Green River from Flaming Gorge Dam downstream to the southern boundary of Dinosaur National Monument (48 Fed. Reg. 56,449, December 21, 1983). This recommendation, however, was conditioned upon completion of a number of interrelated activities, including the quantification and litigation of the Federal reserved water rights for Dinosaur National Monument and completion of studies to determine the minimum water requirements to preserve the habitat for endangered species of fish in the Green River.

The Bureau of Land Management's Gunnison Resource Management Plan analyzed the Gunnison River pursuant to the Wild and Scenic Rivers Act. Only one segment of the Lake Fork of the Gunnison River (13.3 mi) met eligibility criteria for a potential classification as "recreational" and was carried further into the process. The plan, however, determined that segment was not suitable for inclusion in the National Wild and Scenic Rivers System (57 Fed. Reg. 11,727, April 7, 1992).

The Green River is under continuing consideration for potential additions to the National Wild and Scenic Rivers System. Therefore, Western must consider the status of the river in all planning for the use and development of water and related land resources. Any Federal agency having jurisdiction over any lands that include, border upon, or are adjacent to any river included in the National Wild and Scenic Rivers System, or under consideration for such inclusion, shall take such action as necessary to protect such rivers in accordance with the act (16 USC §1283). In addition, any Federal agency shall inform the Secretary of the Interior and, where national forest lands are involved, the Secretary of Agriculture of any proceedings, studies, or other activities within their jurisdiction that affect or may affect any of the rivers designated as potential additions to the National Wild and Scenic Rivers System. The Bureau of Land Management, the state of Utah, and the U.S. Forest Service jointly manage the land along the section of the Green River under consideration. None of the actions considered in the EIS would affect the wild or scenic river status of either the Colorado, Green, or Gunnison rivers.

9.3.5 Executive Order 11988 ¾ Floodplain Management; Executive Order 11990 ¾ Protection of Wetlands

Executive Order 11988 (May 21, 1977) requires Federal agencies to establish procedures to ensure that the potential effects of flood hazards and floodplain management are considered for any action undertaken in a floodplain, and that floodplain impacts be avoided to the extent practicable. Executive Order 11990 (May 24, 1977) requires all Federal agencies to consider protection of wetlands in decision making for a proposed action.

The DOE has established procedures (10 CFR Part 1022 ¾ Compliance with Floodplain/Wetlands Environmental Review Requirements) for compliance with these Executive Orders. These procedures require Western to assess the effects of a proposed action on the survival, quality, and natural or beneficial values of wetlands and to avoid impacts to floodplains to the extent practicable. Pursuant to the regulations, concurrent with Western's review of a proposed action, Western must prepare a floodplain/wetlands assessment. If the implementation of the proposed action, any alternative, or any hydropower operational scenario under consideration would result in changes or effects on floodplains or wetlands, Western must assess the positive, negative, direct and indirect, and long- and short-term effects of these actions and, if necessary, assess alternatives that may avoid adverse effects in the floodplain or wetlands area (10 CFR 1022.12). Such assessments are included in Section 4.2.3 for floodplains and in Appendix D (Section D.4) for wetlands. The assessments of hydropower operational scenario impacts indicate tradeoffs between the benefits of reduced erosion and increases in upper riparian zone vegetation and the adverse impacts to lower riparian zone vegetation that would occur as fluctuations are reduced.

9.4 ECOLOGICAL RESOURCES

9.4.1 Endangered Species Act of 1973 (16 USC §§1531 et seq.)

The Endangered Species Act is intended to prevent the further decline of endangered and threatened species of animals and plants and to restore these species and their habitats. The act is jointly administered by the U.S. Department of the Interior (all nonmarine plant and animal species and their habitats) and the U.S. Department of Commerce (marine plant and animal species and their habitats). Under terms of Section 7 of the act (16 USC §1536), Western is required to consult with the Department of the Interior, Fish and Wildlife Service (USFWS), to ensure that any action carried out by Western is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of critical habitat of such species. Section 7(b) of the act requires the USFWS to issue a written statement setting forth its opinion detailing how the agency action affects listed species or critical habitat. Biological assessments are required under Section 7(c) of the act if listed species or critical habitat may be present in an area affected by any "major construction activity." No construction is contemplated under the proposed action, any alternatives, or any hydropower operational scenario; therefore, Western is not required to ask for a species list or prepare a biological assessment. However, since hydropower operations affect the timing and release of flows from existing dams and thus might impact downstream aquatic and terrestrial environments, the USFWS recommended that Western prepare a biological assessment (Harris 1991).

Western has consulted the USFWS, and biological assessments concerning potential impacts on endangered and threatened species or their critical habitats in the vicinity of the hydropower facilities are included in Sections 3.4 and 4.2.4. The identification of endangered and threatened species and their habitats is found in 50 CFR Parts 17 and 402. The endangered, threatened, and candidate species found in the vicinities of the hydropower facilities are listed in Tables 3.10 through 3.14. Most impacts identified to species from hydropower operational scenarios would be relatively minor, but there would be tradeoffs as some species responded favorably to fluctuating flows (e.g., bald eagle), while others would benefit from reductions in fluctuations (most other species).

A state is expressly permitted to continue to legislate and regulate with respect to endangered and threatened species of animals and plants within that state provided such legislation or regulation does not impair the effectiveness or relax the requirements of Federal law or contravene the terms of a Federal permit or exemption.

The Arizona Game and Fish Commission Heritage Fund (Arizona Revised Statutes, Title 17) authorizes the Arizona Game and Fish Commission to perform habitat evaluations relative to proposed projects. The evaluators are to assess the status, condition, and ecological value of potentially affected habitat and to make recommendations regarding management, conservation, or other protection measures, or mitigation measures (including reasonable alternatives) for a project that might affect such habitat. In Arizona, the Game and Fish Commission adopted the Federal list of threatened and endangered species (50 CFR 17.11, revised as of April 10, 1987) (Arizona Revised Statutes, Title 17, Article 6, Section 17-296). However, Arizona also recognizes threatened native wildlife species listed in Threatened Native Wildlife in Arizona, published by the Arizona Game and Fish Department (1988) (Arizona Administrative Code, Title 12, Chapter 4, Section R12-4-401). These species are included in Tables 3.10 and 3.11.

Under the Colorado Non-Game, Endangered, or Threatened Species Conservation Act (Colorado Revised Statutes, Title 33, Article 2), the Colorado Wildlife Commission is to establish a list of those species and, where necessary, subspecies of wildlife indigenous to the state that are determined to be endangered or threatened within the state. It is unlawful for any person to take, possess, transport, export, process, sell or offer for sale, or ship any species or subspecies of wildlife appearing on such list. These species are included in Table 3.14.

Under the Wildlife Resources Code of Utah, it is unlawful for any person to take any protected wildlife (Utah Code Annotated, Title 23, Chapter 20, Section 23-20-3). Utah has also adopted the definition of threatened and endangered wildlife as designated in the Federal Endangered Species Act of 1973 (Utah Code Annotated Title 23, Chapter 13, Section 23-13-2). In addition, it is unlawful for any person, company, or corporation owning or controlling any reservoir or other waterway leading from or into any state waterway containing protected aquatic wildlife to drain or divert sufficient water so as to endanger protected aquatic wildlife therein, without giving five days written notice to the Division of Wildlife Resources (Utah Code Annotated, Title 23, Chapter 15, Section 23-15-5). It is also unlawful for any person to pollute any waters deemed necessary by the Wildlife Board for wildlife purposes or any waters containing protected aquatic wildlife and stoneflies (Plecopera), mayflies (Ephemoptera), dragonflies and damsel flies (Odonata), water bugs (Hemiptera), caddisflies (Trichoptera), spongille flies (Neuroptera) and crustaceans (Utah Code Annotated, Title 23, Chapter 15, Section 23-15-6). Utah-listed species are also included in Tables 3.12 and 3.13.

9.4.2 Migratory Bird Treaty Act (16 USC §§703 et seq.)

The Migratory Bird Treaty Act is intended to protect birds that have common migration patterns through North America. The act regulates the harvest of migratory birds by specifying the mode of harvest, hunting seasons, and bag limits. The act stipulates that it is unlawful at any time, by any means, or in any manner to "kill . . . any migratory bird." Although no permit is required under this act, Western would consult with the Fish and Wildlife Service, as appropriate, regarding impacts to migratory birds and ways to avoid or minimize those impacts. Sections 3.4 and 4.2.4 include discussions of birds present near facilities and impacts that would occur under various hydropower operational scenarios. Although most species would benefit from reduced fluctuations, waterfowl below Flaming Gorge Dam could be adversely affected by reduced fluctuations because of the greater ice cover that would occur in the winter.

9.4.3 Bald and Golden Eagle Protection Act (16 USC §§668-668d)

The Bald and Golden Eagle Protection Act makes it unlawful to take, pursue, molest, or disturb bald (American) and golden eagles, their nests, or their eggs anywhere in the United States. No permits or approval procedures are required unless a nest interferes with resource development. In that case, a permit must be obtained from the Department of the Interior to relocate the nest. Bald eagles are common during the winter and migration period below Glen Canyon Dam, Flaming Gorge Dam, and along the shores of all three Aspinall reservoirs. Neither the proposed action, any alternative, nor any hydropower operational scenario under consideration is expected to have important impacts on the bald eagle (Sections 4.2.4.1.3, 4.2.4.2.3, 4.2.4.3.3).

9.4.4 Fish and Wildlife Coordination Act (16 USC §§661 et seq.)

The Fish and Wildlife Coordination Act is intended to ensure that wildlife conservation receives equal consideration and is coordinated with other features of water resource development programs through effective planning, development, maintenance, and coordination of wildlife conservation and rehabilitation. The act applies whenever the waters of any stream or other body of water greater than or equal to 10 acres in surface area are proposed or authorized to be controlled or modified by any department or agency of the United States. Western is required to consult with the USFWS and the head of the state agency administering the wildlife resources of the affected state. The department or agency is also requested to provide for the development and improvement of wildlife resources in conjunction with the proposed action.

Western has consulted with representatives of the USFWS and of the appropriate wildlife agencies in Arizona, Colorado, and Utah. The consultation, conference, and biological assessment procedures under Section 7 of the Endangered Species Act of 1973 have been consolidated with interagency cooperation procedures required by the Fish and Wildlife Coordination Act (50 CFR 402.06). The recommendations of the USFWS shall be given full consideration relative to determining possible damage to wildlife resources caused by the implementation of the proposed action, any alternative, or any hydropower operational scenario under consideration and relative to determining means and measures that should be adopted to prevent the loss of or damage to such wildlife resources.

A Fish and Wildlife Coordination Act report was prepared for this EIS (USFWS 1995). Justifiable means and measures for wildlife protection from that report are incorporated into the impact discussions presented in Sections 4.2.4.2 and 4.2.4.3 of this EIS.

9.5 HISTORICAL, ARCHAEOLOGICAL, AND CULTURAL RESOURCE REQUIREMENTS

9.5.1 National Historic Preservation Act (16 USC §§470 et seq.) and Archaeological and Historic Preservation Act (16 USC §§469a et seq.)

effects of their actions on sites that are eligible for inclusion in the National Register of Historic Places (NRHP). Regulations established in 36 CFR Part 800 require consultation with the State Historic Preservation Officer (SHPO) and notification of the Advisory Council on Historic Preservation if a proposed action could impact such sites. Consultation generally results in execution of a Memorandum of Agreement that stipulates measures to minimize adverse impacts.

If a determination is made that Western's actions will have an effect on an archaeological site or historic structure, Western shall, in consultation with the appropriate SHPO, apply the Criteria of Adverse Effect [36 CFR 800.5(c)]. The effect of an undertaking is deemed adverse when it may diminish the integrity of the property's location, design, setting, materials, workmanship, feeling, or association. Such effects include, but are not limited to, (1) physical destruction, damage, or alteration; (2) isolation of the property from or alteration of the character of the property's setting, when that character contributes to the property's qualification for the NRHP; (3) introduction of visual, audible, or atmospheric elements that are out of character with the property or its setting; or (4) neglect of a property resulting in its deterioration or destruction [36 CFR 800.9(b)].

If the effect is found to be adverse, Western must notify the Advisory Council and consult with the appropriate SHPO to seek ways to avoid or reduce the effect. Such consultation may involve other interested persons, including local government or Indian tribal representatives. In addition, an adequate opportunity must be provided for members of the public to receive information and express their views [36 CFR 800.5(e)(4)]. If Western and the SHPO agree upon how the effects will be taken into account, they are to execute a Memorandum of Agreement and submit it to the Advisory Council. If an agreement cannot be reached and there is no Memorandum of Agreement, Western is to request Advisory Council comments. Western then is to consider the Advisory Council's comments in reaching a final decision on the proposed undertaking [36 CFR 800.6(c)(2)].

None of the commitment-level alternatives would affect any archaeological site or historical structure. In addition, most of the hydropower operational scenarios feature reduced fluctuations that would reduce erosion rates potentially affecting these resources.

9.5.2 American Indian Religious Freedom Act (42 USC §1996)

The American Indian Religious Freedom Act is intended to protect and preserve for Native Americans their inherent right of freedom to believe, express, and protect the traditional religions of Native Americans, including access to religious or traditional sites, use and possession of sacred objects, and freedom to worship through ceremonies and traditional rites.

During preparation of this EIS, representatives of the San Juan Southern Paiute, Southern Ute Tribe, Ute Mountain Tribe, and Ute Indian Tribe (Uintah and Ouray Reservation) were contacted for identification of cultural resources. The sites, areas, or resources of religious or cultural significance in the Glen Canyon affected area are discussed in Sections 3.5 and 4.2.5. No sites, areas or resources of Native American religious or cultural significance currently have been identified to date in the affected areas at Flaming Gorge Dam or the Aspinall Unit.

9.5.3 Wilderness Act of September 3, 1964 (16 USC §§1131 et seq.)

The Wilderness Act of September 3, 1964, establishes the National Wilderness Preservation System to ensure that an increasing population, accompanied by expanding settlement and growing mechanization, does not occupy and modify all areas within the United States, leaving no lands designated for preservation and protection in their natural condition. Each agency administering an area designated as wilderness is responsible for carrying out its duties so as to preserve the wilderness character.

In the Notice of the Availability of the Final Wilderness Environmental Impact Statement, the Bureau of Land Management (BLM) found that 35,380 acres of the Diamond Breaks Wilderness Study Area (which abuts a segment of the Green River) may be suitable for preservation as wilderness in the National Wilderness Preservation System under Section 1(c) of the act (55 Fed. Reg. 48,915, November 23, 1990). The BLM will next make a report to the President. Designation of the area as wilderness would require a recommendation of the President and approval by an act of Congress.

During the period of review and until Congress has determined otherwise, the BLM shall continue to manage such lands so as not to impair their suitability for preservation as wilderness. The BLM shall take appropriate action to prevent unnecessary or undue degradation of the lands and their resources and to afford environmental protection (Federal Land Policy and Management Act of 1976, 43 USC §1782; 43 CFR Part 8560).

In addition to the Diamond Breaks Wilderness Study Area, much of Dinosaur National Monument and of Grand Canyon National Park are being considered for designation as wilderness.

None of the commitment-level alternatives or hydropower operational scenarios considered in this EIS would affect the status of any of the areas being considered for designation as wilderness.

9.6 MANAGEMENT OF WASTES AND HAZARDOUS MATERIALS

Development and implementation of power marketing criteria by Western Power Administration will not result in the generation of solid or hazardous wastes under the Resources Conservation and Recovery Act (42 USC §§6901 et seq.) or the release to the environment of hazardous substances requiring cleanup under the Comprehensive Environmental Response, Compensation and Liability Act (42 USC §§9601 et seq.).

9.7 ENVIRONMENTAL JUSTICE

Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," was issued on February 11, 1994. Under the executive order, each federal agency is directed to "make environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low income populations." DOE has not yet issued formal guidance on implementation of the executive order. Information on environmental justice topics is presented in several sections of the EIS. Information on the distribution of minority and low-income individuals across the nine subregions used in the socioeconomic analysis is presented in Section 3.1.2.2. Impacts of commitment-level alternatives on these communities are discussed in Section 4.1.1.4.2. No disproportionately high and adverse impacts were identified for either low income or minority populations. 1 A major stationary source means any of a number of listed stationary sources of air pollutants that emit, or have the potential to emit, 100 tons per year or more of any pollutant subject to regulation or any stationary source that emits or has the potential to emit 250 tons per year or more of any air pollutant subject to regulation.

10 CONSULTATION, COORDINATION, AND PUBLIC INVOLVEMENT

In preparation of the Electric Power Marketing EIS, agencies, organizations, professional experts, and the public were contacted for information. This information was used (1) in formulating the scope of the impact assessment, (2) in determining the types of resources that could be affected by commitment-level alternatives, (3) in describing the nature and status of resources in the affected environment, (4) as input into models used to analyze impacts, and (5) in determining the scope of potential cumulative effects. This chapter presents a synopsis, by resource, of the various contacts that were made. In addition, the results of scoping and of public review of the draft EIS are summarized.

10.1 CONSULTATION AND COORDINATION

10.1.1 Socioeconomics

Much of the information used in the socioeconomic analyses was obtained from existing data sources or modeling systems developed by academic and commercial entities. Some additional data were obtained from the Energy Information Administration of DOE and various Rural Electrification Associations. Analyses for power systems, financial viability and rates, and demand-side management relied on information obtained from individual long-term firm sales power customers (i.e., the Colorado River Energy Distributor's Association members) and investor-owned utilities likely to be affected by changes in electricity rates under Western power marketing programs. These contacts provided confidential information concerning utility system loads, resources and contracts, and the effects of energy and spot market activities associated with existing and potential Western power marketing activities.

Reclamation was contacted for information on the operational characteristics of SLCA/IP hydroelectric facilities. Reclamation also supplied data on the methods used by the Colorado River Simulation System (CRSS) to model the monthly operations of hydroelectric facilities.

In addition, HBRS, Inc., was consulted regarding data on the dollar value of recreation (both angling and white-water boating) that were developed as part of the Glen Canyon Environmental Studies. These data were also used in the assessment of the economic value of recreation below Flaming Gorge Dam.

10.1.2 Air Resources

Information and data on the region's climate, meteorology, ambient air quality, and ambient air quality monitoring stations were obtained from a number of Federal, state, and local agencies. A selected list of these agencies include the following:

- Air Quality Division, National Park Service, Fort Collins, Colorado;
- Arizona Office of Air Quality, Department of Environmental Quality, Phoenix, Arizona;
- Clark County Air Pollution Control Division, Clark County Health District, Las Vegas, Nevada;
- Colorado Air Pollution Control Division, Colorado Department of Health, Denver, Colorado;
- State Climatologist's Offices, Colorado, Utah, and Nevada;
- State of New Mexico Air Quality Bureau, New Mexico Environmental Department, Santa Fe, New Mexico;

Upper Colorado River Basin Commission, Salt Lake City, Utah;
- Utah Bureau of Air Quality, Air Monitoring Center, Salt Lake City, Utah; and
- Wyoming Air Quality Division, Department of Environmental Quality, Cheyenne, Wyoming.

10.1.3 Water Resources

Information on past reservoir operations (dam releases and reservoir levels), hourly and daily river flow, sediment load, and future release patterns was obtained from several agencies. Some of this information was available from Western's own records for each facility. Other information was obtained through contacts with the following institutions and agencies:

- Arizona State University;
- National Park Service;
- Northern Arizona University;
- Uncompahgre Valley Water User's Association;
- University of Arizona;
- U.S. Bureau of Reclamation, Salt Lake City, Utah;
- U.S. Geological Survey, Boulder, Colorado; Denver, Colorado; Salt Lake City, Utah; and
- U.S. Fish and Wildlife Service, Denver, Colorado.

10.1.4 Ecological Resources

To obtain information and data on ecological resources, agencies responsible for managing lands within the affected area were contacted. Information on ecological resources downstream of the Glen Canyon Dam was also obtained from the Glen Canyon Dam EIS (Reclamation 1995). Of greatest interest were those resources or species deemed important or sensitive by resource agencies. These resources included important habitats (e.g., riparian habitat), game animals, nongame animals of concern (either listed as threatened or endangered or being actively managed as an important resource), recreational fish species (e.g., trout), and nongame fish. Included here are contacts made as part of Section 7 consultations for compliance with the Endangered Species Act. The agencies contacted are listed below.

10.1.4.1 Glen Canyon Dam

- Arizona Game and Fish Department;
- Bureau of Land Management, Shivlitz and Vermillion Resource Area;
- National Park Service, Arches National Park;
- National Park Service, Canyonlands National Park;
- National Park Service, Glen Canyon National Recreation Area;
- National Park Service, Grand Canyon National Park;
- National Park Service, Lake Mead National Recreation Area;
- Northern Arizona University, Cooperative Park Study Unit;
- U.S. Fish and Wildlife Service, Phoenix District Office;
- U.S. Fish and Wildlife Service, Ecological Services, Phoenix District; and
- U.S. Forest Service, Kaibab National Forest.

10.1.4.2 Flaming Gorge Dam

- Bureau of Land Management, Bookcliffs Recreation Area;
- Bureau of Land Management, Grand Resource Area;
- Bureau of Land Management, Diamond Mountain Resource Area;

- Bureau of Land Management, Moab District Office;
- Bureau of Land Management, Price River Resource Area;
- Bureau of Land Management, San Juan Resource Area;
- Bureau of Land Management, San Rafael Resource Area;
- Bureau of Land Management, Vernal District Office;
- Colorado Division of Wildlife, Northwest Region;
- Colorado National Heritage Program;
- National Park Service, Canyonlands National Park;
- National Park Service, Dinosaur National Monument;
- U.S. Fish and Wildlife Service, Browns Park National Wildlife Refuge;
- U.S. Fish and Wildlife Service, Utah-Colorado Office;
- U.S. Fish and Wildlife Service, Colorado River Fishery Project;
- U.S. Fish and Wildlife Service, Fish and Wildlife Enhancement, Utah-Colorado Field Office;
- U.S. Fish and Wildlife Service, Vernal Field Office, Utah;
- U.S. Forest Service, Ashley National Forest;
- U.S. Forest Service, Flaming Gorge National Recreation Area;
- Utah Department of Wildlife Resources, Browns Park WildlifeManagement Area; and
- Utah Natural Heritage Program.

10.1.4.3 Aspinall Unit

- Bureau of Land Management, Gunnison Resource Area;
- Bureau of Land Management, Uncompahgre Basin Resource Area;
- Colorado Division of Wildlife, Northwest and Southwest Regions;
- Denver Botanic Gardens, Colorado Native Plant Society;
- National Park Service, Black Canyon of the Gunnison National Monument;
- National Park Service, Curecanti National Recreation Area;
- San Juan College;
- The Nature Conservancy, Colorado National Heritage Program;
- U.S. Fish and Wildlife Service, Colorado River Fishery Project;
- U.S. Fish and Wildlife Service, Grand Junction Field Office;
- U.S. Fish and Wildlife Service, Utah-Colorado Field Office;
- U.S. Fish and Wildlife Service, Fish and Wildlife Enhancement, Western Colorado Sub-office; and
- U.S. Forest Service, Grand Mesa, Uncompahgre, and Gunnison National Forests.

10.1.5 Cultural Resources

Background material for the cultural resources sections was obtained from several agencies. In addition, consultations for compliance with the National Historic Preservation Act and the American Indian Religious Freedom Act were conducted and are referenced here. Consultations for Glen Canyon Dam were not conducted separately for the Electric Power Marketing EIS, but were adopted from the Glen Canyon EIS. Consultations for the Glen Canyon EIS were conducted between Reclamation, NPS, the Arizona State Historic Preservation Office, Indian Tribes (Hopi Tribe, Navajo Nation, Pueblo of Zuni, San Juan Southern Paiute Tribe, Southern Utah Paiute Consortium), and the Advisory Council on Historic Preservation, and a programmatic agreement was developed. The agencies contacted in preparation of the Electric Power Marketing EIS are listed below.

10.1.5.1 Glen Canyon Dam

- National Park Service, Grand Canyon National Park; and
- U.S. Geological Survey, Boulder, Colorado.

10.1.5.2 Flaming Gorge Dam

- Colorado Historical Society, Office of Archaeology and Historic Preservation, Denver, Colorado;
- Bureau of Land Management, Green River Resource Area;
- Bureau of Land Management, Pinedale Resource Area;
- Bureau of Land Management, Vernal District;
- Colorado Historical Society, Office of Archaeology and Historic Preservation;
- National Park Service, Dinosaur National Monument;
- State Historic Preservation Office, Salt Lake City, Utah;
- Uintah and Ouray Reservation, Fort Duschene, Utah; and
- U.S. Forest Service, Vernal, Utah. 10.1.5.3 Aspinall Unit
- Colorado Historical Society, Office of Archaeology and Historic Preservation; and
- National Park Service, Midwest Archaeological Center.

10.1.6 Land Use

Information for the analysis of land use in the affected areas was derived from a variety of sources, such as state and local units of government, Federal agencies, and private citizens involved in the land management process. Contacts for the affected areas of Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit are listed in the following subsections.

10.1.6.1 Glen Canyon Dam

- Bureau of Land Management, Arizona Strip District Office;
- City of Page, Planning and Zoning Department, Page, Arizona;
- Coconino County Department of Planning and Community Development, Flagstaff, Arizona;
- Mohave County Planning and Zoning Commission, Kingman, Arizona;
- National Park Service, Grand Canyon National Park; and
- National Park Service, Western Team Planning Section, Denver, Colorado.

10.1.6.2 Flaming Gorge Dam

- Bureau of Land Management, Colorado State Office;
- Bureau of Land Management, Craig District Office;
- Bureau of Land Management, Vernal District Office;
- Colorado Board of Land Commissioners, Denver, Colorado;
- Colorado Division of Local Government, Denver, Colorado;
- Colorado Division of Property Taxation, Denver, Colorado;
- Daggett County Zoning and Planning Board, Manila, Utah;
- Moffat County, Office of County Clerk, Craig, Colorado;
- National Park Service, Western Team Planning Section, Denver, Colorado;
- National Park Service, Dinosaur National Monument;
- Uintah County Planning Office, Vernal, Utah;
- U.S. Forest Service, Ashley National Forest;
- U.S. Forest Service, Flaming Gorge National Recreation Area;
- Utah Department of Transportation, Salt Lake City, Utah; and
- Utah Office of Planning and Budget, Salt Lake City, Utah.

10.1.6.3 Aspinall Unit

- Bureau of Land Management, Colorado State Office;
- Bureau of Land Management, Montrose District Office;
- Colorado Board of Land Commissioners, Denver, Colorado;
- Colorado Division of Local Government, Denver, Colorado;
- Colorado Division of Property Taxation, Denver, Colorado;
- Gunnison County Department of Planning, Building, and Environmental Health, Gunnison, Colorado;
- Montrose County Land Use Department, Montrose, Colorado;
- National Park Service, Black Canyon of the Gunnison National Monument;
- National Park Service, Curecanti National Recreation Area;
- National Park Service, Western Team Planning Section, Denver, Colorado; and
- U.S. Forest Service, Regional Forester, Lakewood, Colorado.

10.1.7 Recreation

Information for the analysis of recreation in the affected areas was obtained from state and local units of government, Federal agencies, and citizens and firms involved in providing recreational services. These contacts are listed below.

10.1.7.1 Glen Canyon Dam

- Coconino County Department of Planning and Community Development, Flagstaff, Arizona;
- National Park Service, Glen Canyon National Recreation Area, Page, Arizona; and
- National Park Service, Grand Canyon National Park, Grand Canyon, Arizona.

10.1.7.2 Flaming Gorge Dam

- Bureau of Land Management, Colorado State Office, Lakewood, Colorado;
- Bureau of Land Management, Craig District Office, Craig, Colorado;
- Bureau of Land Management, Vernal District Office, Vernal, Utah;
- Colorado Division of Wildlife, Denver, Colorado;
- Flaming Gorge Natural History Association, Dutch John, Utah;
- Hatch River Expeditions, Vernal, Utah;
- National Park Service, Denver Service Center, Western Team Planning Section, Denver, Colorado;
- National Park Service, Dinosaur National Monument, Dinosaur, Colorado;
- Uintah County Planning Office, Vernal, Utah;
- Utah Department of Transportation, Salt Lake City, Utah;
- Utah Division of Parks and Recreation, Salt Lake City, Utah;
- Utah Division of Wildlife Resources, Salt Lake City, Utah;
- U.S. Forest Service, Ashley National Forest; and
- U.S. Forest Service, Flaming Gorge National Recreation Area.

10.1.7.3 Aspinall Unit

- Bureau of Land Management, Colorado State Office, Lakewood, Colorado;
- Bureau of Land Management, Montrose District Office;
- Colorado Department of Natural Resources, Division of Wildlife, Denver, Colorado;
- Elk Creek Marina, Inc. Gunnison, Colorado;
- National Park Service, Denver Service Center, Western Team Planning Section, Denver, Colorado;
- National Park Service, Black Canyon of the Gunnison National Monument; and
- National Park Service, Curecanti National Recreation Area.

10.1.8 Visual Resources

Information used in the analysis of visual resources in the affected areas was obtained from the few Federal agencies that have almost exclusive jurisdiction. These are listed below for each facility.

10.1.8.1 Glen Canyon Dam

- National Park Service, Glen Canyon National Recreation Area; and
- National Park Service, Grand Canyon National Park.

10.1.8.2 Flaming Gorge Dam

- Bureau of Land Management, Vernal District Office;
- National Park Service, Dinosaur National Monument; and
- U.S. Forest Service, Ashley National Forest.

10.1.8.3 Aspinall Unit

- National Park Service, Curecanti National Recreation Area.

10.2 PUBLIC INVOLVEMENT

10.2.1 Scoping Process

An extensive effort was made to notify all potentially interested parties about the EIS process. This effort included notification in the Federal Register, mailings of letters and informational packets to interested parties, press releases, and paid advertising concerning the schedule for the public scoping meetings. The Federal Register notice of the scoping period was published on April 4, 1990.

In addition to the Federal Register notice, a press release was sent to approximately 1,000 media representatives throughout the areas where the public meetings were to be held. Ads were run for several days before each scoping meeting in major newspapers in the cities where the meetings were held.

A letter announcing the EIS was also mailed to approximately 1,300 groups and individuals. The mailing list used for this process was compiled through records already in existence at Western and originating from a variety of sources, including previous environmental processes in which Western has participated. This list was supplemented with the names of individuals who specifically requested that they be placed on the mailing list for the EIS. A special information packet was also prepared and mailed to this same list of interested parties. The packet summarized the reasons for the EIS and some of the issues under consideration. It also provided a list of power marketing terms and their definitions, as well as a schedule for the full EIS process.

A letter inviting state agencies to comment on the scoping process was sent to state clearinghouses in Utah, Arizona, New Mexico, Colorado, and Wyoming. The letter explained the rationale behind the EIS and explained that Western representatives would be available to discuss the EIS process with any state agencies desiring a briefing on the subject. In addition, several Federal and state agencies were included on the mailing list of the letter to interested parties announcing the EIS.

An EIS update brochure was also sent to the list of interested parties. The brochure contained the most recent information concerning the EIS (e.g., schedules, scoping meeting attendance, new meeting times, etc.) and an offer for Western officials to speak with organizations about the EIS.

Seven public scoping meetings were held in Utah, Colorado, New Mexico, and Arizona. Meeting locations were chosen according to two key factors. The first was the general service area affected by the marketing program, that is, that geographic area with utility customers that would be directly influenced by the marketing program decisions made subsequent to the EIS. The second factor was related to areas in which there had already been considerable interest expressed in the operation of the dams within Western's marketing territory. Western scheduled the meetings in those cities so that the greatest numbers of interested persons could attend. The meetings generally lasted 2 to 2.5 hours. A total of 322 persons attended the meetings, with 110 individuals presenting comments.

While public scoping meetings were held, individuals were invited by Western to submit written comments regarding the EIS. More than 20,000 pieces of correspondence were received. The period for submittal of written comments was between April 4 and December 31, 1990.

The environmental, recreational, and utility groups attempted to solicit opinions through grassroots campaigns in addition to their direct and written testimony. For example, an "issue alert" was mailed to members of Friends of the River. The issue alert asked that constituents write letters to Western with the following:

Your letter should urge WAPA officials to consider the following in the Scope of their EIS:

- WAPA must identify and evaluate the effects of peak power marketing on downstream river resources ¾ habitat, beaches, fisheries, wildlife, and recreation.
- WAPA must evaluate the effects of peak power marketing on regional energy production and air quality.
- WAPA must consider alternatives for the amount of power produced at different times of day, including specific minimum and maximum flows and the option of producing power at a steady rate around the clock.
- WAPA must consider alternatives for the selection of its preference power customers, including alternatives that will encourage energy conservation and environment compliance.
- WAPA must consider alternatives for power pricing to encourage energy conservation.

The National Wildlife Federation distributed an "action alert" with a similar message to its constituents. Western received 182 letters reflecting these solicitations. Additional letters came from individuals throughout the country, some of which were in response to the issue and action alerts, but that also included other substantive points.

The Intermountain Consumer Power Association initiated a postcard campaign through their member utilities to induce its customers to submit a prewritten comment. Western received 19,522 of these postcards. The postcard stated: "The scope of the study should be limited to the impacts of the marketing criteria. It should not encompass operations of the Colorado River beyond the proposed marketing criteria. Economic impacts of any alternatives to the present marketing criteria should be fully evaluated, including the impact on power costs."

The greatest number of those who signed and submitted these cards were in favor of this message. Also, 577 individuals wrote additional comments on the card in support of this approach to the EIS. However, 120 individuals either changed the wording on the card to reverse its intended message or submitted a card with a note that stated they did not support their utility's position on the EIS.

Western also received letters from individuals living or doing business near the locations of the scoping hearings. Some of these individuals were not aware of the hearing in their community or could not come. In some cases, they attended the hearings and did not testify, choosing instead to write a comment letter at a later time. Comments were also received from state and regional agencies and government entities.

Another type of letter received by Western was written follow-up to oral testimony. In some cases, the written submittal added comments not included in the oral presentation. In other cases, these comments changed over time as issues were raised at the scoping meetings.

Although some individuals submitted comments on their own behalf during the scoping period, by far the greatest number of comments came from representatives of established organizations. Some of the organizations most frequently represented during the scoping period include those described below:

Intermountain Consumer Power Association: Intermountain Consumer Power Association (ICPA) represents about 37 municipal utilities and rural electric cooperatives scattered throughout the states of Utah, Arizona, and Nevada. The utilities in ICPA serve about 25% of the population of Utah.

Colorado River Energy Distributor's Association: The Colorado River Energy Distributor's Association (CREDA) is a Colorado corporation representing nonprofit public utilities that purchase most of the power generated by the Colorado River Storage Project. CREDA's members are located in Arizona, Colorado, New Mexico, Nevada, Utah, and Wyoming and serve some 3 million consumers.

National Wildlife Federation: The National Wildlife Federation is the nation's largest conservation-education organization with more than 5.8 million members and supporters and 51 state and territorial affiliates.

National Audubon Society: The Rocky Mountain States Region of the Audubon Society represents about 25,000 members scattered throughout these states in more than 50 chapters.

The Wilderness Society: The Wilderness Society is a nonprofit membership organization dedicated to the preservation and wise management of public lands and natural ecosystems. The society has a membership of 420,000 people.

Colorado Wildlife Federation: The Colorado Wildlife Federation is an affiliate of the National Wildlife Federation. It is Colorado's largest conservation-education organization, with more than 14,000 nationwide members.

Arizona Municipal Power Users Association: The Arizona Municipal Power Users Association has a collective membership that delivers approximately half the electricity in the state of Arizona.

Trout Unlimited: Trout Unlimited is a national conservation organization dedicated to preserving, protecting, and enhancing the coldwater resource.

Grand Canyon Trust: The Grand Canyon Trust is a regional nonprofit organization advocating the responsible conservation of the natural resources of the Colorado Plateau.

National Parks Conservation Association: The National Parks Conservation Association is a national nonprofit organization representing 200,000 members nationwide. The association works to protect and enhance units in the national park system.

Sierra Club: The Sierra Club is a national nonprofit organization representing approximately 500,000 members that works to protect the environment.

Grand Canyon River Guides: The Grand Canyon River Guides is a not-for-profit association of Grand Canyon white-water river guides and interested members of the general public whose mission is to protect the Grand Canyon, set the standards for the guiding profession, and to promote the highest quality river experience.

Utah Guides and Outfitters: The Utah Guides and Outfitters is an organization representing professional outfitters operating in Utah. It includes a large body of river outfitters.

10.2.2 Alternatives Development

Western solicited public comments on draft commitment-level alternatives and hydropower operational scenarios developed for the EIS. Alternatives and scenarios were presented in a series of five public meetings held in June 1992 in Salt Lake City, Utah; Phoenix and Flagstaff, Arizona; Albuquerque, New Mexico; and Denver, Colorado. For the most part, the meetings were well attended and there was active public participation at each of the presentations. As a result of these meetings, Western received 30 written comments on the alternatives, operational scenarios, and other aspects of the EIS, particularly scope. These comments were taken into consideration in developing the final set of commitment-level alternatives and hydropower operational scenarios evaluated in the EIS.

10.2.3 Comments on the Draft EIS

The draft EIS was made available to the public for review on March 28, 1994, with publication of a Notice of Availability in the Federal Register. Availability was also announced on March 25 through press releases and in the project newsletter EIS Update (Western 1994b). The draft EIS was mailed to about 360 individuals or organizations at the time of notification. An additional 30 copies of the draft EIS were mailed to individuals at their request. At the same time, the draft EIS and all supporting documents were made available for public review in reading rooms established in Flagstaff, Page, and Phoenix, Arizona; Denver, Loveland, and Montrose, Colorado; Albuquerque, New Mexico; Salt Lake City and Vernal, Utah; and in Washington, D.C. The location of these reading rooms was identified in the Notice of Availability and the EIS Update.

Comments on the draft EIS were received from the public either in written mailed-in form or at public hearings held in April 1994 in Denver, Colorado; Salt Lake City, Utah; Flagstaff, Arizona; and Phoenix, Arizona. The public was informed of the hearings through local press releases and the EIS Update. The close of the public comment period was June 30, 1994. During that period, a total of 41 comment documents were received (including hearing transcripts); 444 individual comments were categorized from these documents. The comments covered the entire range of subjects discussed in the EIS, but economic issues, both concerns with the cost of electricity and impacts on the economics of recreation downstream from the dams, and impacts on ecological resources predominated. Each comment was considered individually, and a response was prepared by the technical staff who wrote the EIS. Comments on the draft EIS and their corresponding responses, as well as a summary of all comments and responses, are presented in Appendix E.

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13 ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

ACHP - Advisory Council on Historic Preservation
AFS - American Fisheries Society
AGC - automatic (automated) generation control (see glossary)
ANL - Argonne National Laboratory
ANSI - American National Standards Institute
AOAQ - Arizona Office of Air Quality
AQCR - Air Quality Control Region (see glossary)
BART - Best Available Retrofit Technology
BLM - Bureau of Land Management
C&RE - conservation and renewable energy
CAPCD - Colorado Air Pollution Control Division
CEQ - Council on Environmental Quality
CFR - Code of Federal Regulations
cfs - cubic foot (feet) per second (see glossary)
Cir. - Circuit
CO - carbon monoxide
CO_2 - carbon dioxide
COE - Corps of Engineers (U.S. Army)
CPI - consumer price index
CR - coverage ratio
CRSM - Colorado River Simulation Model
CRSP - Colorado River Storage Project (see glossary)
CRSP-CSO - Colorado River Storage Project Customer Service Office
CRSS - Colorado River Simulation System
CV - contingent valuation
CWA - Clean Water Act
d - day(s)
dBA - decibel(s) (A-weighted) (see glossary)
D/E - debt-to-equity ratio
°C - degrees Celsius
°F - degrees Fahrenheit
DEIS - draft environmental impact statement
DOE - U.S. Department of Energy
DOI - U.S. Department of the Interior
DSM - demand-side management
EA - environmental assessment
e.g. - for example
EIA - Energy Information Administration
EIS - environmental impact statement
EPA - U.S. Environmental Protection Agency
EPAMP - Energy Planning and Management Program
EPRI - Electric Power Research Institute
et al. - and others
et seq. - and the following
Fed. Reg. - Federal Register
FEIS - Final Environmental Impact Statement
FONSI - Finding of No Significant Impacts
ft - foot (feet)

ft/s - foot (feet) per second
ft^2 - square foot (feet)
ft^2/mi - square foot (feet) per mile
ft^3 - cubic foot (feet)
GCES - Glen Canyon Environmental Studies
GRP - gross regional product (see glossary)
GWh - gigawatt hour(s)
h - hour(s)
ha - hectare(s)
h/day - hour(s) per day
H_2S - hydrogen sulfide
I - interstate
ICARUS - Investigation of Costs and Reliability in Utility Systems (computer model)
i.e. - that is
IMPLAN - Impact Analysis for Planning (computer model)
in. - inch(es)
I-O - input-output
IP - Integrated Projects
IPP - Inland Power Pool
IRP - Integrated Resource Plan
km - kilometer(s)
kV - kilovolt(s)
kW - kilowatt(s) (see glossary)
kWh - kilowatt-hour(s) (see glossary)
lb - pound(s)
L_{dn} - day-night-weighted equivalent sound level
LDC - load duration curve
L_{eq} - equivalent sound level
LTF - long-term firm
m - meter(s)
m^3/s - cubic meters per second
maf - million acre-feet
max - maximum
ug - microgram(s)
ug/m^3 - micrograms per cubic meter
um - micrometer(s)
mg - milligram(s)
mg/L - milligrams per liter
mi - mile(s)
mi^2 - square mile(s)
mm - millimeter(s)
mph - mile(s) per hour
MSL - mean sea level
MW - megawatt(s) (see glossary)
MWh - megawatt-hour(s)
NAAQS - National Ambient Air Quality Standards (see glossary)
NBAQ - Nevada Bureau of Air Quality
NCDC - National Climatic Data Center
NCF - net cash flow
NEPA - National Environmental Policy Act
No. - number
NO - nitrogen dioxide

2

NOAA - National Oceanic and Atmospheric Administration
NOI - Notice of Intent
NO_x - nitrogen oxides
NPDES - National Pollutant Discharge Elimination System
NPS - National Park Service
NPV - net product value
NRA - National Recreational Area
NRHP - National Register of Historic Places (see glossary)
NWF - National Wildlife Federation
O_3 - ozone
PACE - Production and Capacity Expansion (computer model)
Pb - lead
PEPCO - Potomac Electric Power Company
P.L. - Public Law
PM - particulate matter
PM_{10} - particulate matter with a diameter of £ 10 mm
PMI - Power Marketing Initiative
PRP - Provo River Project
RCRA - Resource Conservation and Recovery Act
RDM - Resource Dispatch Model (computer model)
Reclamation - Bureau of Reclamation
REMI - Regional Economic Models, Inc.
RM - river mile
ROD - Record of Decision
SAAQS -State Ambient Air Quality Standards
SHPO - State Historic Preservation Officer
SLCA - Salt Lake City Area
SLCA/IP - Salt Lake City Area Integrated Projects
SMN - Spot Market Network (computer model)
SNMAQB - State of New Mexico Air Quality Board
SO_2 - sulfur dioxide
SRP - Salt River Project
SSARR - Streamflow Synthesis and Reservoir Regulation (computer model)
Stat. - statute
STF - short-term firm
Supp. - Supplement
TM - Technical Memorandum
TSP - total suspended particulates
UA - urban area
UBAQ - Utah Air Quality Board
UPA - urban planning area
U.S. - United States
USC - U.S. Code
USDA - U.S. Department of Agriculture
USFS - U.S. Forest Service
USFWS - U.S. Fish and Wildlife Service
USGS - U.S. Geological Survey
VOC - volatile organic compound
vol. - volume
WAPA - Western Area Power Administration
WAQD - Wyoming Air Quality Division
WAUC - Western Area Upper Colorado (control area)

Western - Western Area Power Administration
WTP - willingness to pay (see glossary)
WUA - weighted usable area (see glossary)
yr - year(s)

14 GLOSSARY

A

abiotic:

The physical, nonliving portion of the environment. (See biotic.)

absorption (electromagnetic):

The taking up of energy from radiation by the medium through which the radiation is passing.

acoustic:

Containing, producing, carrying, arising from, actuated by, related to, or associated with sound.

acre-foot:

Volume of water (43,560 cubic feet) that would cover 1 acre, 1 foot deep.

aesthetic:

Pertaining to the beautiful or pleasing; generally, an emotional judgment of that perceived.

affected environment:

Existing biological, physical, social, and economic conditions of an area subject to change, both directly and indirectly, as the result of a proposed human action.

aggradation:

Process of filling and raising the level of a streambed or floodplain by deposition of sediment.

aggregation:

Process of combining or collecting data or results to describe a whole from the sum or combination of its parts.

air quality:

Measure of the health-related and visual characteristics of the air, often derived from quantitative measurements of the concentrations of specific injurious or contaminating substances.

Air Quality Control Region (AQCR):

An interstate area designated by the U.S. Environmental Protection Agency as necessary or appropriate for the attainment and maintenance of national ambient air quality standards.

air quality standards:

The prescribed level of constituents in the outside air that cannot be exceeded during a specific time in a specified area.

algae:

Primarily aquatic, nonvascular plants containing chlorophyll. (See Cladophora and diatoms.)

algorithm:

A procedure for solving a mathematical problem in a finite number of steps that frequently involve repetition of an operation.

alluvial, alluvium:

Relating to material deposited by running water, such as clay, silt, sand, and gravel. Sedimentary material transported and deposited by the action of flowing water.

alluvial fan:

Cone-shaped deposits of alluvium made by a stream. Fans generally form where streams emerge from mountains onto the lowland. (See fans and debris fans.)

ambient:

The surrounding natural conditions (or environment) in a given place and time.

ambient air:

The surrounding atmosphere as it exists around people, plants, and structures.

amphibians:

A class of vertebrate animals that are capable of living either in water or on land but that must lay eggs in water (e.g., salamanders, frogs, toads).

amphipod:

Any of a large group of small crustaceans with a laterally compressed body.

annual capacity factor:
The ratio of the energy produced by a power plant during one year compared with the energy it could have produced if operated at maximum capacity under continuous operation during the whole year.

anthropogenic:
Relating to or resulting from the presence of human beings and human activities.

anticline:
A convex upward fold of rock.

aquatic:
Living in or growing on the water.

archaeology:
The scientific study of extinct peoples or of past phases of the culture of historic people through skeletal remains, fossils, and objects of human workmanship (artifacts) found in the earth.

armored, armoring:
Removal of fine river-bed and river-bank sediments by high-velocity water movement.

arroyo:
A gully or channel cut by an intermittent stream.

artifact:
A man-made object of archaeological or historical interest.

attenuation:
Decrease in the height and velocity of a water wave caused by interactions with deep pools, backwaters, and banks along the flow path.

automatic generation control (AGC):
A computer control system to regulate the power output of electric generators within a range of operations to provide instantaneous response to changes in system frequency, control area load, system time error and tie-line loading so as to maintain the scheduled generation in accordance with prescribed parameters.

B

backwater:
Generally shallow area of a river with little or no current. May occur along the shoreline or within the river channel behind islands and sand or gravel bars.

baseline, electric power marketing:
In this EIS, the baseline for electric power marketing is the 1978 Colorado River Storage Project (CRSP) Marketing Plan with certain modifications made by the court. The electric power marketing baseline includes the full complement of power resources available under historical programs for Provo River, Collbran, and Rio Grande Projects.

baseline, socioeconomic:
In this EIS, the conditions predicted to prevail under the Post-1989 Marketing Criteria for the years 1993 through 2008.

baseload:
The minimum assigned load in a power system over a given period of time. Generation resource that is best suited to deliver relatively constant amounts of power over the entire day. Baseload may also refer to the minimum assigned load on a power system over a period of time.

beach:
Depositional area along a shoreline covered by mud, sand, gravel, or larger rock fragments and extending into the water for some distance.

bedrock:
Solid rock exposed at the surface of the earth or overlain by unconsolidated material.

benthic:
Associated with the bottoms of surface waters, including rivers, lakes, and oceans.

benthos: </ Organisms living in or on the bottom of a lake, pond, stream, etc.

Biological Opinion:
A document that states the opinion of the U.S. Fish and Wildlife Service as to whether a Federal action is likely

to jeopardize the continued existence of a threatened or endangered species or result in the destruction or adverse modification of critical habitat.

biota:

The plant and animal life of a region.

biotic:

Pertaining to life or living organisms; the living portion of the environment. (See abiotic.)

C

candidate species:

Plant or animal species that are not yet officially listed as threatened or endangered but are undergoing status review by the U.S. Fish and Wildlife Service. They are candidates for possible addition to the list of threatened and endangered species. (See Appendix D.)

capacity:

The rated output of a generator, and also the capability of a transmission line to carry power. Capacity is frequently used to define the amount of generation reserved for an entity's use under a contract. Capacity is measured in such terms as watts, kilowatts, and megawatts. The load for which a generator, turbine, transformer, transmission, transmission circuit, apparatus, station, or system is rated. Capacity is used synonymously with capability. Capacity is also used to define the maximum amount of power that Western's customers may take at any point in time.

channel:

Natural or artificial watercourse with a definite bed and banks to confine and conduct continuously or periodically flowing water.

channel margin bar:

Narrow sand deposits that continuously or discontinuously line a riverbank.

chironomid:

Type of fly commonly referred to as a midge. Eggs are laid in freshwater and hatch into worm-like larvae that remain aquatic. When mature, chironomids leave the water, often in large, flying swarms of gnat-like adults.

Cladophora:

Filamentous green alga occurring in flowing water that attaches itself to hard substrates such as cobble and boulders; grows in long, moss-like strands.

Class I, II, III (rapids):

Class I rapids feature small riffle-like waves and slow-to-moderate currents ideal for beginning boaters; Class II rapids generate waves up to one foot high and faster currents that require basic white-water skills. Class III or above rapids require superior white-water skills and can generate fast currents and waves up to three feet high.

colluvial (deposits):

Relating to deposition by a combination of gravity and water.

Colorado River Basin States:

States that are drained by or entitled to water from the Colorado River and its tributaries.

Colorado River Storage Project:

Act of Congress establishing the legislative authority to construct, operate, and maintain impoundments, diversions, hydropower generation facilities, and other features on the Colorado River and its tributaries.

commitment-level alternatives:

The level of Western's commitment for sales of long-term, firm power and energy generated by the Salt Lake City Area Integrated Projects, as well as power and energy purchased from other sources. (See Section 2.2.2 for a description of these alternatives.)

community:

A group of organisms comprising a number of different species that co-occur in the same habitat or area.

concentration values:

Theoretical city-wide average pollutant concentrations developed over urban areas, based on a simple dispersion model, normalized for uniform average area emission rate. constriction ratio:

Ratio of narrowed channel width to unblocked channel width.

contingent valuation:

Method asking for the maximum values that users would pay for access to a particular activity.

cooperative:

Joint venture organized to supply electric energy to a specified area.

coverage ratio:

Measure of the ratio of cash flow or interest expense on debt. It is an industry-wide standard that the coverage ratio should be >2.0.

criteria:

Elements of Western's power marketing programs that define the amounts and conditions for delivery of long-term firm power and energy offered for sale. The criteria have been known as marketing and eligibility criteria under the 1978 marketing plan because the criteria also specify who qualifies for an allocation. (See preference customers.)

crustaceans:

Any of a large class of mostly aquatic arthropods, including lobsters, shrimp, crabs, water fleas, barnacles, crayfish, and gammarus.

cubic foot per second (cfs):

Unit of discharge, or volume rate of flow, equal to 0.0283 cubic meters per second. As a rate of streamflow, a cubic foot of water passing a referenced section in one second of time. A measure of a moving volume of water (1 cfs = 0.0283 m3/s).

cultural resources:

Areas or objects that are of cultural significance to Native Americans and other ethnic groups.

cutbanks:

Bank of river or stream eroded by water to near vertical face; usually on outside bend of meander.

D

dampening:

Decrease in amplitude and velocity of a wave caused by interactions along the flowpath.

debris fans:

Sloping mass of boulders, cobbles, gravel, sand, silt, and clay formed by debris flows at the mouth of a tributary/stream valley.

debris flows:

Flash flood consisting of a mixture of rocks and sediment containing <40% water by volume; forms debris fans.

debt service coverage:

Represents how much cash flow a retail utility needs to meet its financial obligations.

debt-to-equity (D/E ratio):

A general measure of an entity's ability to pay off its debts with available equity.

decibel, A-weighted (dBA):

Unit of weighted sound-pressure level, measured by the use of a metering characteristic and the "A" weighting specified in ANSI Specification for Sound Level Meters ANSI S1.4-1983 (R1988) and Amendment S1.4A-1985 (Acoustical Society of America 1983, 1985).

degradation:

Geologic process wherein the elevation of streambeds and floodplains is lowered by erosion; the opposite of aggradation.

delta:

Sediment deposit formed at the mouth of a river or stream.

demand:

The energy requirement (load) placed upon a utility's generation at any specific point in time. A utility's demand (i.e., energy needed) increases and decreases instantaneously as consumers turn on or off their electrical appliances. Demand is increased or decreased in such terms as watts, kilowatts, and megawatts.

deposition:

Settlement of material out of the water column and onto the streambed. Occurs when the energy of the flowing water is unable to support the load of suspended sediment.

desiccation:

Removal of moisture from a substance; drying up.

dewatering:

Draining of water.

diatoms:

Microscopic, single-celled or colonial algae having cell walls of silica.

disaggregation:

Process of examining a whole and inferring something about the parts that make up the whole.

diurnal:

Pertaining to daylight hours; opposite of nocturnal.

downcutting:

Lowering of water surface elevation resulting from erosion of the river or stream bed.

down ramp, down ramping:

At hydroelectric facilities, a reduction in generation with a corresponding reduction in water releases through the penstocks and turbines. Also called ramp down. (See ramping.)

drift:

Biotic and abiotic material present in the water column of streams and rivers that is being transported by the current of the water.

E

ecological resources:

Components of terrestrial or aquatic ecosystems that are valued by humans.

ecology:

That branch of the biological sciences that studies the relationships between living organisms and their environment.

economic indicators:

In this EIS, estimates of output, employment, and disposable income that when combined, provide an overview of the aggregate level of economic activity in each of the nine subregions.

ecoregion:

Large area with similarities in ecological characteristics as related to geology and climate.

ecosystem:

Complex system composed of community organisms and their physical environment interacting as a unit.

eddies:

Areas within a stream or river where the local currents move against the main current in a circular motion; occur near obstructions to flow.

electric power marketing baseline:

(See baseline, electric power marketing.)

endangered species:

Any species or subspecies of animal or plant whose survival is threatened with extinction throughout all or a significant portion of its range. (See Appendix D.)

energy:

Amount of power generated over a given period of time (usually one hour).

energy, firm:

Electric energy that is considered to have ensured availability to the customer.

energy, nonfirm:

Energy sold by Western that varies in amount and price according to market conditions and hydrologic availability. Nonfirm energy is usually marketed on a short-term basis and is interruptible on short notice.

entrainment:

Involuntary capture and inclusion of organisms in streams of flowing water. Entrained organisms may include phyto- and zooplankton; fish (eggs, larvae, juveniles, or adults); shellfish larvae; and other forms of aquatic life.

ephemeral:

Lasting a short time (e.g., plants that grow, flower, and die within a few days).

epiphytic:

Refers to plants that grow on other plants but are not parasitic on them (e.g., diatoms living on Cladophora).

equilibrium:
Conditions in which no net erosion or aggradation is occurring. Conditions in which opposing forces are balanced, resulting in a relatively unchanging state.

equivalent sound (pressure) level:
The equivalent steady sound level that, if continuous during a specified time period, would contain the same total energy as the actual time-varying sound. For example, Leq 1- and Leq 24- are the 1-hour and 24-hour equivalent sound levels, respectively.

erosion:
Removal of sediments by water, wind, or anthropogenic activities.

evapotranspiration:
Combined process by which water is transferred from the earth's surface to the atmosphere; evaporation of liquid or solid water plus transpiration from plants.

exchanges:
(See interchanges, purchases and interchanges.)

extirpated:
A species that is no longer present due to extinction in a given area.

F

fan:
Accumulation of debris brought down by a stream descending through a steep ravine and emerging in the plain beneath, where the debris spreads out in the shape of a fan. (See alluvial fan, debris fan.)

fauna:
All animal life associated with a given habitat, area, or period.

firm electric service:
Energy and capacity sold by Western that is considered to have ensured delivery.

firm energy:
(See energy, firm.)

firming purchases:
Purchases of capacity or energy that are required to meet Western's contractual provisions of long-term firm service.

firm power:
Power that is guaranteed by the supplier to be available at all times, except for reasons of certain uncontrollable events or continuity of service provisions. (See power and nonfirm power.)

firm transmission service:
Service provided by Western to transport energy from one place to another under contracts that ensure delivery without interruption.

floodplain:
Portion of a river valley (adjacent to the river) that is covered with water when the river overflows its banks at flood stages.

flora:
All plant life associated with a given habitat, country, or period.

flow:
Daily water-release patterns; the volume of water passing a given point per unit of time.

flow regime:
The daily, monthly, or seasonal pattern of flow in a river.

fluctuating flows:
Variation in water flows throughout the day due to changes in generation to accommodate load patterns.

fluctuation zone:
Area of the stream bed that is exposed on a daily basis by fluctuating flows.

fluvial:
(sediment) Of, found in, or produced by a river.

frequency:
Number of cycles per second that an alternating current passes. In the U.S. electric utility industry, frequency has been generally standardized at 60 cycles per second (60 hertz).

frequency exceedance:
Fraction of time a variable exceeds a given threshold.

fry:
Life stage of fish between the egg and fingerling stages.

full pool:
The volume of water in a reservoir at maximum design elevation.

G

gaging station:
A place where systematic observations of hydrologic data are obtained.

gastropod:
Large class of mollusks composed of snails and slugs.

genera:
Plural of genus, a category in biological classification comprising one or more related and similar species.

generation:
Process of producing elec-trical energy by transforming other forms of energy; also, amount of electric energy produced, expressed in kilowatt hours.

geology:
The science that studies the earth; the materials, processes, environments, and history of the planet, especially the lithosphere, including the rocks and their formation and structure.

geomorphology:
Study of the configuration and evolution of land forms and earth features.

gigawatt(GW):
Unit of power equal to 1 billion watts, 1 million kilowatts, or 1 thousand megawatts.

gigawatt hour (GWh):
One million kilowatt hours of electrical energy.

gross regional product (GRP):
Value of the total output of a region measured in constant (base year) prices.

H

habitat:
Area where a plant or animal lives.

headwaters:
The source and uppermost part of a stream or reservoir.

hectare:
A unit (in the metric system) used to measure surface area equal to 10,000 square meters (2.471 acres).

herbaceous:
Pertaining to nonwoody plant life.

high water zone:
Riparian vegetation above the normal maximum water level.

historical flows or operations:
Those flows or operations occurring since construction of a dam to that time when operations recently were modified to protect downstream natural resources.

Holocene:
That period of time since the last ice age.

hydroelectric plant:
Electric power plant using falling water as its motive force.

hydroelectric power: Electrical capacity produced by water.

hydrograph:

Graph showing, for a given point in a stream, the discharge, stage, or other property of water with respect to time.

hydrologic cycle:

The continuous circulation of water from the atmosphere to earth by precipitation and from earth to the atmosphere by evaporation and transpiration. The land phase includes infiltration, runoff, and exchange between surface water and groundwater.

hydrology:

The science that studies the properties, distribution, and circulation of natural water systems.

I

igneous:

Rocks formed by solidification of hot mobile magma.

input-output (I-O):

Analysis utilizing information on the relationships among the inputs and outputs in an economy to analyze the effects of a change in some measure of economic activity, such as expenditures, on the resulting levels of income, output, and employment in the economy.

Integrated Projects:

The Salt Lake City Area Integrated Projects, which include facilities on the Upper Colorado River and its tributaries. The facilities and features of the SLCA/IP are described in Chapter 3 of this document.

interchange energy:

Energy in kilowatt-hours delivered to or received by one electric utility system from another. It may be returned in kind at a later time or may be accumulated as energy balances until the end of a stated period. Settlement under an interchange agreement may be by payment or by delivery of equivalent amounts of electricity.

interchanges:

Trading of generation resources from different locales to increase total system efficiency or avoid transmission limits; also called exchanges.

interties:

An interconnection permitting passage of current between two or more electric utility systems.

introduced species:

Species not indigenous to a given area; not naturally occurring (native in a given area but present due to human activities, e.g., stocked or accidentally released).

inundation:

To cover with impounded waters or floodwaters.

invertebrate:

Animals lacking a backbone.

isopleth:

In meteorology, a line drawn through points on a graph at which a given quantity has the same numerical values (or occurs with the same frequency) as a function of the two coordinate variables.

K

kilovolt (kV):

1,000 volts.

kilowatt (kW):

Unit of electric energy equal to 1,000 watts or about 1.34 horsepower.

kilowatt hour (kWh):

Basic unit of electric energy, equaling an average of one kilowatt of power applied over one hour.

L

larval, larvae:

A stage in development between hatching and attainment of adult form.

lithic:

Pertaining to stone or a stone tool (e.g., lithic artifact).

littoral:

Pertaining to the shore of a river, stream, or lake.

load:

The amount of power or energy required at any specified point on a system. Load is the sum of all customer demands plus electricity required for station services and project uses.

load factor:

Ratio of the average load in kilowatts supplied during a designated period to the peak or maximum load in kilowatts occurring in that period. Load factors represent, in general terms, the type of service offered under the contracts, which is meant to service either the baseload or peaking portion of customer loads. Load factor, in percent, may be derived by multiplying the kilowatt hours in the period by 100 and dividing by the product of the maximum demand in kilowatts and the number of hours in the period.

load shaping:

Either the arrangement and operation of generating resources to meet a given load or the arrangement of a load to meet a given resource over specified periods of time.

long-term firm contracts:

Contracts that are greater than 1 year and legally limited to 40 years in duration.

long-term firm power:

Power that is sold by Western under long-term contracts. Power is considered to have ensured availability to the customer over long periods of time to meet the contractually committed portion of the customer's load requirements.

lower riparian zone:

That portion of the riparian zone that occurs between the elevations of typical minimum and maximum flows. Usually supports marsh or other wetland plants.

M

macroinvertebrate:

Invertebrate organisms that are visible to the naked eye.

main channel:

The main course of a stream.

main stem:

The main course of a stream.

marketing criteria:

Defines how much electrical power Western will sell under long-term firm contract and the terms and conditions for the receipt of power. Allocation criteria, which are normally developed with the marketing criteria, define the eligibility requirements to receive power and the methods to dis-tribute the power to successful applicants.

mean:

Average value in a distribution.

median:

Middle value in a distribution, above and below which lie an equal number of values.

megawatt (MW):

A unit of capacity equal to one million watts. MW defines electricity produced.

megawatt hour (MWh):

One million watt-hours of electrical energy.

million-acre feet (maf):

A unit of volume; the volume of water that would cover one million acres at a depth of one foot.

minimum schedule requirements:

Quantity of capacity that Western must provide and that a contract customer must accept on an hourly basis.

mitigation:

Action taken to avoid, reduce the severity of, or eliminate an adverse impact.

mixing layer (or height or depth):
The layer above the surface through which relatively vigorous vertical mixing occurs.

N

nameplate generating capacity:
Full-load continuous rating of a generator or other electrical equipment under specified conditions designated by the manufacturer. This rating is specified on the nameplate that is attached to all such equipment by the manufacturer.

National Ambient Air Quality Standards (NAAQS):
Air quality standards established by the Clean Air Act. The primary NAAQS are intended to protect the public health with an adequate margin of safety; the secondary NAAQS are intended to protect the public welfare from any known or anticipated adverse effects of a pollutant.

National Register of Historic Places (NRHP):
A list maintained by the National Park Service of architectural, historic, archaeological, and cultural sites of local, state, or national significance.

Native American:
Refers to indigenous peoples of the Western Hemisphere (e.g., American Indian, Eskimo, Aleut).

nonattainment areas:
An air quality control region (or portion thereof) in which the U.S. Environmental Protection Agency has determined that ambient air concentrations exceed national ambient air quality standards for one or more criteria pollutants.

nonfirm power:
Power that does not have the guaranteed continuous availability feature of firm power, generally interruptible on short notice; capacity sold by Western that varies in amount and price according to market.

nonfirm transmission service:
Service provided by Western to transport energy from one place to another on an interruptible basis.

nonimpulsive noise:
Noise of longer duration (continuous) than that of impulse noise, which is typically less than one second.

nonpreference customers:
Investor-owned utilities or other power marketing entities that do not qualify for preference in allocations of SLCA/IP long-term firm power and energy commitments.

nonuse value:
The economic benefit that arises from the knowledge that a resource exists (existence value), has been preserved for potential use in the future (option value), and will be available for use by one's heirs (bequest value). Nonuse value is theoretically and conceptually distinct from use value. Contingent valuation is the only technique currently available for estimating nonuse value.

O

off-peak:
Period between late evening and early morning (11 p.m. to 7 a.m.) when electrical loads for most utilities are much lower than other times during the day.

oligotrophic:
Lakes and reservoirs low in nutrients and organic productivity, having nutrient-poor sediments, few rooted aquatic plants, a low production of unattached algae (phytoplankton), and well-oxygenated deep waters.

on-peak:
Energy supplied during periods of relatively high system demands as defined by inter-utility agreements.

operational scenarios:
Series of historical and hypothetical constraints on SLCA/IP hydropower operations specified by setting minimum and maximum flows, ramp rates, or variation in total flows during the day. Hydropower Operational Scenarios are described in detail in Appendix A.

P

palisade:
Precipitous rock cliff rising from the margin of a stream.

particulate matter:
Any material, except uncombined water, that exists in a finely divided form as a liquid or solid.

peak demand:
Maximum electrical demand (load) on a utility system in a stated period of time (peak load).

peaking capacity:
Generating equipment operated during the hours of highest daily, weekly, or seasonal loads. Some generating equipment may be operated at certain times as peaking capacity and at other times to serve loads on a round-the-clock basis.

peaking power:
Capacity and associated energy available to help meet that portion of a customer's peak load that is above baseload. Peaking power is normally delivered during those hours of the day when the demand for energy is higher.

peaking power/peaking generation:
Power plant capacity that is typically used to meet rapid increases or the highest levels of demand in a utility's load or demand profile. Peaking generation is usually oil, gas-fired, or hydropower generation.

peaking units:
Generating units that are available to assist in meeting that portion of load that is greatest during the day.

peak shaving:
Use of hydroelectric power plants to serve (shave) the highest electric load (peak) during a 24-hour period.

penstock:
Conduit pipe used to convey water under pressure to the turbines of a hydroelectric plant.

periphyton:
Organisms that live attached to underwater surfaces.

petroglyphs:
Symbols or pictures engraved or painted on a rock surface.

phytoplankton:
(See plankton.)

plankton:
Tiny plants (phytoplankton) and animals (zooplankton) with limited powers of locomotion, usually living free in the water away from substrates.

pool:
Deep area of a stream between rapids or where the current is slow.

power:
Measure of the amount of energy (work) being used at a specific point in time. Power is measured in such terms as watts, kilowatts, and megawatts. Power implies capacity in addition to energy.

power marketing initiative:
Combination of services and sales programs that Western has adopted as the basis for future marketing activities.

power marketing programs:
The sum total of all power-related services and sales activities offered by Western.

power pool:
Organization of interconnected electric utilities that plan and coordinate aspects of the production, transmission, or distribution of electricity. (The Inland Power Pool only shares reserves.)

preference customers:
In accordance with various laws, especially the Reclamation Project Act of 1939, public bodies that must be given preference over investor-owned systems for purchase of power from Federal projects, including municipal utilities, other public corporations or agencies, and cooperatives and other nonprofit organizations financed under the Rural Electrification Act of 1936; and Federal, state, and tribal entities.

price elasticity of demand:
Ratio of the percentage change in quantity demanded to the percentage change in price. Indicates the sensitivity

of quantity demanded to a change in price.

purchases and interchange:
: Activities by Western to supplement and enhance the value of hydrogeneration resources. Purchases and interchange are components of hydrothermal integration.

purchases, firming:
: Purchases of capacity or energy that are required to meet Western's contractual commitments to provide long-term firm electrical service.

R

ramp down:
: Reduction in generation with a corresponding reduction in water release; decrease in water release per time. (Also called down ramp, down ramping.)

ramp rate:
: The rate of change in instantaneous output from a power plant.

ramp up:
: Increase in water release per time; increase in water release causing an increase in stage downstream of the dam with a corresponding increase in power generation; also called upramping or ramping up.

rapid:
: Section of a river where the current moves very swiftly, caused by a steep descent in the riverbed through a constriction of the main channel.

reach:
: Any specified segment of a stream or river.

real disposable income:
: Total real income adjusted for taxes and transfer payments.

reattachment bar:
: Deposits found at the downstream edge of a recirculation zone that are important for establishing backwater areas.

recirculation zone:
: Area of flow composed of one or more eddies immediately downstream from a constriction in the channel, such as a debris fan.

recovery plans:
: Plans prepared by the USFWS to delineate reasonable actions that are believed to be required to recover and/or protect the species.

recruitment:
: Survival of young plants and animals from birth to a life stage less vulnerable to environmental change.

redd:
: Nests constructed in gravel by trout and salmon; spawning sites.

release patterns:
: Changes over time in the rate that water is released from a dam.

reliance levels:
: In this EIS, a utility is considered to have high reliance on Western power if 25% or more of its total system load is met by Western sources; less than 25% is considered low reliance.

reregulation dam:
: Low dam located downstream from a large hydroelectric power plant used to even out the flows further downstream.

reserves:
: Extra generating capacity available to meet unanticipated capacity demand for power in the event of generation loss due to scheduled or unscheduled outages of regularly used generating capacity.

reservoir:
: An artificially impounded body of water.

reservoir release patterns:
: Reservoir release rates specified for a time period on a continuous basis or at fixed-time intervals, such as one

hour.

residual sound level:
: Represents a low-limit value to which the ambient environmental noise drops frequently but below which it seldom goes.

rewind:
: Act of putting new copper-insulated wire in the armature windings of a generator.

riffle:
: Fast-water section of stream where the shallow water flows over stones and gravel.

riparian:
: Of, on, or pertaining to the bank of a river, stream, or lake.

riprap:
: Stones placed on the face of a dam or on stream banks or other land surfaces to protect them from erosion. A loose assemblage of stones used in water or soft ground as a foundation.

riverine:
: Pertaining to a riverbank.

river mile (RM):
: A unit of measurement (in miles) used on the Colorado River with River Mile 0 located at the U.S. Geological Survey gauge at Lees Ferry; miles downstream from that point are positive and miles upstream are negative.

S

Salt Lake City Area Integrated Projects (SLCA/IP):
: Federally owned and operated facilities mainly on the Colorado and Rio Grande rivers and their tributaries. The facilities and features of the SLCA/IP are described in Chapter 3 of this EIS.

Salt River Project (SRP) Exchange:
: Agreement between Western and the Salt River Project, a utility in Phoenix whereby capacity and energy at SRP generation units in Craig and Hayden, Colorado, are exchanged with capacity and energy at Glen Canyon dam. This agreement reduces the need for transmitting northern generation to meet southern loads, and vice versa.

sandbars:
: Deposits associated with eddies that exist upstream and downstream of debris fans created at the mouths of side canyons by debris flows (also called beaches, channel margin bars, separation bars, and reattachment bars).

scatter:
: In archaeology, a concentration of artifacts, e.g., lithic scatter.

scouring:
: Removing rooted plants at high water flows.

sediment:
: Any usually finely divided organic and/or mineral matter deposited by air or water in nonturbulent areas.

seeps:
: Area where groundwater discharges to the surface.

sensitive species:
: Species whose populations are small and widely dispersed or restricted to a few localities; species that are listed or candidates for listing by the state or Federal government.

separation bar:
: Sandbar located at the upstream end of a recirculation zone, where downstream flow becomes separated from the riverbank. Deposits found at the leading edge of a recirculation zone.

seston (sestonic):
: Total organic particulate matter suspended in water.

shale:
: Laminated sediment in which the constituent particles are predominantly of the clay grade; shale includes the indurated, laminated, or fissile claystones and siltstones.

shaving:
: The process to reduce (shave) peak loads at specific times of the day to reduce the total load placed on a utility

system or to move load to off-peak periods.

short-term firm power:
Power that is marketed on a noninterruptible basis for periods of time of less than one year.

sinusoidal:
Having a shape like a sine function; a changing from high to low in regular cycle.

slope:
Change in elevation per unit of horizontal distance.

spawn:
To lay eggs; especially fish.

spawning beds:
Places in which eggs of aquatic animals lodge or are placed during or after fertilization.

species:
The basic category of biological classification intended to designate a single kind of animal or plant.

spills:
Flows through a dam in excess of power plant capacity that do not produce power.

spillway:
Overflow channel of a dam.

spinning reserves:
Unloaded and available capacity of generating facilities synchronized to the interconnected electric system where automatic control action will cause such generating capacity to ensure load.

spot-market sales:
Short-term nonfirm sales made in the open market at prices and conditions set by the market. Spot-market sales may be made between any willing buyer and seller.

stage:
Elevation of a water surface above or below an established reference point, such as minimum flow.

steppe:
Area of grass-covered and generally treeless plains, with a semiarid climate.

step-up transformer:
Transformer in which the energy transfer is from a low- to a high-voltage winding or windings. (Winding means one or more turns of wire forming a continuous coil for a transformer, relay, rotating machine, or other electric device.)

stranding pools:
Areas that become isolated from the main channel of a river during declining water levels, trapping fish and other aquatic biota.

strata:
Section of a formation that consists of the same type of material throughout.

stream:
Natural water course.

substrate:
Surface on which a plant or animal grows or is attached.

system losses:
Difference between the amount of energy that is produced and the amount delivered that results from losses between the sources of supply and the metering points of delivery on a system.

T

tableland:
Broad, level, elevated area.

tailwaters:
That portion of the river below a reservoir that exhibits water conditions (such as temperature and clarity) that are very similar to the conditions of the water that is being withdrawn from the reservoir.

talus:
Rock debris at the base of a cliff or slope, chiefly as the result of gravitational roll or slide.

terrace:
Relatively level area with steep slope facing the river.

terrain:
Complex group of strata accumulated within a definite geologic epoch; area of ground considered as to its extent and natural features in relation to its use for a particular operation.

terrestrial:
Pertaining to plants or animals living on land rather than in the water.

threatened species:
Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. (See endangered; also Appendix D.)

topography:
Physical shape of the ground surface.

total suspended particulates (TSP):
Particulate matter present in the atmosphere.

transect:
Linear sampling unit.

tributary:
River or stream flowing into a larger river or stream.

turbidity:
Cloudiness of water, measured by how deeply light can penetrate into the water from the surface.

turbine:
Fluid acceleration machine for generating rotary mechanical power from the energy in a stream of fluid.

turbine generator:
Electric generator driven by a steam, hydraulic, or gas turbine.

U

uprate:
Increase in generating capacity.

upper riparian zone:
That portion of the riparian zone that occurs above the elevation of typical maximum flows. Usually supports plants adapted to moist but not wet soils, including a variety of woody species.

up ramp:
(See ramp up.)

use-value:
Economic benefit associated with the physical use of a resource, usually measured by the consumer surplus or net economic value associated with such use. The contingent value method is one technique used to estimate use value. (See nonuse values.)

V

videography:
An airborne multispectral video/radiometer remote sensing system. Videography is collected by flying over an area at a fixed altitude and videotaping the area below.

volatile organic compound (VOC):
Organic compound that participates in atmospheric photochemical reactions.

W

water year:
Period of time beginning October 1 of one year and ending September 30 of the following year and designated by the calendar year in which it ends.

wave heights:

The difference between maximum and minimum water elevation.

weighted usable area (WUA):

An estimation of the availability of potential fish habitat as a function of discharge; includes consideration of water depth, velocity, and substrate data for a particular stream location.

wetlands:

Lands or areas exhibiting hydric soils, saturated or inundated soil during some portion of the plant growing season, and plant species tolerant of such conditions (includes swamps, marshes, bogs).

wheeling:

Use of the electric transmission facilities of one system to transmit power to or from another system.

Y

young-of-the-year:

Fish less than one year of age.

Z

zooplankton:

(See plankton.)

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Utah Guides and Outfitters
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Morrison and Foerster
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Libraries

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Resources Library
Phoenix, AZ

Arizona State Library
Department of Library, Archives and Public Records
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Arizona State Regional Library for the Blind and Physically Handicapped
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Colorado River Board of California Library
Glendale, CA

Environmental Protection Agency
Region IX Library
San Francisco, CA

Los Angeles Public Library
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Water and Power Section
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Stanford University Libraries
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Doheny Memorial Library
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Colorado State University Libraries
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Denver Central Library
Denver, CO

University of Colorado at Boulder
Norlin Library
Boulder, CO

University of Denver
Penrose Library
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U.S. Air Force Academy
Academy Library
Colorado Springs, CO

Boulder City Library
Boulder City, NV

Clark County Library District

Las Vegas, NV

Nevada State Library
Carson City, NV

University of Nevada
Reno Library
Reno, NV

University of Nevada at Las Vegas
James Dickinson Library
Las Vegas, NV

Albuquerque Public Library
Albuquerque, NM

New Mexico State Library
Santa Fe, NM

New Mexico State University Library
Las Cruces, NM

University of New Mexico Library
Albuquerque, NM

Brigham Young University
Harold B. Lee Library
Provo, UT

Cedar City Library
Cedar City, UT

Kanab City Library
Kanab, UT

Moab City Library
Moab, UT

Salt Lake City Public Library
Salt Lake City, UT

Salt Lake County Library System
Salt Lake City, UT

Southern Utah State University Library
Cedar City, UT

University of Utah Marriott Library
Salt Lake City, UT

Utah State Library
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Utah State University
Merrill Library
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St. George, UT

Weber State University
Stewart Library
Ogden, UT

Laramie County Library System
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Rock Springs Public Library
Rock Springs, WY

University of Wyoming
Coe Library
Laramie, WY

Wyoming State Library
Cheyenne, WY

APPENDIX A: SOCIOECONOMICS

A.1 DEMAND ANALYSIS METHODS

This section describes the methods used to estimate the electricity demands of each of the end-user classes served by Western's customers. The purposes of the demand analysis were to (1) forecast the growth in the load (i.e., the amount of energy sold) served by each of the utility systems serviced by the Colorado River Storage Project Customer Service Office (CRSP-CSO) over the period 19932008, and (2) estimate the price elasticity of demand for all the major end-user classes and customer groups. The results of the demand analysis were used as inputs to the power system analysis described in Section A.2.

The demand analysis used statistical regression methods together with stratification as necessary. Nonparametric methods were used in situations where they were most beneficial in determining attributes of the demand and price relationship that parametric methods would not readily uncover. The detailed steps of the analysis are briefly described below. A more detailed description of the demand analysis and resulting empirical results are presented by Morey and Ungson (1993).

The first step in the process was the analysis of customer demand data and other relevant variables. This step included identification and characterization of homogeneous customer groups and end-user service classes. It also required the empirical investigation of the variables relevant to the estimation of demand functions for the end-use customer classes served by Western's customers. This investigation included (1) examination of demand history (19801990) of end-user classes for Western's customers, (2) characterization of empirical distributions of energy and peak demand variables, (3) examination of economic data obtained from DRI/McGraw-Hill, (4) examination of weather variables provided by the National Climatic Data Center (National Oceanic and Atmospheric Administration 1991), and (5) examination of local economic variables and indicators deemed relevant to the analysis.

The second step involved the preliminary estimation of energy demand forecasts for the major utility systems served by Western's SLCA Office. Although other utilities serve parts of the region served by Western power, no analysis has been performed on the effects of changes in Western's operations or allocation procedures on non-Western utilities or their customers because it is not known how these utilities would be affected. The preliminary forecasts were used by the power system task group to initiate the analysis of capacity expansion, and the estimations provided experience dealing with the sometimes severe data limitations that inevitably accompany such a project. Most of the initial estimates were developed by time-series methods, although some preliminary models for customer classes were developed as well.

The third step in the analysis was the estimation of short- and long-term price elasticities of demand for all major end-user classes and customer groups. It was important to have measures of the incremental effects of price changes in both the short term and the long term. Time-series studies were used in the estimation of short-term price elasticities. Long-term elasticities were developed through the use of nonparametric regression methods.

The fourth step was the statistical testing for structural shifts in demand functions during the 1980s and the statistical examination of the relationship between price elasticities of demand and prices for selected end-user customer groups. This part of the investigation relied on traditional regression-based methods. Where structural shifts were found, the estimated functions were further examined.

The next task in the analysis was construction of a baseline forecast of load from the DRI/McGraw-Hill trend scenario of independent variables. A load forecast was developed for each major system modeled in the power systems analysis. The forecasts showed a range of annual growth rates ranging from 0.5 to 2.9% for the forecast period.

The final task in the demand analysis was the inclusion of short-term forecasts of load growth from Western's customers. For the expansion period it was felt that Western's customers would have a better vantage point to foresee short-term changes in their service territory sales and peak demands than analysts from outside the region. To incorporate this better vantage point, the first three years of demand projections were drawn from forecasts supplied by the utilities. It was felt that in later years (after 1995), the advantage of better regional knowledge would diminish, and the needs for consistency of method across forecasts for different utilities would increase. The forecast, therefore, used the growth rates developed through econometric modeling of the individual systems to develop the energy and peak demand forecasts from 1996 through 2008.

A.2 POWER SYSTEMS ANALYSIS METHODS

A.2.1 Introduction

This section describes the methods used to simulate electricity production, forecast utility capacity expansion, and estimate air emissions for utility systems that could be affected by the commitment-level alternatives. The Production and Capacity Expansion (PACE) Model, estimated the effects of each alternative on Westerns's CRSP-CSO and its longterm firm (LTF) customers. The PACE Model consists of a set of integrated electric utility system modules that are configured to analyze various aspects of utility dispatch, capacity expansion, and air emissions. Some of the modules and computational techniques employed in the analysis have been used for previous projects. A more detailed description of the power systems analysis and results are presented in Veselka et al. (1995).

Several aspects of electric utility systems were analyzed, including (1) historical loads, (2) hourly demand projections, (3) utility dispatch and supply expansion, (4) spot market transactions, and (5) hydroelectric operations. Detailed simulations were preformed for several utilities in the SLCA Office's marketing area. Utilities in this marketing area range in size from small municipalities to large investor-owned utilities that have service territories spanning several states. In general, larger utilities own and operate generating resources and have extensive transmission capabilities. A few of the larger systems also have load control responsibilities. Smaller systems have very limited or no generating resources and rely principally on purchases to meet load.

The utilities that were modeled in detail are listed in Table A.1. Figures A.1 through A.6 show the service territories of the major customer utilities served by Western power. A utility was selected for detailed analysis either because (1) it is a CRSP-CSO longterm firm customer that is relatively large in size compared to other CRSP-CSO longterm firm customers and has a significant allocation of CRSP-CSO capacity and energy or (2) it is a large investor-owned utility that purchases from CRSP-CSO on the spot market and is interconnected with CRSP-CSO longterm firm customers. The 12 longterm firm customers listed in Table A.1 account for approximately 80% of Western's longterm firm capacity and energy commitments under the no-action alternative. Because the smaller utility systems do not have any generating capacity and must purchase power to serve customer load, these were not modeled in the analysis of power systems. The impacts of EIS alternatives on small utility systems were assessed with financial modeling methods described in Section A.3.

The PACE modeling system was configured to project the future behavior of affected electric utilities under baseline conditions and to measure the impacts of altering Western's long-term firm sales programs (commitment levels) and dam operations. The schematic diagram in Figure A.7 provides an overview of the power systems modeling method. The modeling system was designed such that decisions concerning supply-side expansion, demand-side management, and hourly purchases of CRSP-CSO long-term firm energy are made for each individual utility system. Energy transactions between utility systems are made through spot market simulations and the modeling of existing long-term firm contracts.

A.2.2 Commitment Level

Through its long-term firm marketing program, Western sells wholesale, long-term, noninterruptible electric services to qualified preference entities. Under a long-term firm contract, a customer (i.e., preference utility system) has a seasonal energy and capacity allocation from Western for a specified term. Firm energy can be used at the customer's discretion, subject to certain maximum and minimum limits, and contractual restrictions. For this EIS, it was assumed that all contracts would be effective for 15 years. Commitment-level alternatives analyzed in detail for this EIS include (1) no-action (moderate capacity, high energy), (2) alternative 2 (high capacity, low energy), (3) alternative 4 (low capacity, low energy), and (4) alternative 5 (low capacity, high energy). The impacts of other alternatives were interpolated from these results.

TABLE A.1 Utility Systems Modeled in Detail for the Power Marketing EIS

Utility Name	Abbreviation	Location	Type	Western LTF Customer
Arizona Power Pooling Authority	APPA	Arizona	Federal, state, and district	Yes
Arizona Public Service Company	APS	Arizona	Investor owned	No
Colorado-Ute Electric Assn. Inc.	Col-Ute	Colorado	Rural electric cooperative	Yes
Colorado Springs Dept. of Utilities	Col. Springs	Colorado	Municipal	Yes
Deseret Generation & Transmission Coop.[a]	Deseret	Utah	Rural electric cooperative	Yes
Farmington Electric Utility	Farmington	New Mexico	Municipal	Yes
Nevada Power Company	NPC	Nevada	Investor owned	No
PacifiCorp (East Division)	PacifiCorp	Utah	Investor owned	No
Plains Electric Generation & Transmission Coop. Inc.	Plains	New Mexico	Rural electric cooperative	Yes
Platte River Power Authority	PRPA	Colorado	Federal, state, and district	Yes
Public Service Company of Colorado	PSCO	Colorado	Investor owned	No
Salt River Project Agricultural Improvement & Power District	SRP	Arizona	Federal, state, and district	Yes
Tucson Electric Power Company	TEP	Arizona	Investor owned	No
Tri-State Generation & Transmission Assn. Inc.	Tri-State	Colorado	Rural electric cooperative	Yes
Utah Associated Municipal Power Systems	UAMPS	Utah	Federal, state, and district	Yes
Utah Municipal Power Agency	UMPA	Utah	Federal, state, and district	Yes
Wyoming Municipal Power Agency	WMPA	Wyoming	Federal, state, and district	Yes

[a] Because of the relatively small size of this cooperative, the nature of its supply-side resources, and lack of data, capacity expansion and dispatch runs were not performed for this system. However, a detailed financial analysis was

performed.

A.2.3 Long-Term Firm Purchase

Because of the noninterruptible nature of CRSP-CSO's LTF capacity and energy commitments, Western must make purchases from other utility systems when it is unable to supply sufficient firm capacity and/or energy from its own hydroelectric generating resources. When marketing long-term firm capacity and energy, Western must consider elements that are outside of its influence and such well-known factors as hydroelectric generator nameplate capacities and transmission limitations. Because of the external influences, Western's resources are often highly variable over time. Therefore, Western is at risk of not fulfilling its contractual obligations when it offers firm capacity and energy to its customers. However, there are a number of ways for Western to minimize such risks. For example, its purchasing programs allow Western to secure generating capacity and energy from other electric utility companies.

For this analysis, estimates of LTF purchases were based on Western's LTF commitment level, projected average hydroelectric energy, projected hydroelectric capacity at a 90% exceedance level, project use (e.g., priority obligations to the Bureau of Reclamation), and system considerations (e.g., losses and Inland Power Pool obligations). It was assumed in the analysis that when Western's risk of not meeting all of its capacity obligations exceeded 10%, Western would purchase LTF capacity to reduce its long-term risk. LTF energy would be purchased when Salt Lake City Area Integrated Projects (SLCA/IP) obligations were greater than average hydroelectric generation. Under adverse conditions, i.e., when hydroelectric resources and long-term firm purchases would be inadequate to meet Western's firm obligations, short-term firm and spot market purchases would have to be made.

A.2.4 Determination of Dependable Capacity

One factor that has a large impact on the amount of LTF capacity that Western must purchase is operational restrictions at each of the hydroelectric facilities. Three different supply options were analyzed in detail: (1) high operational flexibility, (2) moderate flexibility, and (3) low flexibility. Under the high flexibility option, hydroelectric units would have no institutional ramp rate limitations and could operate under a wide range of release levels. For most facilities, the amount of dependable capacity available under the high flexibility case depends on the amount of water behind the dam. The low flexibility option specified constant seasonal release from all dams. Under this option, the capacity of each dam would be equal to the generation at constant flow.

The moderate flexibility case is identical to the full flexibility case except that there would be hourly and daily ramp rate restrictions at Glen Canyon Dam. Also, the maximum release at Glen Canyon Dam would be lowered in all but the wettest years. To determine dependable capacity under these operational conditions, a simple geometric algorithm was developed. The objective of the geometric approach was to estimate the maximum generation level that could be achieved for each peak day during one month. The algorithm accounted for flow restrictions at dam sites, including limits on upramp and downramp rates, maximum daily fluctuations, and minimum and maximum flow rates. The geometric approach also recognized Sunday as an off-peak period and accounted for the amount of energy that could be released in each month and the length of time that the capacity must be available during on-peak periods.

A.2.5 Short-Term Firm Sales

Short-term firm (STF) sales are offered by Western if projected supply resources exceed long-term firm commitments. STF capacity and energy commitments are contractual power agreements that are either seasonal or monthly. For the purposes of the analysis, it was assumed that surpluses are marketed to Western's preference customers. If LTF commitments are low and supply resource levels are high, the excess above the long-term commitments will occur frequently. Thus, Western has numerous opportunities to offer its customers STF resources. At the other extreme, if Western's LTF commitments are high and supply resources are low, excess resources will occur very infrequently (if ever), and STF sales will be at a minimum. Low supply-side conditions occur under one or more of the following circumstances: (1) hydro conditions are dry, (2) stringent operational restrictions are in place, and (3) LTF purchases are small or nonexistent. For this analysis, excess energy resources were allocated to individual CRSP-CSO firm customers on a prorata basis up to the point that the load factor on CRSP-CSO's contracts (LTF + STF) equaled 100%. In addition, no excess capacity was offered to any customer.

A.2.6 Selection of Hydrologic Cases

Operations of SLCA/IP hydroelectric resources and STF sales depend on hydrologic conditions. Therefore, three hydrologic conditions C wet, moderate, and dry C were analyzed in this study. The three conditions were selected on the basis of results from the Colorado River Simulation Model (CRSM).

The CRSM is a deterministic model developed by the U.S. Bureau of Reclamation (Reclamation). It estimates monthly water releases from the Colorado River Storage Project (CRSP) and Seedskedee Project dams in accordance with all the water laws pertaining to the Colorado River. Also factored into the model are the requirements of operating criteria for maintaining equal storage in Lake Powell and Lake Mead so long as sufficient upper storage basin exists for a targeted release of at least 8.23 million acre-feet from Glen Canyon. The model uses historical hydrological data from 1906 through 1990 to simulate river basin flows and end-of-the-month reservoir levels. The CRSM was used to produce different potential capacity and energy outcomes for each month of the study period (i.e., January 1993 through December 2008) for each CRSP dam.

The CRSM estimates of monthly capacity and energy, along with typical values for the Rio Grande and Collbran projects, were input into a clustering algorithm that partitioned capacity and energy estimates into three different clusters representing dry, moderate, and wet conditions. This procedure produced average estimates of capacity and energy for each hydrological condition. This method was used because it considers both capacity and energy simultaneously.

A.2.7 Supply-Side Resource Expansion

Based on CRSP-CSO LTF capacity and energy commitment levels, supply-side expansion paths for each of the 17 utility systems listed in Table A.1 were determined with the BUILD module of PACE. BUILD selects a supply-side path by assembling various combinations of expansion states or "snapshots" in time into a time sequence of capacity expansion paths. The model uses a dynamic modeling approach that minimizes the number of paths that must be explored to arrive at the least-cost solution. The amount of capacity that must be built in the future depends on a number of factors, including (1) contractual capacity and energy agreements with another utility system, (2) projected demand, (3) demand-side management (DSM) programs, (4) committed units, (5) retirement schedules, and (6) system reliability targets.

Expansion paths were based on the assumption that each system is an independent entity that has LTF obligations to other utility systems. Therefore, supply-side expansion decisions were based on a utility systems' loads, resources, and LTF contractual agreements. Interactions among utility systems on the spot market and STF contracts were also estimated by PACE but did not affect DSM programs and long-term supply paths.

Forecasts of peak loads were modified and the penetration of DSM programs was estimated on the basis of initial estimates of short- and long-term marginal costs over a short period of time. Short-term marginal costs are the additional costs of increasing electricity production over a short period of time. Long-term marginal costs include capacity expansion and other fixed costs that will occur in addition to increased production costs if energy production is increased over a longer period of time. With adjusted load forecasts, least-cost supply-side expansion paths for affected utility systems were revised.

A.2.8 Demand-Side Management Reductions

The method used to estimate the load reductions from cost-effective DSM programs was patterned, in large part, after the method used by the Potomac Electric Power Company (PEPCO) in its 1990 and 1992 integrated resource plans (Hill et al. 1991). The initial step was to assemble a large set of DSM options for possible inclusion in the expansion plans. To accomplish this task, analysts consulted reports published by the Electric Power Research Institute (EPRI) and the SURIS database compiled by EPRI (see Cavallo et al. 1995 for details). Additional DSM options were drawn from material submitted as testimony from the executive director of the American Public Power Association to the U.S. House of Representatives, Subcommittee on Water, Power and Offshore Energy Resources (Hobart 1992). In this initial step, no attempt was made to eliminate DSM programs or measures that might later be rejected as inappropriate for the local region. The initial set included over 100 DSM options.

After assembling the set of DSM options, analysts performed an initial screening to reduce the DSM options to a number both computationally manageable and inclusive of cost-effective programs. The initial screening rejected DSM options that failed to meet three criteria: (1) applicability in the Western region, (2) market maturity, and (3) acceptable level of reductions. These criteria were used to screen out possible DSM programs that were almost certain to fail to meet local needs in a cost-effective manner. The resulting set of DSM programs included 18 programs C 10 residential programs, 5 commercial-industrial programs, and 3 agricultural programs.

These 18 DSM programs were then modeled with the computer program DSManager developed by Electric Power Software for EPRI (Cavallo et al. 1995). DSManager uses program cost information, estimates of program participation, and marginal system cost estimates to compute the costs and benefits of proposed DSM programs. The output of the modeling with DSManager includes hourly load reductions for the expansion period from the individual DSM programs and benefit-cost ratios for each DSM program.

The marginal system cost estimates were generated from the PACE system modeling performed as part of the power systems analysis. By agreement with Western, one system (the City of Colorado Springs) was chosen for DSM modeling as a prototype. Appropriate program cost and participation were determined through consultation with experienced DSM analysts and were compared with ranges of estimates used in similar studies. The modeling results for Colorado Springs were generalized to the other systems served by Western by proportionally increasing or decreasing the individual hourly program reductions.

Five of the 18 DSM programs consistently displayed cost-effectiveness in all modeled alternatives as determined by the "total resources cost test." One other program was cost-effective in the baseline alternative but not in other alternatives. The cost-effective programs can be described as energy conserving rather than peak load managing. The reason for this result is the low cost of Western's power. It was found that in all alternatives studied, the hourly marginal system costs after accounting for power purchased from Western do not vary enough to provide an economic basis for peak load management programs such as direct load control of residential air conditioners or electric water heaters. The relatively low marginal system costs resulted in small total reductions from DSM programs and little difference in reductions among alternatives. In all years of the expansion period (1993-2008), DSM reductions never reached 2% of energy sales or peak demand. Also, the differences among alternatives due to DSM was small C approximately 0.2% of energy sales in the final year of the expansion period (Cavallo et al. 1995).

A.2.9 Modeling Purchase and Sales Contracts

Both existing and new long-term firm capacity and energy contracts between utilities were taken into account in the simulation of utility dispatch and supply-side expansion. The simulation method used depended upon the contract type and information provided by utility contacts. The methods presented below were tailored to best represent the unique terms and conditions of a specific contract. PACE uses several methods for estimating LTF contractual obligations between utility systems, including (1) hourly load modifications, (2) thermal unit representation, (3) limited energy source representation, and (4) load duration curve (LDC) modifications.

Terms and conditions of the CRSP-CSO commitments differ among commitment-level alternatives. However, except for one contract, all other LTF contracts between utility systems remained constant for all EIS alternatives. CRSP-CSO contracts were modeled with a load-modification algorithm that maximizes reductions in the system peak load, subject to a number of constraints. Constraints incorporated in to the model included maximum energy usage, minimum schedule requirements, maximum contract capacities, and maximum changes in hourly and daily schedules. The algorithm assumed that capacity and/or energy is prescheduled and cannot be used to replace resources during times of forced outages. Results from the load-reduction algorithm provided an estimate of hourly demands for CRSPCSO LTF energy. That is, the loads reduced by the algorithm were those supplied by Western. CRSP-CSO supplies this energy through hydroelectric generation, LTF purchase agreements, and spot market sales. CRSP-CSO supply activities were estimated by the SLCA/IP dispatch algorithm.

A.2.10 Utility Dispatch

The Investigation of Costs and Reliability in Utility Systems (ICARUS) module was used to estimate electricity dispatch. ICARUS is an energy system planning tool for assessing the reliability and economic performance of alternative expansion paths of electric utility generating systems. The model calculates (1) a system maintenance schedule (if not fully specified), (2) the loss-of-load probability, (3) unserved demand for electrical energy, (4) required capacity reserve to meet a specified reliability criterion, (5) the effects of emergency interties, (6) expected energy generation and cost from each unit and block, (7) total generating system costs, and (8) fuel use. ICARUS uses a probabilistic simulation technique that significantly reduces computation requirements. Module calculations are based on system loads, unit-level generating resources, system operational constraints, and capacity and energy transfers among utility systems. ICARUS was used in conjunction with long-term expansion plans to produce hourly cost-production functions that in turn were used to simulate spot market activities.

ICARUS was also used to estimate the change in utility dispatch when Western sells short-term firm energy. Utility dispatch is based on a fixed capacity expansion plan as determined by the BUILD module of PACE.

A.2.11 Spot Market Activities

Spot market transactions between utility systems were estimated with the Spot Market Network (SMN) module. Estimates of spot market activities were made for combinations of four commitment-level alternatives, three hydroelectric operational restrictions, and three hydrologic conditions (i.e., dry, moderate, and wet). SMN is a linear program that assesses the effects of commitment-level alternatives on spot market activities and SLCA/IP hydroelectric operational constraints. Spot market transactions among the 17 utility systems shown in Table A.1 were estimated through the use of a network of nodes and links. In this network, nodes represent generating resources and load centers. Generating resources are represented as piece-wise linear marginal cost curves, and load centers are represented by estimates of hourly electricity demand. Nodes are connected by links that represent transmission limitations and line losses for power flows between nodes. The module minimizes production costs subject to utility-specific minimum profit margins that trigger spot market transactions. The module recognizes line ownership and includes wheeling, sales-for-resale transactions, and line usage that is reserved for LTF transactions.

A.2.12 Dispatch SLCA/IP Resources

Simulations of SLCA/IP dispatch were approximated by the Hydro LP Module. The Hydro LP Module is a linear programming model that simulates the operation of SLCA/IP hydroelectric facilities and LTF purchase contracts to meet LTF loads. It also projects CRSPCSO's hourly participation in spot market transactions. The module solves for hourly generation, purchases made under LTF contracts, and spot market activities on the basis of the assumption that Western maximizes the value of its hydroelectric resources and minimizes charge rates to long-term firm customers. Spot market activities were based on market prices as determined by SMN and Western's ability to shift hydroelectric generation from off-peak periods to on-peak periods. Spot market purchases and sales depend on the amount of water available for generation, Western's hourly firm commitments, flow restrictions at each of the hydroelectric dams, and Western's LTF purchasing programs. Operational restrictions incorporated into this module include (1) minimum and maximum flow restrictions, (2) hourly and daily ramp rate restrictions, and (3) minimum and maximum elevation levels at specific reservoirs. The Hydro LP Module also includes a profit margin requirement for off-peak to on-peak hydroelectric shifting.

A.3 FINANCIAL ANALYSIS

This section provides an overview of the analytical framework used in performing the rate and financial impact assessment for the alternatives studied in this EIS. More detailed descriptions of the financial analysis and resulting empirical results are presented in Bodmer et al. (1995).

A.3.1 Introduction

Alternative commitment levels could change the cost of power to Western's customers, because Western's wholesale rates would have to be adjusted to meet its debt repayment obligations. In addition to producing cost changes, different programs could also affect the cost of alternative power and the capacity expansion plans of the utilities. The purpose of the rate and financial analysis was to quantify the full range of impacts that changes in the costs and quantities of Western's power could have on its customers. These impacts appear as changes in the financial health of the reselling utility and/or changes in the prices and the quantities of electricity consumed by residential, commercial, industrial, and other retail consumers.

The analysis of the impact on rates took into account the quantity adjustments consumers make when faced with changes in price. It also considered financial constraints of the utilities. The financial viability analysis estimated economic impacts that arise in cases where changes in Western's marketing programs might create potential financial difficulties for a utility. In such cases, utilities often do not make optimal investment and maintenance decisions because of financial constraints on capital investment. The uneconomical investment decisions could have harmful long-term impacts on consumers of electric power.

Retail rate impacts and financial viability were combined into one analytical process because there is a direct link between the financial condition of the utilities that sell power and the prices that consumers pay for electricity. For example, if costs increased and rates stayed constant, the impact of the cost increase would appear as a deteriorating financial condition of the utility. Alternatively, if the entire cost increase was passed on to the customers of the utility in the form of higher electric rates, there would be no financial impact on the utilities. The link between financial viability and electric rates is influenced by many factors. Rate differentials with neighboring utilities, management strategy, regulation, past investment in capacity, and consumers' willingness to buy all play a role in how cost changes are split between the utility and its customers. As changes in costs occur, the utility's manager decides (on the basis of multiple constraints) whether to increase or decrease its financial health or to increase or decrease rates to utility customers.

A.3.2 Classification of Western's Customers

Entities to whom Western sells power were classified into three different types: (1) customers that resell power directly to end-users (distribution utilities), (2) customers that resell power to other utilities that then resell the power to end-users (wholesale utilities), and (3) customers that do not resell the power but use it for their own purposes (retail end-users). Distributors include municipal utilities and distribution cooperatives that purchase and resell Western power directly to end-users. Generation and transmission cooperatives and joint-action agencies were classified as wholesale utilities because they primarily sell power to other utilities, which in turn resell the electricity to end-users. The retail end-users classification contains military bases and other Federal installations, as well as universities and irrigation districts, that purchase power directly from Western but do not resell the power.

The analysis for each of these types of customers differed because of differences in the financial structure, rate-setting policy, and demand characteristics of the utilities. Because Western's retail end-users do not resell power, the impacts of each commitment-level alternative would be limited to a change in the rates Western charges and a corresponding change in the quantity of electricity consumed by each retail end-user. Distributors and wholesalers, however, have the option of either altering rates or absorbing costs through changes in financial position. Consequently, the analysis had to take into account how each of these types of customers would alter its rates and financial standing to accommodate changes in the costs of acquiring power.

A.3.3 The Utility Finance and Rate Impacts Model

Even though distributors and wholesalers both have the option of altering rates or absorbing costs internally, the two types of utilities required different modeling approaches. Since distributors sell primarily to end-users and do not sell electricity for resale, the demand for power from distributors comes from their end-use customers. In contrast, wholesaler utilities primarily sell bulk electric power to distribution utilities and other wholesale utilities. Thus, wholesale demand is a derived demand from the utilities that ultimately sell to the end-users.

Argonne National Laboratory (ANL) developed a utility financial model to help analyze management strategies of utility companies. The model was initially constructed to compare the effects of different management strategies facing utility managers. For example, the model can project the effects of financing a new plant with equity or debt, as well as any combination of equity and debt. The model can also project future revenues by customer classes in response to changes in costs, including an elasticity adjustment for end-user response to changes in prices. The model can determine purchased power costs on the basis of a portfolio of purchased power contracts.

The financial model has been developed over a number of years on the basis of consultations with utility companies, government agencies, and consulting firms. The model generates output on retail prices and financial viability on the basis of cost structure, demand, and the rate-setting policy of the utility. For the purposes of this EIS, application of the model differed depending on whether a wholesale or a distribution utility was being modeled.

At the core of the model are two equations that define an entity's income and interest coverage. To simplify the discussion of the model, the following "stripped-down" equations are presented to illustrate the general algorithms:

Income = revenue - operating cost - interest cost (A.1)

Interest coverage = (income + interest cost)/interest cost. (A.2)

Equations A.1 and A.2 are the basis of the financial model. Substituting for income in Equation A.2 and simplifying yields:

Interest coverage = (revenue - operating cost)/interest cost (A.3)

or

Revenue = interest coverage H interest cost + operating cost. (A.4)

In addition, the average rate paid by the utility's end-users is calculated as

Rate = revenue/sales. (A.5)

Note that Equations A.3 and A.4 can be used to examine the effect of a change in one component on the other components of the equation. For example, if operating costs were to change and revenue and interest costs remained constant, the interest coverage would have to change in the opposite direction. In a similar manner, if interest costs increased, either revenues would have to increase or operating costs would have to decrease for the interest coverage to remain constant.

Equations A.3 and A.4 capture the link between the financial health of the utility (as measured by interest coverage) and the revenues the utility receives. Thus, a change in operating cost, as represented as a change in the cost of Western power (or the cost of adding/replacing Western power), could show up as a change in the interest coverage, a change in revenues, or both. Taken together, Equations A.3, A.4, and A.5 show how the link between the financial health of the utility and the revenues that the utility receives can be used to quantify the effects of a change in Western's commitment levels on both the financial condition of the utility and the rate paid by electricity end-users.

The model explicitly takes into account the customer's response to price changes through an elasticity adjustment. Such an adjustment is important because it has implications for covering operating costs that are not directly related to the level of output. Some costs, like production costs, increase or decrease with the level of electricity sold. Other costs, such as distribution, sales, and administrative costs, do not depend on the amount of electricity sold. These relatively fixed operating costs are incurred regardless of sales revenues.

The model relates the coverage of these relatively fixed costs to the elasticity adjustment. If demand is price inelastic, an increase in price induced by a cost increase leads to a reduction in quantity demanded. This leads to a reduction in revenues. If fixed costs are to be covered, a further increase in price is necessary. This price increase leads to a further reduction in quantity demanded, and this iteration starts again. It is possible for these effects to cycle out of control, leading to a "death spiral" for the utility. However, if the elasticity effect is minor and the fixed portion of operating costs is small, the price and quantity adjustments converge so that further price increases do not induce a significant reduction in demand.

The ANL approach to modeling distribution utilities used data from the demand and power system subtasks and produced data on rates, bills, and financial condition. Interest and depreciation costs were computed on the basis of existing financial structure and the projected capacity additions. Nonproduction costs were computed from regression analysis and the database of historical costs. The projections of baseline financial status were compiled on the basis of inputs collected from the companies' financial records, secondary data sources collected from Federal and state reporting requirements, and other inputs and assumptions as outlined below:

- Historical rates, sales, and energy disposition from EIA Form 861;

- Forecasts of peak demand and energy sales from the companies and other sources;
- Projected production costs from the power systems production analysis;
- Nonproduction costs; and
- Other economic variables, such as inflation, carrying costs, and input prices.
- Purchased power costs were derived from the power systems analysis and the Western marketing programs.

The link between rates and the financial condition of utilities was an important part of this analysis. Modeling of the relationship between the financial condition of the utility company and rates paid by consumers is illustrated by the following fourstep process:

Step 1: Compute prices on the basis of historical financial criteria such as debt service criteria.

Step 2: Examine prices generated from Step 1 in terms of the overall level and the year-to-year change.

Step 3: Determine the maximum year-to-year price increases and maximum absolute levels on the basis of neighboring utilities, management policy, empirical data analysis, and judgment.

Step 4: If the prices examined in Step 2 exceed the constraints determined in Step 3, run the model on the basis of constrained prices rather than the financial driver from Step 1.

Modeling of wholesale utilities differed from the modeling of the distribution utilities. For the wholesale utilities, the power cost was modeled directly in the power systems analysis. Other modeling algorithms are similar (e.g., between the wholesale utility and the distribution utility). It is important to note how the modeling integrated distributors and wholesalers. It is common for the wholesaler to purchase power from Western and other sources and then resell the power to its affiliated distributors, as well as to the end-use consumers of the wholesaler. In modeling this situation, the impacts of commitment-level alternatives on the wholesaler's required revenues reflected the cost changes attributable to the commitment-level alternative as well as the effects of changes in demand by both the distributors and end users with whom the wholesaler does business. The differences in cost and required rates for the distributor affect the demand for electricity from the distributor's end-use customers, which in turn affects the demand and revenue of the wholesale utility.

The crux of the relationship between modeling distribution utilities and wholesale utilities is that the production costs incurred by the distribution utility are equivalent to rates of the wholesale utility. In addition, the overall retail demand from the distribution utility (including line loss) is also demand to the wholesale utility.

The financial analysis was organized so as to provide information similar to that of financial statements prepared for annual reports of corporations. This information included income statements, supply analyses, balance sheet information, cash flow statements, financial ratio analysis, and a price analysis by customer class for each utility examined in the impact analysis. In the income statement analysis, the "operating revenue" projections were made on the basis of a demand analysis performed earlier (Morey and Ungson 1993) and were broken down by end-user categories: residential, irrigation, commercial, industrial, and public lighting. Operating revenues represent sales that the retail utility earns from its end-use customers.

The "operating expenses" were estimated for the various costs incurred by the retail utility. The cost of bulk power was projected on the basis of a production cost analysis. Other miscellaneous expenses, such as administrative, sales, and general expenses, were projected on the basis of a regression analysis. Other income sources, such as generation and transmission credits, nonoperating margin on interest, and extraordinary items, were added to operating income. Interest paid on both long- and short-term debt was subtracted from operating income. Interest expense was calculated on the basis of projected financing requirements, debt maturities, and interest rates. When factored in, these additions and subtractions yielded the retail utility's "net margin" or profit. The net margin plus depreciation equals the working capital for the municipal utility system. Operating cash flow minus capital expenditures yields cash flow before financing. Cash that must be raised externally was determined on the basis of cash after capital expenditures and debt market conditions.

The supply analysis calculated sales/price statistics, peak load and capacity, and fuel cost and fuel clause information.

The sales/price statistics include energy sold and the average retail price paid for electricity over all rate categories. From this the average revenue was calculated (in $/MWh).

A.4 CONSERVATION AND RENEWABLE ENERGY ANALYSIS METHODS

This section describes the methods used to assess the impacts of the commitment-level alternatives on current conservation and renewable energy (C&RE) activities. A more detailed discussion of the methods and empirical results is presented by Cavallo et al. (1995).

All of Western's long-term firm power customers were required to implement three to five C&RE activities, depending on the customer's size. Western designed its C&RE requirements to promote the efficient use of energy and to facilitate the use of renewable energy sources. Some activities were designed to improve energy consumption efficiency or reduce peak load. Other activities were developed to use renewable sources of energy supply or to cogenerate electricity with the use of energy for some other purpose. Although cooperative or municipal utilities could have adopted new C&RE activities or expanded participation for a variety of reasons (such as reduced dependance on outside power or an improved global environment) the analysis developed for this EIS postulated that additional C&RE activities would only be implemented if the utilities found economic advantage in such new activities. Similarly, it was assumed that C&RE activities would not be expanded if the costs of such expansion exceeded the benefits.

The C&RE analysis was divided into four parts: (1) identifying currently operating C&RE activities of each utility, (2) estimating the energy and peak demand reductions attributable to each activity, (3) identifying the activities that would likely be affected by a change in Western's commitment levels, and (4) modeling the potentially affected activities with the marginal system costs of the alternative showing the greatest deviation from the baseline. The initial step in the C&RE analysis was the identification of C&RE activities. Analysts developed an extensive database from the C&RE files of Western's CRSP-CSO. As described by Cavallo et al. (1992), the database contains 1,242 entries and tracks the development of C&RE activities at the cooperatives and municipals served by Western's CRSP-CSO. Extensive descriptions of individual activities are given in the database, along with the size and type of utility employing the activity.

The second step of the analysis was to estimate reductions realized by Western's customers from their C&RE activities. Since quantitative program evaluations of activities are not performed by Western or its customers, this information is not readily available. To develop rough quantitative estimates of the reductions from the activities, analysts solicited information from Western's customers through telephone conversations. This information was compared to and expanded with estimates from EPRI publications. The estimates of the energy and peak demand reductions from C&RE activities are detailed in Cavallo et al. (1995).

After estimating the reductions associated with the C&RE activities, analysts identified the activities most likely to be affected by a shift from the baseline to an alternative commitment level. Many activities, such as those associated with production efficiency, were unlikely to be affected. Furthermore, the results of the power systems analysis indicated that renewable energy programs and cogeneration were not cost-competitive under any of the commitment-level alternatives and, thus, could be excluded. The remaining activities included consumption efficiency and load-management activities.

The final step in the C&RE analysis involved modeling the costs and reductions of the remaining activities under the conditions of the alternative showing the greatest deviation from the baseline C commitment-level alternative 4. The activities remaining after the third step were similar to the DSM programs being modeled as part of the capacity expansion analysis, and therefore the modeling task was combined with the DSM program analysis. Each type of activity was matched with a similar DSM program among the 18 DSM programs modeled for capacity expansion. The 18 DSM programs were then modeled with the EPRI software DSManager (see Cavallo et al. 1995 for details). DSManager uses program cost information, estimates of program participation, and marginal system cost estimates to compute the costs and benefits of proposed DSM programs. The marginal system cost estimates were generated from the PACE system modeling performed in the power systems analysis. Appropriate program costs and participation were determined through consultation with experienced DSM analysts and compared with ranges of estimates used in similar studies.

A.5 REGIONAL ANALYSIS

This section describes the methods used to assess the regional economic impacts of the commitment-level alternatives and presents extended empirical results. A more detailed discussion of the methods and empirical results is presented by Allison and Griffes (1995).

A.5.1 Introduction

The regional impacts assessment used the Regional Economic Models, Inc. (REMI) and Impact Analysis for Planning (IMPLAN) modeling systems to obtain comprehensive information on selected socioeconomic impacts of the various commitment-level alternatives. Compared with alternative input-output (I-O) and econometric modeling frameworks, the REMI modeling system provides a substantial amount of information for a range of region-specific variables important to the measurement of economic impacts. The REMI modeling system combines this information in a general equilibrium framework that can be used to estimate the impacts of changes in a wide range of policy variables. The core of the REMI modeling system is an I-O structure representing interindustry linkages and linkages to final demands by industry. The modeling system also includes substitution among factors of production in response to changes in relative factor costs, migration in response to changes in expected income, wage responses to changes in labor market conditions, and changes in the share of local and export markets in response to changes in regional profitability and production costs.

The basic REMI modeling system has five parts. Output linkages, or I-O accounts, represent the core of the system to show interindustry linkages and endogenous final demand. The standard REMI modeling system is based on a 53-sector model of the U.S. economy, regionalized through the use of location quotients, to produce interindustry tables at the county level. Final demand in the modeling system includes 25 sectors. Also included is an occupational matrix including 94 occupational groups that provides output on likely changes in occupational structure given any change in final demand in each county economy. Within this matrix, 202 age/sex cohorts also give additional information on the demographic impacts of changes in exogenous expenditures.

The interindustry section of the system is linked to an econometric model with four distinct blocks, with extensive linkages among the various blocks. Outputs in the I-O block drive labor demand, with labor demand interacting with labor supply to determine wages. In tandem with other factor costs, wages determine relative production costs and relative profitability, which in turn affect market shares. The market-shares block models the proportion of local demand and exogenous export demand in the region that is filled by local production.

Endogenous final demands include consumption, investment, and state and local government demand. Real disposable income drives consumption demands. Nominal disposable income is derived as wage income, plus property income related to population calculated, plus transfer income related to population minus employment and retirement population, minus taxes. Real disposable income comes from nominal disposable income deflated by the regional consumer price deflator. Optimal capital stock determines state and local final demand, and the endogenous final demands, combined with exports, determine outputs.

The REMI modeling system was used to estimate the impact of the various commitment-level alternatives on population, gross regional product (GRP), disposable income, and employment for the nine subregions. The IMPLAN modeling system was used to measure the impacts of alternatives on output, personal income, and employment in the two high-reliance counties and on income distribution in the nine subregions. The three rural subregions encompass large areas and contain a number of Western customer utility service territories. To estimate the magnitude of impacts of each commitment-level alternative in individual utility service territories, additional analysis was also performed at the county level. Two separate counties were chosen where there are utilities with high reliance on Western power and where a high proportion of power sold in the county comes from these utilities. The impacts of each alternative were modeled with this approach by estimating the effects of changes in total electricity expenditures in each county, as opposed to measuring the effects of changes in commercial and industrial electricity prices and changes in residential expenditures on electricity as was used in the measurement of impacts at the subregional level. A more detailed discussion of the approach and modeling techniques can be found in Allison and Griffes (1995).

Measurement of the household income impacts used the IMPLAN modeling system combined with disaggregated information on the household and consumption sectors of the input-output table. These modifications used data from the Bureau of Labor Statistics, the New York Stock Exchange, and the Internal Revenue Service. The modified model contains a series of income accounts showing information on the sector and income bracket of recipients and the sector and income bracket of consumers. The model was used to estimate the impact of changes in final demand (changes in electricity expenditures) on changes in individual household income for 11 household income groups. A more detailed discussion is provided in Rose and Frias (1993a,b).

A.5.2 Calibration of the REMI and IMPLAN Modeling Systems for the Western Study Region

The counties that make up the affected area for Western operations were defined by calculating the proportion of power consumed in each county in 12 states that is provided by Western. Included was power coming from Western either directly, in a small number of cases, or indirectly through the various distribution cooperatives and other such entities to which Western sells power. Individual counties were then combined into groups of counties to produce nine subregions. The counties were grouped together on the basis of similarities of economic structure.

Individual REMI models were constructed for each of the nine subregions to measure impacts on population, GRP, disposable income, and employment. As described below, these groupings included six metropolitan subregions and three rural subregions. IMPLAN models were calibrated for each of the nine subregions to measure the impacts on income distribution and for the two high-reliance counties to measure local impacts on output, personal income, and employment.

Because each of the 195 counties included in the nine subregions used in the REMI analysis receives power from Western, the effect of aggregating from the county level, where impacts of each alternative and supply option on individual utility service districts could be measured, to the subregional level is to average the impact across all utilities in each of the subregions. Aggregation to the subregional level, however, does not reduce the impact of each alternative and supply option. This would be the case if, for example, the analysis were to measure the impacts of each alternative and supply option in a subregion containing a large number of counties, only one of which contained a utility receiving Western power.

A.5.2.1 Metropolitan Subregions

Each of the six states in Western's affected area C Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming C has at least one metropolitan county. Within these counties, the larger metropolitan centers of Phoenix (Maricopa County; 1988 employment of 975,200), Denver/Boulder (Adams, Arapahoe, Boulder, Denver, and Jefferson counties; 952,200), and Salt Lake City (Davis, Salt Lake, and Weber counties; 473,500) have highly diversified economies, with a range of manufacturing, consumer, and producer service activities. Las Vegas (Clark County; 270,247) is a growing regional center based on gaming and hospitality industries and is attempting to diversify its economy. For all but two of these counties, at least 80% of the population is located in urban areas. Additionally, for the majority of these counties, agricultural and resource extraction industries constitute less than 2% of total county employment. A number of smaller metropolitan centers C Albuquerque/Santa Fe (Bernalillo and Santa Fe counties; 210,152), Colorado Springs (El Paso County; 122,359), Fort Collins (Larimer County; 50,613), Greeley (Weld County; 34,501), Pueblo (Pueblo County; 30,159), Casper (Natrona County), and Tucson (Pinal County; 14,632) C specialize in a smaller number of activities, with an emphasis on service employment. Each of these counties has an essentially urbanized population, and less than 5% of its employment is in agriculture and resource extraction.

These metropolitan areas were grouped to create six separate subregions C the Arizona Metropolitan, Colorado Metropolitan, Nevada Metropolitan, New Mexico Metropolitan, Utah Metropolitan, and Wyoming Metropolitan subregions (Table A.2).

A.5.2.2 Rural Subregions

The remainder of the counties in each of the states served directly or indirectly by Western are rural, and in many cases remote, with few large centers of population. The economies in these counties are based primarily on agriculture, resource extraction, recreation, and tourism. These counties were grouped into three separate rural subregions for a total of nine subregions for the regional impact analysis (Table A.2).

High Plains Subregion: A group of High Plains counties east of the Rocky Mountain chain in western Colorado, western New Mexico, and central Wyoming were used as a separate subregion in the regional impact analysis. With the exception of the areas north and south of the Platte River irrigation project, the subregion's economy is based primarily on ranching. Wyoming and New Mexico have substantial interest in the energy economy, with oil, gas, and coal being recovered in Wyoming and oil and gas being recovered in New Mexico.

Rocky Mountain Subregion: Counties in the central section of Western's affected area were combined to form the Rocky Mountain Subregion. The subregion varies in width and stretches from north-central Wyoming, through western Colorado, and into New Mexico. This area is sparsely populated, and the economy is based primarily on recreation and tourism, although historically, development has been based on the timber and minerals (hard metals) industries. Topographic features and poor proximity to urban markets have limited further development. A significant proportion of the land surface in the subregion is owned or administered by U.S. government agencies.

Table A.2 Counties Included in the Nine Subregions

Subregion	States	Counties
Metropolitan Subregions		
Arizona	Arizona	Maricopa, Pinal, Pima
Colorado	Colorado	Adams, Arapahoe, Boulder, Douglas, Jefferson, El Paso, Larimer, Weld, Pueblo
Nevada	Nevada	Clark
New Mexico	New Mexico	Bernalillo, Los Alamos, Santa Fe
Utah	Utah	Davis, Salt Lake, Weber, Utah
Wyoming	Wyoming	Natrona
Rural Subregions		
High Plains	Colorado	Baca, Bent, Cheyenne, Crowley, Elbert, Kiowa, Kit Carson, Las Animas, Lincoln, Logan, Morgan, Otero, Phillips, Prowers, Sedgwick, Washington, Yuma
	Montana	Big Horn
	Nebraska	Arthur, Banner, Box Butte, Chase, Cherry, Cheyenne, Dawes, Deuel, Dundy, Garden, Grant, Hayes, Hooker, Keith, Kimball, Lincoln, McPherson, Morrill, Perkins, Scotts Bluff, Sheridan, Sioux
	New Mexico	Chaves, Colfax, Curry, De Baca, Eddy, Guadalupe, Harding, Lea, Mora, Quay, Roosevelt, San Miguel, Union
	Oklahoma	Cimarron

	Texas	Cochran, Gaines, Hartley, Yoakum
	South Dakota	Fall River
	Wyoming	Albany, Campbell, Converse, Goshen, Johnson, Laramie, Niobrara, Platte, Sheridan, Weston
Rocky Mountains	Arizona	Cochise, Graham, Greenlee
	Colorado	Alamosa, Archuleta, Chaffee, Clear Creek, Conejos, Costilla, Custer, Eagle, Fremont, Gilpin, Grand, Gunnison, Hinsdale, Huerfano, Jackson, La Plata, Lake, Mineral, Ouray, Park, Pitkin, Rio Grande, Routt, Saguache, San Juan, Summit, Teller
	Montana	Carbon
	New Mexico	Catron, Cibola, Grant, Hidalgo, Lincoln, Luna, McKinley, Otero, Rio Arriba, Sandoval, Sierra, Socorro, Taos, Torrance, Valencia
	Utah	Daggett, Morgan, Summit, Wasatch
	Wyoming	Big Horn, Carbon, Fremont, Hot Springs, Lincoln, Park, Sweetwater, Uinta, Washakie
Great Basin	Arizona	Apache, Coconino, Gila, La Paz, Mohave, Navajo, Santa Cruz, Yavapai, Yuma
	California	Inyo, Mono
	Colorado	Delta, Dolores, Garfield, Mesa, Moffat, Montezuma, Montrose, Rio Blanco, San Miguel
	Nevada	Elko, Esmeralda, Eureka, Lincoln, Mineral, Nye, White Pine
	New Mexico	San Juan
	Utah	Beaver, Box Elder, Cache, Carbon, Duchesne, Garfield, Iron, Juab, Kane, Millard, Piute, San Juan, Sanpete, Sevier, Tooele, Uintah, Washington, Wayne

Great Basin Subregion: Between the Rocky Mountains to the east and the Sierra Nevada range in eastern California is a region of high desert, including western Wyoming and all of Utah, Arizona, and Nevada. The geographic distribution of water resources has determined the location and level of economic activity in much of this area, and the main centers of population have grown largely in response to man-made changes in regional hydrological systems, particularly in southwestern Nevada and in central and southwestern Arizona. The majority of agricultural activity is located close to the urban centers in Maricopa and Pinal counties in Arizona, with a smaller concentration in Clark County, Nevada. The agricultural sector is highly capital intensive, with employment in that sector making up less than 1% of total county employment in the majority of counties. Tourism and recreation have become significant parts of the subregion's economy, with both mountain-based and water-based activities. As is the case with the Rocky Mountain Subregion, a significant proportion of the land surface in the Great Basin Subregion is owned and/or administered by U.S. government agencies.

A.5.2.3 High-Reliance Counties

Two separate counties in New Mexico were chosen for the analysis of impacts at the local level. Both counties contained more than one Western customer utility, with utility reliance on Western power ranging from approximately 20% to more than 75%. This situation translates into an overall county reliance on Western power ranging from 20% in one county to 59% in the other. Neither county contains a non-Western customer selling to end-use customers. Changes in retail electricity rates in these counties under each alternative and supply option would be relatively large, with a maximum change from the baseline of more than 22% in both counties.

A.5.3 Specification of Data for Input to the REMI and IMPLAN Models

The regional economic analysis used changes in retail prices and expenditures on electricity at the level of the individual customer utility and converted these changes to changes at the county level. This procedure involved calculating the proportion of power sales to industrial, commercial, and residential customers coming from Western and from other, non-Western sources for each county in the affected region. Shares at the county level were then aggregated to the subregional level to give the proportion of electricity sales coming from Western for each of the subregions. Based on these shares, changes in prices and expenditures on electricity for each customer class were calculated and used as inputs to the REMI models and IMPLAN models employed for the analysis of income distribution impacts. The impact of each commitment-level alternative on the cost of doing business in each subregion was estimated by changing commercial and industrial electricity rates. The impact of each alternative on the consumer price index (CPI) was estimated by calculating the change in residential expenditures (real disposable income) resulting from changes in residential electricity rates. The impact of each commitment-level alternative on the distribution of income among households in each subregion was estimated on the basis of the change in total expenditures on electricity in each subregion. Aggregating price and expenditure changes to the subregional level meant that the resulting changes represented the average across all utility service districts in each subregion. Impacts in the two high-reliance counties were based on changes in total electricity expenditures measured at the county level for each commitment-level alternative and supply option.

In addition to impacts that arise from changes in electricity prices and expenditures from each commitment-level alternative, secondary impacts on other industries in each subregion may also arise from changes in the source of electricity supplies and from the construction and operation of additional generating capacity. The impacts of expansion in production elsewhere in the system to meet shortfalls in Western electricity production is likely to lead to gains in population, GRP, disposable income, and employment. However, because the technology and locations of alternate or additional new generating capacity that may be used to offset losses in Western production were not known at the time the impact analysis was undertaken, no analysis of secondary socioeconomic impacts was included in the EIS. The measurement of impacts resulting from changes in electricity prices in each of the subregions used in the EIS therefore overestimates the size of these impacts.

A.6 RECREATION ANALYSIS

This section describes the methods used to assess the economic effects of the operational scenarios at Glen Canyon Dam and Flaming Gorge Dam on recreation and nonuse values. The analysis is based on the assumption that a change in streamflows could alter the quantity and quality of recreational activities at a site. Instream flows are a major determinant of the quality of boating and angling, and therefore the benefits received by recreationists. It follows that the amount of revenues received by many recreation-related businesses, such as commercial outfitters that offer white-water boating trips and angling guide service, could also be influenced by instream flows. In addition, there is the potential for effects on nonuse benefits, that is, benefits accruing to individuals who do not directly use the hydro resource but nonetheless attach a positive value to its existence. A more detailed description of the methods, underlying theory, and empirical results is presented in Carlson (1995).

A.6.1 Underlying Theory

According to the theory of welfare economics, the gross benefits (measured in monetary terms) derived from a good (or service) are measured by the aggregate willingness to pay for the good. Willingness to pay can in turn be divided into two components: (1) actual expenditures on the good, and (2) any additional amount individuals would pay for the continued right to consume the quantity in question. This latter amount, which is equal to the difference between total willingness to pay and actual expenditures, is called surplus value or "consumer surplus."

When the potential impacts of a policy are viewed from the national level, the change in surplus values attributable to the policy question is the appropriate measure of economic benefits. The change in surplus values, that is, consumer surplus, measures the amount by which individuals are better (or worse) off as a result of the policy. When the benefits of a policy option are assessed at the local economy level, expenditures then become the focus of the analysis. In particular, the analysis addresses the effects of a change in expenditures on the levels of income and employment in the regional economy. One of the primary underlying assumptions of regional economic analysis is that changes in expenditures result in changes in income and employment. The link between expenditures on the one hand, and income and employment on the other, is known as the multiplier process. According to the theory of the multiplier, a change in spending in the local economy will result in a change in income that is some multiple of the initial spending change.

In this analysis, the term "total value" is used to describe the total amount individuals are willing to pay for a resource of a given quality. The total value of a natural resource can be decomposed into two principal components: use value and nonuse value. The term "use value" refers to the value of the direct (and sometimes indirect) uses to which a resource can be put. The use values of a resource are measured by consumers' total willingness to pay C that is, the sum of expenditures and surplus values. Surplus value can also be thought of as net use value.

Nonuse values include what have been termed "existence value" and "bequest value." As its name suggests, existence value measures the value an individual attaches to the existence of a resource, whether or not the individual ever intends to use the resource personally. In the present case, it is plausible to assume that some individuals would be willing to pay a positive amount of money simply to know that the Grand Canyon C as well as other similar sites C would continue to exist in their current condition. In particular, individuals may attach positive values to the preservation of the existing ecology, historic and prehistoric artifacts and sites, and the current quality of recreational opportunities, to name but a few possibilities. In a similar vein, individuals may attach a positive value to the preservation of such resources for future generations. This type of value is called bequest value. In this case the distinguishing factor is the time frame.

Some disagreement exists among economists regarding the legitimacy of nonuse value as a value distinct from use value. For example, Brookshire et al. (1986) argued that although existence values may exist, they should nonetheless be excluded from benefit-cost analyses since they reflect considerations other than the efficiency motive. More recently, Rosenthal and Nelson (1992) and Quiggin (1993) have argued that although nonuse values may exist, they present a number of problems that raise serious questions about the legitimacy of including them in the decision-making process.

Proponents of the case for the inclusion of nonuse values in total valuation studies, however, have offered strong rebuttals to the arguments described above. For example, a report prepared by HBRS, Inc. (1991, p.17) contends that:

Motives based on feelings of environmental responsibility have to do with people's concerns about the effects of their consumption on environments that they do not personally plan to use. For example, if Gamma's consumption of electricity would contribute to deterioration of Grand Canyon Beaches, then she might be willing to pay something to reduce or eliminate this effect so that she is not responsible for such harm. Bequest motives are a temporal extension of motives relating to benevolence toward relatives and other people in the temporal realm.... If the benefactor's utility depends on the bequest, an additional value is created, and this additional value is missed if the beneficiary's use value alone is included in benefits.

As the preceding discussion suggests, there are strong arguments both for and against including nonuse values in a total valuation study.

A.6.2 Estimation Techniques

Regional or local economic impacts are usually estimated with the use of an input-output model. For example, the regional economic impacts of a change in Western's commitment-level alternatives were estimated with the REMI Model (Section A.5). The analysis of the regional effects of recreation below Flaming Gorge Dam were estimated with the IMPLAN regional economic model. Regional economic impacts associated with recreation at Glen Canyon Dam were based on results reported in the Glen Canyon EIS (Reclamation 1995). A complete discussion of the IMPLAN model and the analysis of recreation below Flaming Gorge Dam is presented in Rose and Frias (1993a). The principal results of their analysis and the implications for the operational scenarios at Flaming Gorge Dam are summarized in Sections 3.1.1 and 4.1.1.

With respect to the estimation of use values, an approach that has received increased attention in the literature is that of "benefits transfer." As its name implies, benefits transfer entails the use of existing estimates of benefits at one site, commonly referred to as the "study site" to estimate the benefits of recreation at some other site, referred to as the "policy site." Thus, the Green River below Flaming Gorge Dam is a policy site. Because it has been the subject of a number of previous studies of the economic benefits of recreation, the area below Glen Canyon Dam is both a policy site and a study site.

Benefits transfer can be more or less rigorous depending upon the available data and the needs of the policy analyst. For example, in some situations benefits transfer amounts to the development of rough estimates based on averages from previous studies. This type of approach would be acceptable in cases where the analyst requires a "ballpark" figure to determine whether further analysis is warranted. In other cases, provided that sufficient information is available, empirical relationships estimated in previous studies may be applied to the site in question to generate estimates of consumer surplus. Once again, the choice of whether to use this approach depends upon the needs of the analyst and the amount of available information. These issues are addressed in more detail by Carlson (1995).

As is discussed below, a benefits assessment of recreation below Glen Canyon Dam was completed by Bishop et al. (1987) as part of the Glen Canyon Environmental Studies. The results of that study were incorporated directly into this EIS. However, in light of time and budget constraints that were imposed on this analysis, the benefits of recreation below Flaming Gorge Dam were estimated by the benefits transfer process. To complete the benefits transfer, studies had to be identified, assessed, and (where appropriate) summarized for use in this process. For the reasons discussed in Section 3.7, the analysis was confined to angling and white-water boating. Although a number of studies were identified as potential candidates for the benefits transfer in the initial screening process, most of them were eliminated for various reasons (Carlson 1995). Two studies emerged as potential candidates C a study by Walsh et al. (1980) and the study by Bishop et al. (1987).

The study by Walsh et al. (1980) examined recreational activities (including fishing, kayaking, and rafting) on nine rivers in western Colorado. In addition to estimating the effects of congestion on the demand for individual activities, the authors also estimated the relationship between changes in streamflow, measured as a percent of bank-full conditions, and the average consumer surplus per day for each activity. Given the proximity of the study sites to the policy sites being considered here and the types of questions that were addressed, the Walsh et al. (1980) study would appear to be a good candidate for use in a benefits transfer. However, the fact that the benefit estimates were conditioned on the optimal amount of congestion per stream mile would make transfer of the estimates to Flaming Gorge extremely difficult. This difficulty results from the lack of information on what would constitute the optimal concentration of anglers and white-water boaters along the Green River. Given this lack of information, it would not be possible to determine the likely direction of bias in the resulting estimates.

Bishop et al. (1987) conducted an attribute survey and contingent valuation (CV) survey of anglers, white-water boaters, and day rafters on the Colorado River below Glen Canyon Dam. The purpose of the surveys was to identify the aspects of angling and white-water boating that are most likely to influence the net benefits from the experience, and to derive estimates of the benefits derived from angling, white-water boating, and day rafting under different dam operational scenarios. According to the results of the attributes survey and CV survey that followed, the benefits of day rafting between the dam and Lees Ferry are largely unaffected by changes in streamflows. It was concluded, therefore, that the use value of day rafting on this stretch of the river would not change with a change in dam operations.

For multiple-day white-water boating trips, the attributes survey revealed that boaters tend to prefer constant flows to fluctuating flows, since the former is more consistent with natural conditions. In addition, if flows are constant, higher flows are preferred to lower flows over the range of 1,000 cfs to approximately 33,000 cfs (commercial boaters) and 29,000 cfs (private boaters). In the case of fluctuating flows, higher flows are preferred to lower flows over the range from 5,000 to 25,000 cfs for both groups. The attributes survey revealed that anglers also prefer constant flows to fluctuating flows, since the former are more consistent with natural conditions. In addition, higher flows are preferred to lower flows over the range of 1,000 cfs to approximately 10,000 cfs for both constant and fluctuating flows.

Estimates of surplus value associated with various flow levels and assumptions about fluctuations in flows were developed from results of the CV survey. These estimates were then used to construct "flow valuation curves" that relate surplus values to flow levels. Separate flow valuation curves were constructed for commercial white-water boating, private white-water boating, and angling for both constant and fluctuating flows, (i.e., a total of six flow valuation curves were constructed). These curves were then used to estimate the recreation benefits associated with different operational scenarios and hydrological conditions at Glen Canyon Dam. These curves were subsequently modified by ANL to estimate the benefits from recreation below Flaming Gorge Dam.

Although the study by Bishop et al. (1987) was selected as the best candidate for benefits transfer, several potential sources of bias exist. First among these is the fact that part of the use values attributed to recreation below Glen Canyon Dam may reflect the unique scenic beauty of the area. Although the Green River and surrounding environment below Flaming Gorge Dam are also considered to be quite scenic, it is nonetheless possible that the difference between the two sites results in an upward bias in the estimates of the value of recreation below Flaming Gorge Dam. Another source of bias is the assumption of constant use rates. To the extent that use rates actually increase or decrease with change in flows, benefits estimates would be either downward or upward biased. This observation applies equally to the benefit estimates for both sites.

In order to conduct the benefits transfer, some of the flow valuation curves developed by Bishop et al. (1987) had to be modified before they could be transferred to the Flaming Gorge site. Modification was required because of the significant difference in flow regimes at the two sites, and in light of information on individual preferences for flows at Flaming Gorge. In the case of angling, benefits are maximized at flows of 10,000 cfs below Glen Canyon Dam. However, in the case of Flaming Gorge Dam, as is discussed in Section 3.7, angling satisfaction is at a maximum when flows are between 1,100 cfs (shore anglers) and 1,500 cfs (boat anglers). Consequently, the flow valuation functions had to be scaled to reflect the range of preferred flows at Flaming Gorge. The resulting modified value functions were then combined with data on use rates and monthly average flows below Flaming Gorge Dam to obtain the estimates presented in Section 4.2.1.2. In the case of the white-water boating flow valuation curves, the functions were not modified. Instead, the functions developed by Bishop et al. (1987) were combined with use rates and flows to estimate the value of white-water boating in Dinosaur National Monument. This approach was based on the similarity of the minimum flows at the two locations (1,000 cfs at Glen Canyon and 800 cfs in Dinosaur National Monument) and the lack of information suggesting that the flow level at which use values are maximized differed substantially across the two locations.

With respect to nonuse values, previous research suggests that nonuse values may account for a substantial portion of the total value of a resource. For example, Fisher and Raucher (1984) reviewed a number of studies that estimated use and nonuse values of particular resources. They concluded that "non-use benefits generally are at least half as great as recreational use benefits (p. 60)." As was noted in Section 3.1.2, a study by Loomis (1987) estimated that nonuse values were approximately 73 times as large as the corresponding use values associated with Mono Lake in California. This broad range indicates both the potential magnitude of nonuse values and difficulties that would be encountered in attempts to estimate nonuse values on the basis of existing studies. In light of the considerable variability in existing estimates of nonuse values, and the lack of information on the effect different operational scenarios could have on such values, no empirical estimates were attempted. Instead, observations on the potential effects on nonuse values were confined to qualitative assessments.

A.7 IRRIGATED AGRICULTURE

This section describes the method that was used to estimate the impacts of the commitment-level alternatives on agricultural output in selected states. A more detailed description of the analysis and empirical results see presented by Edwards et al. (1995).

A.7.1 Introduction

The irrigated agriculture impacts analysis is based on the assumption that within the agricultural sector, farmers are able to choose from a large number of crops. Moreover, the farmers have alternative means of producing each crop. At the broadest level, the farmers can choose between cropping practices C irrigated versus dryland agriculture C and for each of these practices can choose levels of other inputs, such as fertilizers, pesticides, capital equipment, and management labor. In the case of dryland cropping, farmers rely on rainfall for water and choose crops, acreage, and other inputs accordingly. For irrigated cropping practices, farmers can purchase surface water or they can pump groundwater. Pumping groundwater requires power to operate the pumps; for most farms that power is electricity. For the region under consideration in this analysis, electricity is used to power nearly 80% of all irrigation pumps. Natural-gas- and diesel-powered irrigation pumps make up most of the remaining 20%. As a result of these options, a change in electricity prices implied under different commitment-level alternative/supply option combinations can trigger a broad set of responses by farmers as they attempt to maximize profits. The approach taken in this analysis was to capture the full range of options at the disposal of farmers. In particular, the approach emphasized the substitution between inputs and acreage across cropping practices that typify the farmer's resource allocation decision.

A.7.2 Scope of Analysis

The analysis was performed for each of six states (Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming). The analysis concentrated on field crops (barley, corn, silage, cotton, hay, sorghum, and wheat) and allowed for both irrigated and dryland cropping, depending on the extent to which irrigated and dryland cropping practices are combined in each state. The data used to determine baseline values of acreage, outputs, water use, energy inputs, and input costs were taken from individual state agriculture publications and U.S. Department of Agriculture (USDA) publications. The baseline price forecasts were taken from a recent USDA forecast of crop prices. The most recent year for which most of the required data were available was 1990, so that was used as the test year for purposes of constructing the baseline. Forecasted acreage for each crop in each state was then determined from the USDA forecasts of national level acreage. As the baseline was constructed, it was assumed that the basic technology of farming was fixed; for example, yields per acre and water application rates (acre-feet per acre of water) for all crops were assumed not to change over the 1993-2008 forecast period. In effect, this amounts to assuming no fundamental changes occur in agriculture technology. Innovations such as higher-yield seed, more efficient groundwater pumping, and changes in the efficiency of specific irrigation practices (e.g., drip irrigation) were ruled out.

A.7.3 Method of Analysis

The analysis relied on the method of positive mathematical programming (PMP), which combines linear with nonlinear programming techniques. This approach involves two stages. The first, or calibration, stage solves a linear program of agriculture activity. This stage accomplishes two tasks. First, the model is calibrated to actual baseline data. Second, the opportunity costs of the resources used are determined. The nonlinear programming problem solved in the second stage determines the optimal mix of inputs. Given the optimal input mix that includes acreage for each crop by cropping practice, the optimal set of outputs of each crop is determined. For this analysis, the results of the first (linear programming) stage were calculated under the assumption of no change in electricity costs for groundwater pumping and, hence, represented the baseline simulation. The second stage (nonlinear programming) incorporated the change in electricity prices under the different commitmentlevel alternative/supply option combinations. The impacts were then determined by comparing the results of the analysis under this second stage to the baseline results.

This analysis permits a broad set of substitution possibilities. First, crops could be switched between practices (i.e., between dryland and irrigated agriculture). Within irrigated agriculture, farmers could switch crops between pumped irrigated and surface water acreage. Within pumped irrigation, farmers could switch between fuels (e.g., between electricity, natural gas, and diesel, and other fuels). For purposes of this analysis, nonelectric fuel sources (e.g., natural gas, diesel, LP gas, gasoline and gasohol) were aggregated into one groundwater pumping energy source identified as "other." In addition, farmers could also alter fertilizer, pesticide, and capital usage. All of these substitution possibilities are captured in a constant elasticity of substitution production function broken into nests that reflect these different levels of substitution. For this analysis, two large nests were assumed. The first was for dryland farming, which broke input use into two broad categories (land and variable inputs). The variable input nest was then assumed to depend on three inputs (capital, chemical, and other). The second nest was for irrigated cropping practices. Production in this nest was broken into three groups (land, variable inputs, and water). The variable input nest included capital, chemical, and other inputs. The water input nest included surface water, groundwater electric, and groundwater other.

The principal input decision for a farmer is acreage allocation between crops. Once that decision is made, the other input allocations will closely follow suit (i.e., will be roughly proportional to the acreage decisions and other input requirements for each crop). Higher electricity prices make the electrically irrigated acreage more expensive relative to other acreage. This situation can lead farmers to switch to less water intensive crops or can cause farmers to move less profitable crops away from electrically irrigated acreage towards nonelectrically irrigated acreage, surface water acreage, or even to dryland farming. The detail in the approach taken in this analysis made it possible to estimate the role played by all of these impact channels in a farmer's resource allocation decision.

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APPENDIX B: AIR RESOURCES

The air resources (including acoustical environment) of the six-state study region considered in this Electric Power Marketing Environmental Impact Statement (EIS) are described in Section 3.2 of the main text, and the environmental consequences of commitment-level alternatives and operational scenarios are evaluated in Sections 4.1.2 and 4.2.2, respectively. This appendix provides additional information in support of these descriptions and evaluations. Information regarding the affected environment and environmental consequences is presented in Sections B.1 and B.2, respectively.

B.1 AFFECTED ENVIRONMENT

B.1.1 Climate and Meteorology

The six-state study region includes the states of Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming. The climate of this region is generally semiarid to arid. The most important factors affecting the climate of the region are the wide variations in topography and latitude and the presence of warm, moist air masses that originate over the Pacific Ocean and move eastward. Additional influences include the Gulfs of California and Mexico, which occasionally spawn summer rainstorms over the southern portion of the region; and Canadian air masses, which occasionally settle over the northern portion of the region (Upper Colorado Region State-Federal Inter-Agency Group 1971; U.S. Army Corps of Engineers [COE] 1982).

B.1.1.1 Wind

Winds in the region generally move from west to east but are greatly modified by local topographic features. Mountain slopes with westerly exposures experience high wind speeds, whereas wind speeds are relatively low in the protected valleys. During much of the year, high-pressure regions dominate, causing only light wind movement. Surface winds are most often associated with the movement of air masses up the slopes during the day and down the slopes during the night (Upper Colorado Region State-Federal Inter-Agency Group 1971). In desert and plateau regions, the strongest winds are associated with summer rainstorms and can reach speeds of up to 100 miles per hour (mph). In the northernmost regions and in the mountains, the greatest wind speeds are recorded during the winter and spring months (COE 1982).

B.1.1.2 Temperature, Humidity, and Fog

Temperatures in the region vary widely with elevation, latitude, season, and time of day. Temperatures vary about 3EF per 1,000 ft of elevation. Average temperatures range from freezing in the mountains to 50EF in the lower mountains and plateaus and up to 70EF in the desert regions in the south (Upper Colorado Region State-Federal Inter-Agency Group 1971; COE 1982). In New Mexico, average temperatures between points of similar elevation vary about 0.6EF per 1E of latitude; in Utah, the variation is about 1.5 to 2EF per 1E change in latitude (Ruffner 1985). The mean monthly temperature is highest in July and lowest in January. Diurnal variations are usually large in summer, averaging about 40EF and as much as 50 to 60EF in desert regions. During winter, these variations average about 20 to 25EF, although they can be higher in the desert regions (Upper Colorado Region State-Federal Inter-Agency Group 1971; COE 1982; Ruffner 1985).

Humidity in the region is generally quite low, especially in the deserts in the southern portion of the region. Annual average relative humidity values, based on four readings per day, range from 30% in Las Vegas, Nevada, and 36% in Phoenix, Arizona, to 55% in Salt Lake City, Utah, and 56% in Casper, Wyoming (National Oceanic and Atmospheric Administration 1990ag). Because of the low humidity, days with heavy fog are rare, especially in the desert regions in the lower basin. The annual average number of days with heavy fog limiting visibility to 0.25 mi or less ranges from 0.7 in Las Vegas, Nevada, and 1.5 in Phoenix, Arizona, to 11.4 in Flagstaff, Arizona, and 11.5 in Salt Lake City, Utah (National Oceanic and Atmospheric Administration 1990ag).

B.1.1.3 Precipitation and Evaporation

An average of 14 in./yr of precipitation falls on the Colorado River Basin. The local annual precipitation varies from less than 5 in.

in desert regions to more than 50 in. at the highest mountain elevations. For most of the upper basin, the largest part of the annual precipitation occurs during October through April from Pacific storms. In the lower basin, summer storms from the gulfs of California and Mexico during July through September account for the largest part of annual precipitation; however, precipitation is highly variable from year to year and can be less in summer than in winter (Upper Colorado Region State-Federal Inter-Agency Group 1971; COE 1982).

Evaporation rates are high throughout the river basin, as a result of the combination of high temperatures, low humidities, clear skies, and moderate winds. In northern Arizona, annual evaporation rates range from about 30 in. at high elevations to about 60 in. in the lower valleys. In central and southern Arizona, annual evaporation rates range from about 50 in. to more than 80 in. along the Colorado River (COE 1982).

B.1.1.4 Severe Weather

Thunderstorms in the basin usually result from air masses moving in from over the gulfs of California and Mexico, and they occur most frequently in the lower basin during July through September. The thunderstorms consist of heavy downpours, which are often associated with high winds that occasionally reach speeds of up to 100 mph (Upper Colorado Region State-Federal Inter-Agency Group 1971; COE 1982). The annual average number of thunderstorms ranges from 7 in Yuma, Arizona, and 14 in Las Vegas, Nevada, to 42 and 51 in Tucson and Flagstaff, Arizona, respectively (National Oceanic and Atmospheric Administration 1990ag). Tornadoes are less frequent and destructive in this region than in the Midwest (Ruffner 1985). Severe weather in the upper basin is most often associated with winter storms, which are widespread and usually last several days (COE 1982).

B.1.1.5 Atmospheric Dispersion

Atmospheric dispersion of air pollutants improves if wind speed increases, atmospheric stability lessens, and depth of mixing layer (mixing height) increases. Annual and seasonal data for average wind speed throughout the mixing layer, mixing height, and normalized average pollutant concentration values for the contiguous United States have been estimated and presented as isopleth maps by Holzworth (1972). These isopleth maps indicate that the conditions for atmospheric dispersion in this region are, in general, poorer than in other regions of the United States during morning hours but somewhat better during afternoon hours. The worst conditions for atmospheric dispersion exist during the winter months, when the average mixing height is lowest in both morning and afternoon and the average wind speed in the mixing layer is reduced.

B.1.2 Air Quality

Tables B.1 through B.4 and Figures B.1 through B.9 provide detailed information regarding air quality and visibility within the six-state study region. Table B.1 presents the National Ambient Air Quality Standards (NAAQS) and State Ambient Air Quality Standards for criteria pollutants applicable to each of the six states. Table B.2 identifies the designated nonattainment areas in each state with respect to the NAAQS. Emissions of sulfur dioxide (SO2), nitrogen oxides (NOx), and volatile organic compounds (VOCs) in the six states are listed in Table B.3. Emissions of carbon dioxide (CO2) in the six states are compared with U.S. CO2 emissions in Table B.4.

Figure B.1 shows the locations of the major electric power plants (total capacity of 25 MW or greater) located within the six-state study region. (Table B.5 provides a key to the plants in the figure.) Figure B.2 shows the areas within the study region designated as nonattainment for SO2, carbon monoxide (CO), ozone (O3) and PM10 (particulates with a diameter #10 Fm). Figures B.3 through B.9 show the locations of ambient air quality monitoring stations operating within the six-state study region during 1989; these stations monitored SO2, nitrogen dioxide (NO2), CO, O3, PM10, TSP, and lead (Pb), respectively. The regional visual range for the contiguous United States is shown in Figure B.10, and the Federal Class I air quality areas in the contiguous United States are shown in Figure B.11. Visibility has been determined to be an important value in 156 of the Class I areas (EPA 1979).

TABLE B.1 National Ambient Air Quality Standards (NAAQS) and State Ambient Air Quality Standards (SAAQS) for Criteria Pollutants Applicable to the Six States in the Study Region

	NAAQS^b (:g/m^3)	SAAQS (:g/m^3)

Pollutant[a]	Averaging Time	Primary	Secondary	Arizona[c]	Colorado[d]	Nevada[d]	New Mexico[e]	Utah[d]	Wyoming[d]
SO_2	Annual	80	-[f]	80	80	80	60	80	60
	24 hours	365	-	365	365	365	260	365	260
	3 hours	-	1,300	1,300	1,300	1,300	1,300	1,300	1,300
NO_2	Annual	100	100	100	100	100	100	100	100
	24 hours	-	-	-	-	-	200	-	-
CO	8 hours	10,000	10,000	10,000	10,000	10,000	9,200	10,000	10,000
	1 hour	40,000	40,000	40,000	40,000	40,000	14,800	40,000	40,000
O_3	1 hour	235	235	235	235	235	118	235	160
TSP[g]	Annual[h]	-	-	-	75	75	60	-	-
	24 hours	-	-	-	260	150	150	-	150
PM_{10}	Annual[i]	50	50	50	50	50	50	50	50
	24 hours	150	150	150	150	150	150	150	150
Pb	Calendar quarter	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5

TABLE B.2 Designated Nonattainment Areas within the Colorado River Basin and the Six-State Study Region

	Nonattainment Areas for Respective Pollutants[b]				
State	SO_2	CO	O_3	TSP	PM_{10}
Arizona	Portions of Ajo, Douglas, Hayden, Miami, Morenci, and San Manuel	Portions of Maricopa County[c] (Phoenix area) and Pima County[d] (Tucson area)	Portion of Maricopa County[c] (Phoenix area)	Portions of Ajo, Douglas, Hayden, Joseph City, Miami, Morenci, Paul Spur, Phoenix, and Tucson	Portions of Cochise, Gila, Maricopa, Pinal, Santa Cruz, and Yuma counties[c]
Colorado	None	Colorado Springs area,[c] Denver-Boulder area,[c] Fort Collins area,[c] Greeley area,[d] and Longmont area[c]	Denver, Douglas, and Jefferson counties; portions of Adams, Arapahoe, and Boulder counties[e]	Fort Collins, Greeley, Denver UA, Boulder UA, Colorado Springs 3-C UA, and Grand Junction UA	Denver metropolitan area, Aspen, Canon City, Lamar, Pagosa Springs, and Telluride[c]
Nevada	Steptoe Valley	Lake Tahoe (Nevada) area,[d] Las Vegas area,[c] and Reno area[c]	Reno area[f] (Washoe County)	Las Vegas Valley, Carson Desert, Winnemucca segment, Lower Reese Valley, Fernley area, Truckee Meadows, Mason Valley, and Clovers area.	Portions of Washoe and Clark counties
New Mexico	Portions of Grant County	Bernalillo County[c]	None	Portions of city of Albuquerque	Portion of Dona Ana County[c]
Utah	Salt Lake County and portions of Tooele County	Salt Lake City,[d] Ogden,[c] and Provo[c]	Salt Lake and Davis counties[c]	Portions of Salt Lake and Utah counties	Salt Lake and Utah counties[c]
Wyoming	None	None	None	Trona industrial area in Sweetwater County	City of Sheridan[c]

a

Notation: UA indicates urban area or urbanized area; 3C UA is a planning term used to designate continuing, cooperative, and comprehensive transportation planning area boundaries.

[b] For PM_{10}, initial nonattainment area.

[c] Moderate nonattainment.

[d] Not classified.

[e] Transitional nonattainment.

[f] Marginal.

Source: Code of Federal Regulations, Title 40, Part 81, Subpart C.

TABLE B.3 Annual Emissions of SO2, NOx, and VOCs from Electric Utility and Other Sectors within the Six-State Study Region, 1981-1990a

Pollutant/ Sector	Emissions by Year (10^3 tons)									
	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
SO_2										
Electric utility	458	465	451	474	397	359	379	459	469	410
Others	1,571	1,036	1,112	1,074	971	870	601	519	445	429
Total[b]	2,029	1,501	1,563	1,548	1,368	1,229	980	979	914	839
NO_x										
Electric utility	482	499	484	521	532	509	570	623	675	979
Others	839	880	940	969	753	710	733	743	769	773
Total[b]	1,322	1,380	1,424	1,490	1,284	1,219	1,304	1,366	1,444	1,752
VOCs										
Electric utility	3	3	3	3	3	3	3	3	3	3
Others	1,024	980	972	973	878	830	841	864	831	802
Total[b]	1,026	983	975	976	881	833	845	867	835	805

[a] The six states are Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming.

[b] Individual values may not add up to the total because of rounding.

Source: Cilek (1993).

TABLE B.4 Annual Emissions of CO2 from Electric Utility and Other Sectors within the Six-State Study Region and the United States, 1981-1990

Emissions (10^6 tons as carbon)

	Six States[a]			United States		
Year	Electric Utility	Others	Total[b]	Electric Utility	Others	Total[b]
1981	39	78	117	473	1,830	2,303
1982	40	76	115	447	1,715	2,162
1983	38	75	114	459	1,671	2,130
1984	42	78	120	479	1,770	2,249
1985	44	75	120	492	1,743	2,235
1986	41	74	115	488	1,749	2,237
1987	47	75	122	506	1,806	2,313
1988	51	80	131	531	1,892	2,423
1989	52	81	134	539	1,904	2,443
1990	53	93	145	531	1,901	2,432

[a] The six states are Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming.

[b] Individual values may not add up to the total because of rounding.

Source: Cilek (1993).

TABLE B.5 Key to Figure B.1

State/Power Plant	Type of Plant	MW	State/Power Plant	Type of Plant	MW
Arizona			Colorado (Cont.)		
1 Aqua Fria	Fossil steam	390	30 Burlington	Combustion turbine	118
	Combustion turbine	223	31 Craig	Fossil steam	1,284
2 Apache	Fossil steam	399	32 Crystal	Hydroelectric	29
	Combined cycle	80	34 Nixon	Fossil steam	207
	Combustion turbine	84	35 Pawnee	Fossil steam	500
3 Cholla	Fossil steam	1,156	36 Mt. Elbert	Hydroelectric	200
5 Cross Cut	Fossil steam	30	37 Rawhide	Fossil steam	255
	Hydroelectric	3	38 Green Mountain	Hydroelectric	26
6 Davis	Hydroelectric	225			
7 De Moss-Petrie	Combustion turbine	66	Nevada		
9 Glen Canyon	Hydroelectric	1,267	1 Clark	Fossil steam	190

10 Horse Mesa	Hydroelectric	130
11 Irvington	Fossil steam	505
	Combustion turbine	81
12 Kyrene	Fossil steam	108
	Combustion turbine	227
13 Mormon Flat	Hydroelectric	58
14 North Loop	Combustion turbine	108
15 Ocotillo	Fossil steam	220
	Combustion turbine	174
16 Roosevelt	Hydroelectric	35
17 Saguaro	Fossil steam	225
	Combustion turbine	114
18 Navajo	Fossil steam	2,410
20 Yuma Axis	Fossil steam	75
	Combustion turbine	148
21 Phoenix	Fossil steam	75
	Combustion turbine	106
	Combined cycle	396
22 Santan	Combustion turbine	414
25 Coronado	Fossil steam	821
26 Hoover	Hydroelectric	671
27 Springerville	Fossil steam	794
28 Palo Verde	Nuclear	3,810
29 Douglas	Combustion turbine	26
30 Valencia	Combustion turbine	50
	Internal combustion	4
Colorado		
1 Alamosa	Fossil steam	20
	Combustion turbine	58
2 Arapahoe	Fossil steam	251
4 Blue Mesa	Hydroelectric	60
5 Clark	Fossil steam	39
6 Comanche	Fossil steam	778
7 Cabin Creek	Hydroelectric	300
8 Cameo	Fossil steam	75
9 Fort Lupton	Combustion turbine	110
10 Cherokee	Fossil steam	802
11 Estes	Hydroelectric	45
12 Flatiron	Hydroelectric	74
13 Birdsall	Fossil steam	63
14 Fruita	Combustion turbine	29
16 Hayden	Fossil steam	465
17 Republican River	Combustion turbine	225
19 Lamar	Fossil steam	35
	Internal combustion	2
20 Drake	Fossil steam	282
	Combustion turbine	66
21 Morrow Point	Hydroelectric	120
22 Nucla	Fossil steam	38
23 Pole Hill	Hydroelectric	33
24 Pueblo	Fossil steam	23
	Internal combustion	10
28 Valmont	Fossil steam	282
	Combustion turbine	66
29 Zuni	Fossil steam	115
	Combustion turbine	270
2 Fort Churchill	Fossil steam	220
3 Hoover	Hydroelectric	676
4 Mohave	Fossil steam	1,636
5 Reid Garder	Fossil steam	342
6 Sunrise	Fossil steam	82
	Combustion turbine	75
7 Tracy	Fossil steam	243
	Combustion turbine	25
8 Westside	Internal combustion	32
9 Valmy	Fossil steam	254
New Mexico		
1 Algodones	Fossil steam	51
4 Cunningham	Fossil steam	265
5 Lordsburg	Fossil steam	37
	Combined cycle	5
	Combustion turbine	13
6 Four Corners	Fossil steam	2,268
7 North Lovington	Fossil steam	49
	Internal combustion	19
8 Maddox	Fossil steam	114
	Combustion turbine	66
9 Person	Fossil steam	120
11 Rio Grande	Fossil steam	266
12 Reeves	Fossil steam	175
14 San Juan	Fossil steam	1,572
15 Plains Escalante	Fossil steam	233
16 Animas	Fossil steam	32
	Internal combustion	2
17 Navajo	Hydroelectric	30
Utah		
1 Carbon	Fossil steam	189
2 Cutler	Hydroelectric	30
3 Flaming Gorge	Hydroelectric	108
4 Gadsby	Fossil steam	252
9 Huntington Canyon	Fossil steam	893
10 Hunter	Fossil steam	1,338
12 Bonzana	Fossil steam	400
13 Intermountain	Fossil steam	1,522
Wyoming		
1 Alcova	Hydroelectric	36
2 Bridger	Fossil steam	2,024
3 Johnston	Fossil steam	788
5 Fremont Canyon	Hydroelectric	48
8 Kortes	Hydroelectric	36
9 Naughton	Fossil steam	711
11 Osage	Fossil steam	36
	Internal combustion	1
12 Seminoe	Hydroelectric	45
13 Laramie	Fossil steam	1,650
14 Wyodak	Fossil steam	331
15 Glendo	Hydroelectric	38

Figure B.1 Major Electric Power Plants in the Six-State Study Reigon (see Table B.5 for key to Facilities).

Figure B.2 Areas Within the Six-State Study Region Designated Nonattainment for SO_2, CO, O_3, and PM_{10}

Figure B.3 Ambient Air Quality Monitoring Sataions for SO_2 Operating in 1989 within the Six-State Study Region

Figure B.4 Ambient Air Quality Monitoring Stations for NO_2 Operating in 1989 within the Six-State Study Region

Figure B.5 Ambient Air Quality Monitoring Stations for CO Operating in 1989 within the Six-State Study Region

Figure B.6 Ambient Air Quality Monitoring Stations for O_3 Operating in 1989 within the Six-State Study Region

Figure B.7 Ambient Air Quality Monitoring Stations for PM_{10} Operating in 1989 within the Six-State Study Region

Figure B.8 Ambient Air Quality Monitoring Stations for TSP Operating in 1989 within the Six-State Study Region

Figure B.9 Ambient Air Quality Monitoring Stations for Lead Operating in 1989 within the Six-State Study Region

Figure B.10 Contour Plot of Summer 1984 Median Standard Visual Range for the Contiguous United States

Figure B.11 Federal Class I Air Quality Areas in the Contiguous United States

B.1.3 Noise

The EPA guideline recommends an Ldn of 55 dBA, which is sufficient to protect the public from the effect of broad-band environmental noise in typically quiet outdoor and residential areas (EPA 1974)., For protection against hearing loss in the general population from nonimpulsive noise, the EPA guideline recommends an Leq of 70 dBA or less over a 40year period.

Under the Noise Control Act of 1972 and its amendments (Quiet Communities Act of 1978, 42 United States Code 4901-4918), the states have authority to regulate environmental noise, and governmental agencies are directed to comply with local community noise statutes and regulations. Of the six states within the study region, Colorado is the only one with quantitative noise regulations. The maximum permissible noise limits for the various classes of source areas under the Colorado Noise Abatement Law are listed in Table B.6.

B.1.3.1 Glen Canyon Dam

The acoustic environment in the areas away from the major noise sources at the Glen Canyon power plant is that of a rural location with typical residual sound levels of approximately 30 to 35 dBA (Liebich and Cristoforo 1988). However, close to the boundary of the transformer substation, the residual environmental noise levels are estimated to rise to about 55 dBA (Chun et al. 1995).

TABLE B.6 State of Colorado Regulations on Maximum Permissible Noise Levels

	Maximum Permissible Noise Level[a] (dBA)	
Zone	7 a.m. to 7 p.m.[b]	7 p.m. to next 7 a.m.
Residential	55	50
Commercial	60	55
Light industrial	70	65
Industrial	80	75

[a] At a distance of 25 ft or more from the property line. Periodic, impulsive, or shrill noises are considered a public nuisance when such noises are at a level of 5 dBA less than those listed.

[b] For a period not to exceed 15 minutes in any one hour, the noise level may be exceeded by 10 dBA.

Source: Colorado Revised Statutes, Title 25 C Health, Article 12 C Noise Abatement.

The noisesensitive receptors closest to the transformer substation at the Glen Canyon power plant are the residences located along the northwestern perimeter of the city of Page, approximately 1.1 mi east of the substation. If the Glen Canyon power plant were not present, these residences would have residual nighttime sound levels typical of rural communities near a lightly traveled highway (approximately 30 dBA) (Liebich and Cristoforo 1988). However, acoustic emissions from the noise sources at the Glen Canyon power plant are estimated to raise the residual background environmental noise levels in the residential area up to about 39 dBA (Chun et al. 1995).

The ambient environmental noise level at these residences is increased at times when traffic is passing on nearby roadways. An automobile can produce a momentary level of up to 77 dBA when passing along a roadway at a distance of 50 ft from a receptor. A large, heavily loaded tractortrailer truck can create maximum levels as high as 87 dBA when passing at a distance of 50 ft (Flynn 1979; Fuller and Brown 1981). At such times, vehicular noise completely masks (makes inaudible) all other environmental background noise at these residences, including the levels attributable to the noise sources at Glen Canyon power plant.

B.1.3.2 Flaming Gorge Dam

The acoustic environment in the areas away from the major noise sources at the Flaming Gorge hydroelectric plant is that of a remote rural-to-wilderness location with typical residual sound levels of approximately 20 to 25 dBA (Liebich and Cristoforo 1988). However, close to the boundary of the transformer substation, the residual environmental noise levels are estimated to rise to about 44 dBA (Chun et al. 1995).

The noisesensitive receptors closest to the transformer substation at the Flaming Gorge power plant are the Arch Dam and Deer Run campgrounds C approximately 0.9 mi east and 1.1 mi westsouthwest of the transformer substation, respectively. If the Flaming Gorge power plant were not present, these campgrounds would have residual nighttime sound levels typical of remote rural-to-wilderness areas (approximately 20 dBA) (Liebich and Cristoforo 1988). Acoustic emissions from the noise sources at the Flaming Gorge power plant are estimated to raise the residual background environmental noise levels at these campgrounds up to about 30 and 28 dBA, respectively (Chun et al. 1995). The ambient environmental noise levels at the three campgrounds are increased at times when traffic is passing on nearby roadways (Section 3.2.3.1). At such times, vehicular noise completely masks all other environmental background noise at the campgrounds, including the levels attributable to the noise sources at Flaming Gorge power plant.

B.1.3.3 Aspinall Unit

The acoustic environments in the areas away from the major noise sources of the Aspinall Unit (Blue Mesa, Morrow Point, and Crystal dams) are that of a rural-to-remote-rural location with typical residual sound levels of approximately 25 to 30 dBA (Liebich and Cristoforo 1988). However, close to the boundary of the Curecanti substation (located about 1.5 mi south of the Morrow Point power plant), which serves the three power plants, the residual environmental noise levels are estimated to rise to about 44 dBA (Chun et al. 1995).

The noisesensitive receptor closest to the Curecanti substation is a trailer residence about 0.25 mi northwest of the substation transformer. If the Curecanti substation were not present, the area surrounding the trailer residence would have residual nighttime sound levels typical of rural-to-remote-rural locations (approximately 25 dBA) (Liebich and Cristoforo 1988). The acoustic emissions from the substation transformer are estimated to raise the residual background environmental noise levels at the trailer residence up to about 37 dBA (Chun et al. 1995). The ambient environmental noise levels at the trailer residence are substantially increased at times when traffic is passing on nearby roadways (Section 3.2.3.1). At such times, vehicular noise completely masks all other environmental background noise at the trailer residence, including the levels attributable to the substation transformer.

B.2 ENVIRONMENTAL CONSEQUENCES

The potential consequences of Western's commitment-level alternatives and operational scenarios on air quality and the acoustic environment are discussed in Sections 4.1.2 and 4.2.2, respectively, of this EIS. Additional information regarding potential environmental consequences are presented in Tables B.7 and B.8 of this appendix. Estimated annual air pollutant emissions from the region's 17 utility systems and the percent change from the noaction alternative are presented in Table B.7. Estimated annual air pollutant emissions from the region's utility systems under supply options A, B, and C are presented in Table B.8.

TABLE B.7 Annual Emissions of SO2, NOx, TSP, and CO2 from Electric Energy Generated by 17Utility Systems under Selected Commitment-Level Alternatives for 1993, 1998, and 2008

		1993			1998			2008		
Pollutant/ Supply Option	Alternative[a]	Annual Emissions (10^3 tons)[b]	Annual Emission Change[b,c] (10^3 tons)	Percent Change[c]	Annual Emissions (10^3 tons)[b]	Annual Emission Change[b,c] (10^3 tons)	Percent Change[c]	Annual Emissions (10^3 tons)[b]	Annual Emission Change[b,c] (10^3 tons)	Percent Change[c]
SO_2										
Option A	0	364	0.0	0.0	375	0.0	0.0	418	0.0	0.0
	2	361	-3.1	-0.9	372	-3.5	-0.9	415	-3.1	-0.8
	4	363	-1.3	-0.3	374	-1.2	-0.3	418	-0.9	-0.2
	5	364	0.3	0.1	376	0.6	0.2	421	2.0	0.5
	Average	363	-1.0	-0.3	374	-1.0	-0.3	418	-0.5	-0.1
Option B	0	361	-3.0	-0.8	373	-2.3	-0.6	416	-2.4	-0.6
	2	359	-5.1	-1.4	369	-5.5	-1.5	414	-4.9	-1.2
	4	361	-2.8	-0.8	372	-3.0	-0.8	415	-2.9	-0.7
	5	363	-0.8	-0.2	375	-0.6	-0.2	419	0.1	0.0
	Average	361	-2.9	-0.8	372	-2.9	-0.8	416	-2.5	-0.6
Option C	0	359	-4.9	-1.4	371	-4.5	-1.2	415	-3.9	-0.9
	2	356	-7.5	-2.1	367	-8.2	-2.2	411	-7.1	-1.7
	4	359	-5.2	-1.4	370	-5.6	-1.5	413	-5.3	-1.3
	5	362	-2.2	-0.6	373	-2.4	-0.7	417	-1.0	-0.2
	Average	359	-4.9	-1.4	370	-5.2	-1.4	414	-4.3	-1.0
NO_x										
Option A	0	399	0.0	0.0	429	0.0	0.0	538	0.0	0.0
	2	397	-1.7	-0.4	429	0.0	0.0	539	1.3	0.2
	4	396	-3.4	-0.9	429	0.7	0.2	541	3.7	0.7
	5	397	-2.1	-0.5	429	0.1	0.0	539	1.2	0.2
	Average	397	-1.8	-0.5	429	0.2	0.1	539	1.6	0.3
Option B	0	398	-1.1	-0.3	429	-0.2	-0.1	537	-0.9	-0.2
	2	399	0.2	0.0	429	0.3	0.1	539	1.6	0.3
	4	396	-3.1	-0.8	429	0.6	0.1	541	3.3	0.6
	5	397	-1.7	-0.4	429	0.3	0.1	537	0.0	0.0
	Average	398	-1.4	-0.4	429	0.2	0.1	539	1.0	0.2

TABLE B.7 (Cont.)

		1993			1998			2008		
		Annual	Annual Emission		Annual	Annual Emission		Annual	Annual Emission Change[b,c]	

Pollutant/ Supply Option	Alternative[a]	Emissions (10^3 tons)[b]	Change[b,c] (10^3 tons)	Percent Change[c]	Emissions (10^3 tons)[b]	Change[b,c] (10^3 tons)	Percent Change[c]	Emissions (10^3 tons)[b]	(10^3 tons)	Percent Change[c]
NO_x										
Option C	0	399	-0.4	-0.1	427	-1.6	-0.4	536	-1.5	-0.3
	2	401	1.6	0.4	428	-0.6	-0.1	538	0.9	0.2
	4	395	-3.6	-0.9	427	-1.2	-0.3	539	1.9	0.3
	5	397	-2.0	-0.5	427	-1.2	-0.3	537	-0.5	-0.1
	Average	398	-1.1	-0.3	427	-1.2	-0.3	538	0.2	0.0
TSP										
Option A	0	169	0.0	0.0	166	0.0	0.0	163	0.0	0.0
	2	168	-0.8	-0.5	166	-0.8	-0.5	162	-0.4	-0.2
	4	169	-0.2	-0.1	166	-0.4	-0.2	163	-0.1	-0.1
	5	170	0.5	0.3	167	0.4	0.3	164	0.9	0.6
	Average	169	-0.1	-0.1	166	-0.2	-0.1	163	0.1	0.1
Option B	0	168	-0.8	-0.5	166	-0.6	-0.4	162	-0.6	-0.4
	2	168	-1.7	-1.0	165	-1.6	-1.0	162	-1.1	-0.7
	4	168	-1.0	-0.6	165	-1.2	-0.7	162	-0.8	-0.5
	5	169	-0.1	-0.1	167	-0.1	-0.1	163	0.2	0.1
	Average	168	-0.9	-0.5	166	-0.9	-0.5	162	-0.6	-0.4
Option C	0	168	-1.6	-0.9	165	-1.5	-0.9	162	-1.1	-0.7
	2	167	-2.4	-1.4	164	-2.4	-1.5	161	-1.6	-1.0
	4	167	-1.7	-1.0	165	-2.0	-1.2	161	-1.4	-0.9
	5	168	-0.8	-0.5	165	-1.0	-0.6	162	-0.3	-0.2
	Average	168	-1.6	-1.0	165	-1.7	-1.0	162	-1.1	-0.7
CO_2										
Option A	0	341	0.0	0.0	380	0.0	0.0	489	0.0	0.0
	2	340	-1.0	-0.3	380	-0.1	0.0	489	-0.1	0.0
	4	339	-2.1	-0.6	378	-1.3	-0.3	489	-1.0	-0.2
	5	340	-1.5	-0.4	379	-0.8	-0.2	490	0.5	0.1
	Average	340	-1.2	-0.3	379	-0.5	-0.1	489	-0.1	0.0
CO_2										
Option B	0	340	-0.9	-0.3	381	1.1	0.3	490	0.4	0.1
	2	340	-0.4	-0.1	381	0.9	0.2	490	0.9	0.2
	4	339	-2.2	-0.6	379	-0.8	-0.2	488	-1.1	-0.2
	5	340	-1.2	-0.4	381	0.9	0.2	490	0.8	0.2
	Average	340	-1.2	-0.3	380	0.5	0.1	490	0.3	0.1
Option C	0	341	-0.4	-0.1	380	0.5	0.1	490	0.7	0.1
	2	341	0.1	0.0	381	1.0	0.3	491	1.0	0.2
	4	339	-2.6	-0.8	378	-1.9	-0.5	488	-1.9	-0.4
	5	340	-1.5	-0.4	379	-1.0	-0.3	490	0.3	0.1
	Average	340	-1.1	-0.3	379	-0.4	-0.1	490	0.0	0.0

[a] 0 represents the no-action alternative.

[b] 10^5 tons for CO_2.

[c] Change from the no-action alternative/option A case.

Source: Chun et al. (1995).

TABLE B.8 Annual Emissions of SO2, NOx, TSP, and CO2 from Electric Energy Generated by 17Utility Systems under Selected Operational Scenarios for 1993, 1998, and 2008

		1993			1998			2008		
Pollutant/ Alternative[a]	Supply Option	Annual Emissions (10^3 tons)[b]	Annual Emission Difference[b,c] (10^3 tons)	Percent Change[c]	Annual Emissions (10^3 tons)[b]	Annual Emission Difference[b,c] (10^3 tons)	Percent Change[c]	Annual Emissions (10^3 tons)[b]	Annual Emission Difference[b,c] (10^3 tons)	Percent Change[c]
SO_2										
Alt. 0	A	364	0.0	0.0	375	0.0	0.0	418	0.0	0.0
	B	361	-3.0	-0.8	373	-2.3	-0.6	416	-2.4	-0.6
	C	359	-4.9	-1.3	371	-4.5	-1.2	415	-3.9	-0.9
	Average	361	-2.7	-0.7	373	-2.2	-0.6	416	-2.1	-0.5
Alt. 2	A	361	-3.1	-0.9	372	-3.5	-0.9	415	-3.1	-0.8
	B	359	-5.1	-1.4	369	-5.5	-1.5	414	-4.9	-1.2
	C	356	-7.5	-2.1	367	-8.2	-2.2	411	-7.1	-1.7
	Average	359	-5.2	-1.4	369	-5.7	-1.5	414	-5.0	-1.2
Alt. 4	A	363	-1.3	-0.4	374	-1.2	-0.3	418	-0.9	-0.2
	B	361	-2.8	-0.8	372	-3.0	-0.8	415	-2.9	-0.7
	C	359	-5.2	-1.4	370	-5.6	-1.5	413	-5.3	-1.3
	Average	361	-3.1	-0.9	372	-3.3	-0.9	415	-3.0	-0.7
Alt. 5	A	364	0.3	0.1	376	0.6	0.2	421	2.0	0.5
	B	363	-0.8	-0.2	375	-0.6	-0.2	419	0.1	0.0
	C	362	-2.2	-0.6	373	-2.4	-0.7	417	-1.0	-0.2
	Average	363	-0.9	-0.3	374	-0.8	-0.2	419	0.4	0.1
NO_x										
Alt. 0	A	399	0.0	0.0	429	0.0	0.0	538	0.0	0.0
	B	398	-1.1	-0.3	429	-0.2	-0.1	537	-0.9	-0.2
	C	399	-0.4	-0.1	427	-1.6	-0.4	536	-1.5	-0.3
	Average	399	-0.5	-0.1	428	-0.6	-0.1	537	-0.8	-0.2
Alt. 2	A	397	-1.7	-0.4	429	0.0	0.0	539	1.3	0.2
	B	399	0.2	0.0	429	0.3	0.1	539	1.6	0.3
	C	401	1.6	0.4	428	-0.6	-0.1	538	0.9	0.2
	Average	399	0.0	0.0	429	-0.1	0.0	539	1.2	0.2

TABLE B.8 (Cont.)

		1993			1998			2008		
Pollutant/ Alternative[a]	Supply Option	Annual Emissions (10^3 tons)[b]	Annual Emission Difference[b,c] (10^3 tons)	Percent Change[c]	Annual Emissions (10^3 tons)[b]	Annual Emission Difference[b,c] (10^3 tons)	Percent Change[c]	Annual Emissions (10^3 tons)[b]	Annual Emission Difference[b,c] (10^3 tons)	Percent Change[c]

NO_x										
Alt. 4	A	396	-3.4	-0.9	429	0.7	0.2	541	3.7	0.7
	B	396	-3.1	-0.8	429	0.6	0.1	541	3.3	0.6
	C	395	-3.6	-0.9	427	-1.2	-0.3	539	1.9	0.3
	Average	396	-3.4	-0.9	429	0.0	0.0	541	3.0	0.6
Alt. 5	A	397	-2.1	-0.5	429	0.1	0.0	539	1.2	0.2
	B	397	-1.7	-0.4	429	0.3	0.1	537	0.0	0.0
	C	397	-2.0	-0.5	427	-1.2	-0.3	537	-0.5	-0.1
	Average	397	-1.9	-0.5	428	-0.3	-0.1	538	0.2	0.1
TSP										
Alt. 0	A	169	0.0	0.0	166	0.0	0.0	163	0.0	0.0
	B	168	-0.8	-0.5	166	-0.6	-0.4	162	-0.6	-0.4
	C	168	-1.6	-0.9	165	-1.5	-0.9	162	-1.1	-0.7
	Average	168	-0.8	-0.5	166	-0.7	-0.4	162	-0.6	-0.4
Alt. 2	A	168	-0.8	-0.5	166	-0.8	-0.5	162	-0.4	-0.2
	B	168	-1.7	-1.0	165	-1.6	-1.0	162	-1.1	-0.7
	C	167	-2.4	-1.4	164	-2.4	-1.5	161	-1.6	-1.0
	Average	168	-1.6	-1.0	165	-1.6	-1.0	162	-1.0	-0.6
Alt. 4	A	169	-0.2	-0.1	166	-0.4	-0.2	163	-0.1	-0.1
	B	168	-1.0	-0.6	165	-1.2	-0.7	162	-0.8	-0.5
	C	167	-1.7	-1.0	165	-2.0	-1.2	161	-1.4	-0.9
	Average	168	-1.0	-0.6	165	-1.2	-0.7	162	-0.8	-0.5
Alt. 5	A	170	0.5	0.3	167	0.4	0.3	164	0.9	0.6
	B	169	-0.1	-0.1	167	-0.1	-0.1	163	0.2	0.1
	C	168	-0.8	-0.5	165	-1.0	-0.6	162	-0.3	-0.2
	Average	169	-0.1	-0.1	166	-0.2	-0.1	163	0.2	0.2

TABLE B.8 (Cont.)

		1993			1998			2008		
Pollutant/ Alternative[a]	Supply Option	Annual Emissions (10^3 tons)[b]	Annual Emission Difference[b,c] (10^3 tons)	Percent Change[c]	Annual Emissions (10^3 tons)[b]	Annual Emission Difference[b,c] (10^3 tons)	Percent Change[c]	Annual Emissions (10^3 tons)[b]	Annual Emission Difference[b,c] (10^3 tons)	Percent Change[c]
CO_2										
Alt. 0	A	341	0.0	0.0	380	0.0	0.0	489	0.0	0.0
	B	340	-0.9	-0.3	381	1.1	0.3	490	0.4	0.1
	C	341	-0.4	-0.1	380	0.5	0.1	490	0.7	0.1
	Average	341	-0.4	-0.1	380	0.5	0.1	490	0.4	0.1
Alt. 2	A	340	-1.0	-0.3	380	-0.1	0.0	489	-0.1	0.0
	B	340	-0.4	-0.1	381	0.9	0.2	490	0.9	0.2
	C	341	0.1	0.0	381	1.0	0.3	491	1.0	0.2
	Average	340	-0.5	-0.1	380	0.6	0.2	490	0.6	0.1
Alt. 4	A	339	-2.1	-0.6	378	-1.3	-0.3	489	-1.0	-0.2
	B	339	-2.2	-0.6	379	-0.8	-0.2	488	-1.1	-0.2

	C	339	-2.6	-0.8	378	-1.9	-0.5	488	-1.9	-0.4
	Average	339	-2.3	-0.7	378	-1.4	-0.4	488	-1.3	-0.3
Alt. 5	A	340	-1.5	-0.4	379	-0.8	-0.2	490	0.5	0.1
	B	340	-1.2	-0.4	381	0.9	0.2	490	0.8	0.2
	C	340	-1.5	-0.4	379	-1.0	-0.3	490	0.3	0.1
	Average	340	-1.4	-0.4	379	-0.3	-0.1	490	0.5	0.1

[a] 0 represents the no-action alternative.

[b] 10^5 tons for CO_2.

[c] Change from the no-action alternative/supply option A case.

Source: Chun et al. (1995).

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APPENDIX C: WATER RESOURCES FOR FLAMING GORGE DAM AND THE ASPINALL UNIT

C.1 FLAMING GORGE DAM

C.1.1 Reservoir Release Patterns and Downstream Flows

Release patterns for Flaming Gorge Reservoir were developed for year-round high fluctuating flows, seasonally adjusted high fluctuating flows, seasonally adjusted moderate fluctuating flows, and seasonally adjusted steady flows. The year-round high fluctuating flow operational scenario assumes that the monthly total reservoir releases would be the same as historical releases and that no changes would be made to the current operating constraints. The seasonally adjusted flow scenarios would comply with the Biological Opinion of the U.S. Fish and Wildlife Service (USFWS 1992), which includes high flows in the spring and limited hourly fluctuations, especially in summer and autumn releases.

The main differences in the operational scenarios are as follows. Assuming no changes in reservoir operating constraints, the maximum and minimum releases under the year-round high fluctuating flow scenario would be limited only by the water available for release, the reservoir minimum release requirement, and the power plant capacity. Ramping between maximum and minimum releases is assumed to occur in one hour. For the seasonally adjusted high fluctuating flow scenario, hourly releases would reach the maximum fluctuation feasible (as limited by the Biological Opinion), the water available for release, the minimum release requirement, and the power plant capacity; however, when ice cover is present on the Green River below the dam (assumed to be February and March), no hourly fluctuations would be allowed to protect fish. For the seasonally adjusted moderate fluctuating flow scenario, the hourly release fluctuations would be 50% of those in the seasonally adjusted high fluctuating flow scenario. For the seasonally adjusted steady flow scenario, reservoir releases would be constant throughout the day in each season, as defined by the Biological Opinion. Seasons here refer to periods of time varying from several weeks to one month.

C.1.1.1 Reservoir Release Patterns

Reservoir release patterns for an average day in each month, or partial month where necessary to comply with the Biological Opinion, are summarized in Tables C.1 through C.3 for the four operational scenarios. The release patterns for each scenario were developed for the three representative moderate, dry, and wet water years (1987, 1989, and 1983, respectively). Each release pattern has a minimum release starting at midnight, ramp up

TABLE C.1 Daily Reservoir Release Patterns for a Moderate Year, 1987a

	Year-Round High Fluctuation				Seasonally Adjusted High Fluctuation			Seasonally Adjusted Moderate Fluctuation			
Period	Min. Release (cfs)	Max. Release^b (cfs)	On-Peak Duration (hours)	Average Release (cfs)	Min. Release (cfs)	Max. Release^b (cfs)	On-Peak Duration (hours)	Min. Release (cfs)	Max. Release^b (cfs)	On-Peak Duration (hours)	Seasonally Adjusted Steady Flow (cfs)
Oct	800	4,700	10	2,590	800	800	0	800	800	0	800
Nov	800	4,700	17	3,720	800	4,700	9	2,220	4,170	1	2,380
Dec	800	4,700	17	3,720	800	4,700	9	2,220	4,170	1	2,380
Jan	800	4,700	12	3,240	800	4,700	9	2,220	4,170	1	2,380

Feb	800	4,700	14	3,240	2,380	2,380	24	2,380	2,380	24	2,380
Mar	800	4,700	2	1,290	2,380	2,380	24	2,380	2,380	24	2,380
Apr	800	4,700	2	1,290	800	4,700	10	2,440	4,390	1	2,600
May	800	4,700	4	1,610	800	4,700	15	2,740	4,700	7	3,390
Jun 1-21	800	4,700	2	1,290	4,700	4,700	24	4,700	4,700	24	4,700
Jun 22-30	800	4,700	2	1,290	800	4,700	17	2,770	4,700	11	3,740
Jul 1-9	800	4,700	4	1,610	800	4,700	6	1,860	3,810	1	2,020
Jul 10-31	800	4,700	4	1,610	890	2,900	1	976	1,980	1	1,060
Aug	800	4,700	3	1,450	990	3,000	1	1,080	2,080	1	1,160
Sep	800	4,700	5	1,780	1,070	3,100	1	1,160	2,160	1	1,240

a The annual average release is 2,230 cfs for the year-round high fluctuation, seasonally adjusted high and moderate fluctuations, and the steady release.
b Maximum release of 4,700 cfs assumes full reservoir conditions.

TABLE C.2 Daily Reservoir Release Patterns for a Dry Year, 1989a

Period	Year-Round High Fluctuation				Seasonally Adjusted High Fluctuation			Seasonally Adjusted Moderate Fluctuation			
	Min. Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	Average Release (cfs)	Min (hours) Release (cfs) .	Max. Release[b] (cfs)	On-Peak Duration (hours)	Min. Release (cfs)	Max. Release (cfs)	On-Peak Duration (hours)	Steady Flow (cfs)
Oct	800	2,370	1	931	800	1,270	1	820	1,050	1	839
Nov	800	2,750	1	962	800	800	0	800	800	0	800
Dec	800	2,740	1	962	800	800	0	800	800	0	800
Jan	800	2,350	1	929	800	800	0	800	800	0	800
Feb	800	1,980	1	899	800	800	0	800	800	0	800
Mar	800	1,970	1	897	800	800	0	800	800	0	800
Apr	800	3,130	1	994	870	4,700	1	1,030	2,980	1	1,200
May	800	2,350	1	929	800	4,700	9	2,260	4,210	1	2,420
Jun 1-7	800	4,700	2	1,290	4,000	4,000	24	4,000	4,000	24	4,000
Jun 8-19	800	4,700	2	1,290	800	4,700	9	2,240	4,190	1	2,400
Jun 20-30	800	4,700	2	1,290	800	800	0	800	800	0	800

Jul	800	1,580	1	865	800	2,380	1	858	1,600	1	920
Aug	800	4,700	2	1,290	950	2,400	1	1,010	1,740	1	1,070
Sep	800	1,970	1	898	1,000	2,450	1	1,060	1,780	1	1,120

a The annual average release is 990 cfs for the year-round high fluctuation, 1,150 cfs for the seasonally adjusted high and moderate fluctuations, and 1,150 cfs for the steady release.
b Maximum release of 4,700 cfs assumes full reservoir conditions.

TABLE C.3 Daily Reservoir Release Patterns for a Wet Year, 1983a

Period	Year-Round High Fluctuation				Seasonally Adjusted High Fluctuation			Seasonally Adjusted Moderate Fluctuation			
	Min. Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	Average Release (cfs)	Min (hours) Release (cfs) .	Max. Release[b] (cfs)	On-Peak Duration (hours)	Min. Release (cfs)	Max. Release (cfs)	On-Peak Duration (hours)	Steady Flow (cfs)
Oct	800	4,700	19	4,050	800	4,700	3	1,320	3,280	1	1,490
Nov	800	4,700	17	3,720	4,700	4,700	24	4,700	4,700	24	4,700
Dec	800	4,700	12	2,910	4,700	4,700	24	4,700	4,700	24	4,700
Jan	800	4,700	12	2,910	4,700	4,700	24	4,700	4,700	24	4,700
Feb	800	4,700	9	2,420	4,700	4,700	24	4,700	4,700	24	4,700
Mar	800	4,700	9	2,420	4,700	4,700	24	4,700	4,700	24	4,700
Apr	800	4,700	11	2,750	4,700	4,700	24	4,700	4,700	24	4,700
May	800	4,700	13	3,080	4,700	4,700	24	4,700	4,700	24	4,700
Jun	8,070	8,070	24	8,0d7d0	7,470	7,470	24	7,470	7,470	24	7,470
Jul 1-19	10,100	10,100	24	10,100	800	4,700	17	2,780	4,700	1d0	3,670
Jul 20-31	10,100	10,100	24	10,100	800	800	0	800	800	0	800
Aug	5,010	5,010	24	5,010	800	800	0	800	800	0	800
Sep 1-15	800	4,700	17	3,720	800	3,250	1	898	2,120	1	1,000
Sep 16-30	800	4,700	17	3,720	1,470	4,410	1	1,600	3,070	1	1,720

a The annual average release is 4,270 cfs for the year-round high fluctuation, 3,870 cfs for the seasonally adjusted high and moderate fluctuations, and 3,870 cfs for the steady release.
b Maximum release of 4,700 cfs assumes full reservoir conditions.

C.1.1.1.1 Year-Round High Fluctuating Flow Scenario

The maximum release for the year-round high fluctuating flow scenario would be 4,700 cfs, and the minimum release would be 800 cfs, as required by the Utah Division of Wildlife Resources (USFWS 1992). Ramping between these flow limits would occur in one hour. For average releases greater than 4,700 cfs, such as occurred in June-August 1983, a constant flow of 4,700 cfs would pass through the power plant and the remaining flow would bypass.

C.1.1.1.2 Seasonally Adjusted Fluctuating Flow Scenarios

The Biological Opinion defines allowable fluctuations for Flaming Gorge Reservoir releases in summer and autumn months and also requires shifting monthly releases to provide high flows in the spring and low flows in the summer and autumn (USFWS 1992).

Allowable Release Fluctuations for Summer and Autumn

The Biological Opinion requires that:

1. A target flow at Jensen, Utah, would be set between 1,100 and 1,800 cfs for summer and autumn, except that up to 2,400 cfs would be allowed after September 15 for wet years. The time periods covered are as follows:

Moderate year: July 10 through October 31

Dry year: June 20 through October 31

Wet year: July 20 through October 31

2. Variations of flow at Jensen for any 24-hour period would be limited to a total of 25% around the target. Variations above or below the target should be as close as possible.

3. Except for the effects of storm runoff, the flow at Jensen for wet years should stay within the range of 1,100 to 1,800 cfs, or up to 2,400 cfs after September 15.

Daily releases for Flaming Gorge Dam that comply with the above constraints are presented in Table C.4 through the end of the three water years assessed. Each daily release to a maximum release in one hour, hold at the maximum for the on-peak duration, and then ramp down to the minimum release. The on-peak period is assumed to center around 4:00 p.m.

TABLE C.4 Allowable Release Fluctuations for Flaming Gorge Reservoir

		Daily Reservoir Release[c] (cfs)			Daily Flow at Jensen[d] (cfs)		
Year/Month	Average Yampa River Flow[a] (cfs)	Target Flow at Jensen[b] (cfs)	Base Flow	Peak Flow	Min.	% Below Target	% Above Target
1989 (Dry)							
Jun 20-30	425	1,500	890	2,900	1,320	12.0	12.0
Aug	325	1,500	990	3,000	1,320	12.0	12.7
Sep	242	1,500	1,070	3,100	1,320	12.0	12.7
1989 (Dry)							
Jun 20-30	1,350	1,100	800	800	-e	-	-
Jul	313	1,100	800	2,280	1,110	0.0	24.5
Aug	155	1,100	95d0	2,400	1,110	0.0	24.5
Sep	101	1,100	1,000	2,450	1,100	0.0	24.5
1983 (Wet)							
Jul 20-31	3,460	1,800	800	800	-e	-	-
Aug	1,400	1,800	800	800	-e	-	-
Sep 1-15	555	1,800	800	3,250	1,360	24.4	0.0
Sep 16-30	333	2,400	1,470	4,410	1,800	25.0	0.0

a As recorded at Deerlodge Park gage.
b Based on the Biological Opinion (USFWS 1992).
c Base and peak flows determined such that maximum and minimum flows at Jensen comply closely with the constraint of 25% fluctuations around the target flows at Jensen. The reservoir also has a minimum release requirement of 800 cfs.
d Flows at Jensen, Utah, computed with the SSARR model.
e Flows at Jensen not computed for cases where the reservoir releases would be constant at 800 cfs.

pattern is expressed in terms of a minimum and a maximum release rate with one hour on peak. The ramp up and ramp down times are both one hour. The average daily release was computed from the minimum and maximum releases and the time on peak. The minimum and maximum allowable releases for each month, or partial month when required by the Biological Opinion, were determined with the SSARR (Streamflow Synthesis and Reservoir Regulation) computer model being used by the U.S. Bureau of Reclamation (Reclamation) for the Green River below Flaming Gorge Dam (Yin et al. 1995). The flow of the Yampa River, which is a major tributary of the Green River between Flaming Gorge Dam and Jensen, Utah, was considered in calculating flows at Jensen. The selection of the target flows shown in Table C.4 was based on the Biological Opinion constraints.

Seasonal Reservoir Releases

In addition to constraints on fluctuations for summer and autumn releases, the Biological Opinion requires shifting releases between seasons (months or partial months) to provide high flows in the spring and low flows in the summer and autumn. The criteria used in deriving the release volumes are summarized in Table C.5. These criteria strive to comply with the Biological Opinion whenever possible; other considerations include the minimum release requirement and reservoir safety. (The resulting seasonal average releases are shown as seasonally adjusted steady releases in Tables C.1 through C.3. The seasonally adjusted high and moderate fluctuating flow scenarios have the same average seasonal releases but may have fluctuations within the day.) For total annual releases (Tables C.1 through C.3), annual total power releases or total reservoir releases (power and nonpower) were not always made equal to the respective actual historical releases. The total reservoir release for the wet year is less than historical to reduce power plant bypass while still maintaining the reservoir level below the normal maximum water surface elevation. The total reservoir release for the dry year is greater than historical in an attempt to comply with the Biological Opinion. Detailed development of the seasonal releases is presented in Yin et al. (1995).

C.1.1.2 Green River Flows

Flows in the Green River resulting from reservoir releases under the four operational scenarios were estimated for five locations below Flaming Gorge Dam: Gates of Lodore, Hells Half Mile, Jones Hole, Rainbow Park, and the Jensen gage (Figure 3.16). The daily maximum and minimum flows in the moderate hydrologic year (1987) for year-round high fluctuating flows, seasonally adjusted high fluctuating flows, and seasonally adjusted moderate fluctuating flows are shown in Tables C.6 through C.8. Under the seasonally adjusted steady flow scenario, the reservoir release and downstream river flow would be steady during each season (Tables C.1 through C.3). The flows at locations upstream of the Yampa River would be the same as reservoir releases, and the flows downstream of the Yampa River would be the sums of the reservoir releases and the Yampa River inflows.

TABLE C.5 Criteria for Developing Flaming Gorge Seasonally Adjusted Releases

Month	Criteria
Oct	The Biological Opinion indicates that October flow should be a continuation of summer flow, which should be 1,100 to 1,800 cfs at Jensen. The flow might be as high as 2,400 cfs at Jensen for wet years. Target flows of 1,500, 1,100, and 2,400 cfs at Jensen were assumed for moderate, dry, and wet years, respectively.
Nov-Mar	The Biological Opinion calls for relatively stable flows and indicates that the months of November through March can be used to manage reservoir storage so that spring peak and summer low flows can be provided. Therefore, average release rates were assumed to be the same for these months.
Apr-Jul	Reservoir releases would gradually increase (up to 400 cfs/d) beginning between April 1 and May 15. The release should reach 2,000 cfs during May. Release of 4,000 to 4,700 cfs (if possible) for one to six weeks begins between May 15 and June 1. This range of releases would last for one week in dry years; post-peak decline would be no more than 400 cfs/d. During moderate years, the entire spring peak would last six to eight weeks. During wet years, additional releases required to maintain reservoir levels would occur during or prior to the spring peak of the Yampa River (mid-April through June). In dry years, flows would decrease to a target flow between 1,100 and 1,800 cfs at Jensen beginning June 20 and remain at that level throughout the summer. The target flow would be reached on about July 10 in moderate years and about July 20 in wet years. Hourly fluctuations in flow would be no more than 25% around the target flow and would remain within 1,100 to 1,800 cfs.
Aug-Sep	Reservoir releases in August and September would be adjusted to maintain flows of 1,100 to 1,800 cfs at Jensen. The target flow in wet years might be increased to within the range of 1,100 to 2,400 cfs beginning September 15. The 25% fluctuation limit would remain in effect.
All	Releases through the power plant range from 800 to 4,700 cfs (if possible). The minimum release is required by an agreement with the Utah Division of Wildlife Resources (USFWS 1992), and the maximum release is based on current

	power plant capacity.

TABLE C.6 Daily Green River Flows in a Moderate Year, 1987, under the Year-Round High Fluctuating Flow Scenario

Month	Daily Reservoir Release (cfs)		Daily Flows at 48 and 58 Miles[a] (cfs)				Yampa River Average Inflow (65 mi)[a] (cfs)	Daily Flows at 72, 82, and 93 Miles[a] (cfs)					
			Gates of Lodore (48 mi)		Hells Half Mile (58 mi)			Jones Hole (72 mi)		Rainbow Park (82 mi)		Jensen Gage (93 mi)	
	Min.	Max.	Min.	Max.	Min.	Max.		Min.	Max.	Min.	Max.	Min.	Max.
Oct	800	4,700	1,150	4,340	1,150	4,280	1,080	2,260	5,340	2,280	5,320	2,310	5,300
Nov	800	4,700	2,270	4,690	2,320	4,680	994	3,360	5,670	3,390	5,670	3,440	5,660
Dec	800	4,700	2,270	4,690	2,320	4,680	610	2,970	4,690	3,010	5,280	3,060	5,280
Jan	800	4,700	1,620	4,630	1,640	4,610	436	2,110	5,040	2,150	5,030	2,180	5,020
Feb	800	4,700	1,620	4,630	1,640	4,610	700	2,380	5,310	2,400	5,300	2,440	5,280
Mar	800	4,700	836	2,010	841	1,990	1,480	2,330	3,460	2,330	3,430	2,340	3,410
Apr	800	4,700	836	2,010	841	1,990	3,870	4,720	5,850	4,720	5,830	4,720	5,820
May	800	4,700	867	2,820	875	2,790	5,580	6,470	8,350	6,470	8,330	6,470	8,300
Jun 1-21	800	4,700	836	2,010	841	1,990	3,040	3,880	5,010	3,880	5,000	3,890	4,970
Jun 22-30	800	4,700	836	2,010	841	1,990	1,130	1,980	3,110	1,980	3,080	1,990	3,060
Jul 1-9	800	4,700	867	2,820	875	2,790	1,000	1,890	3,770	1,900	3,730	1,910	3,670
Jul 10-31	800	4,700	867	2,820	875	2,790	425	1,310	3,190	1,320	3,140	1,350	3,080
Aug	800	4,700	850	2,420	856	2,400	325	1,190	2,710	1,200	2,670	1,220	2,610
Sep	800	4,700	892	3,180	900	3,150	242	1,150	3,350	1,180	3,320	1,210	3,240

a Distance in river miles below Flaming Gorge Dam.

TABLE C.7 Daily Green River Flows in a Moderate Year, 1987, under the Seasonally Adjusted High Fluctuating Flow Scenario

Month	Daily Reservoir Release (cfs)		Daily Flows at 48 and 58 Miles[a] (cfs)				Yampa River Average Inflow (65 mi)[a] (cfs)	Daily Flows at 72, 82, and 93 Miles[a] (cfs)					
			Gates of Lodore (48 mi)		Hells Half Mile (58 mi)			Jones Hole (72 mi)		Rainbow Park (82 mi)		Jensen Gage (93 mi)	
	Min.	Max.	Min.	Max.	Min.	Max.		Min.	Max.	Min.	Max.	Min.	Max.
Oct	800	800	800	800	800	800	1,080	1,880	1,880	1,880	1,880	1,880	1,880
Nov	800	4,700	1,070	4,190	1,080	4,120	994	2,090	5,110	2,120	5,080	2,150	5,050
Dec	800	4,700	1,070	4,190	1,080	4,120	610	1,710	4,720	1,740	4,690	1,780	4,660
Jan	800	4,700	1,070	4,190	1,080	4,120	436	1,540	4,550	1,570	4,510	1,600	4,480
Feb	2,380	2,380	2,380	2,380	2,380	2,380	700	3,080	3,080	3,080	3,080	3,080	3,080
Mar	2,380	2,380	2,380	2,380	2,380	2,380	1,480	3,860	3,860	3,860	3,860	3,860	3,860
Apr	800	4,700	1,150	4,340	1,150	4,280	3,870	5,050	8,130	5,060	8,130	5,070	8,110
May	800	4,700	1,810	4,660	1,830	4,640	5,580	7,440	10,200	7,440	10,200	7,470	10,200
Jun 1-21	4,700	4,700	4,700	4,700	4,700	4,700	3,040	7,740	7,740	7,740	7,740	7,740	7,740

Jun 22-30	800	4,700	2,270	4,690	2,320	4,680	1,130	3,5d00	5,810	3,530	5,810	3,580	5,800
Jul 1-9	800	4,700	925	3,490	933	3,460	1,000	1,950	4,430	1,960	4,420	1,990	4,350
Jul 10-31	890	2,900	902	1,290	903	1,280	425	1,330	1,700	1,330	1,690	1,340	1,680
Aug	990	3,000	1,000	1,390	1,000	1,390	325	1,330	1,710	1,330	1,700	1,330	1,690
Sep	1,070	3,100	1,080	1,490	1,080	1,480	242	1,320	1,720	1,330	1,710	1,330	1,690

a Distance in river miles below Flaming Gorge Dam.

TABLE C.8 Daily Green River Flows in a Moderate Year, 1987, under the Seasonally Adjusted Moderate Fluctuating Flow Scenario

Month	Daily Reservoir Release (cfs)		Daily Flows at 48 and 58 Miles[a] (cfs)				Yampa River Average Inflow (65 mi)[a] (cfs)	Daily Flows at 72, 82, and 93 Miles[a] (cfs)					
			Gates of Lodore (48 mi)		Hells Half Mile (58 mi)			Jones Hole (72 mi)		Rainbow Park (82 mi)		Jensen Gage (93 mi)	
	Min.	Max.	Min.	Max.	Min.	Max.		Min.	Max.	Min.	Max.	Min.	Max.
Oct	800	800	800	800	800	800	1,080	1,880	1,880	1,880	1,880	1,880	1,880
Nov	2,220	4,170	2,220	2,670	2,220	2,660	994	3,220	3,650	3,220	3,650	3,220	3,640
Dec	2,220	4,170	2,220	2,670	2,220	2,660	610	2,830	3,270	2,840	3,260	2,840	3,250
Jan	2,220	4,170	2,220	2,670	2,220	2,660	436	2,660	3,100	2,660	3,090	2,660	3,080
Feb	2,380	2,380	2,380	2,380	2,380	2,3d80	700	3,080	3,080	3,080	3,080	3,080	3,080
Mar	2,380	2,380	2,380	2,380	2,380	2,380	1,480	3,860	3,860	3,860	3,860	3,860	3,860
Aprb	2,440	4,390	2,440	2,890	2,440	2,890	3,870	6,310	6,750	6,310	6,750	6,310	6,740
May[b]	2,740	4,700	2,770	4,300	2,780	4,260	5,580	8,360	9,830	8,360	9,830	8,360	9,810
Jun 1-21	4,700	4,700	4,700	4,700	4,700	4,700	3,040	7,740	7,740	7,740	7,740	7,740	7,740
Jun 22-30	2,770	4,700	2,900	4,600	2,900	4,570	1,130	4,040	5,710	4,070	5,700	4,080	5,690
Jul 1-9	1,860	3,810	1,860	2,290	1,860	2,290	1,000	2,870	3,290	2,870	3,280	2,870	3,270
Jul 10-31	976	1,980	982	1,170	982	1,170	425	1,410	1,590	1,410	1,590	1,410	1,580
Aug	1,080	2,080	1,080	1,280	1,080	1,270	325	1,410	1,600	1,410	1,590	1,410	1,590
Sep	1,160	2,160	1,160	1,360	1,160	1,360	242	1,400	1,600	1,400	1,590	1,410	1,590

a Distance in river miles below the Flaming Gorge Dam.
b Maximum and minimum flows presented are based on the average release for the month; actual daily maximum and minimum flows would differ through the month.

C.1.2 Streamflow Synthesis and Reservoir Regulation (SSARR) Modeling for the Green River

Quantitative estimates of flow as a function of time and distance from Flaming Gorge Dam were required to evaluate the effects of the hydropower operational scenarios on the Green River hydrological system. These data were needed to verify that the operational scenarios would comply with the USFWS Biological Opinion regarding operation of Flaming Gorge Dam (USFWS 1992) and to estimate flows at various points along the river during videography studies (Appendix D, Section D.2). The development of an empirical model for the Green River is discussed in Section C.1.3. Although this model is adequate for predicting flows at Jensen, Utah the point of calibration it does not provide any information on flow at the intermediate locations below the dam. The Streamflow Synthesis and Reservoir Regulation (SSARR) Model, developed by the North Pacific Division of the U.S. Army Corps of Engineers (COE 1987), was used to perform the required calculations. The SSARR model has two principal components: a generalized watershed model and a streamflow and reservoir regulation model. The latter model was used for this analysis.

C.1.2.1 Model Description

The streamflow and reservoir regulation component of SSARR routes flows from upstream to downstream points through channel and lake storage, and it models reservoirs under free-flow or controlled-flow modes of operation. Flows may be routed as a function of multivariable relationships involving backwater effects from tides or reservoirs. The basic routing method used in the watershed and streamflow models is referred to as a cascade-of-reservoirs technique, where the lag and attenuation of the flood wave are simulated through successive increments of lake-type storage. With SSARR, a channel or river can be visualized as a series of small lakes that represent the natural delay of runoff from upstream to downstream points. The routing characteristic of the prototype lake and the number of lake increments are specified for the model and adjusted in the calibration process (COE 1987).

Routing through watershed, river system, and reservoir components of the model relies on the law of continuity in the storage equation:

$$[(I_1 + I_2)/2 - (O_1 + O_2)/2]\ t = S_2 - S_1 \tag{C.1}$$

where

I_1 =Inflow at the beginning of the computational period,

I_2 =Inflow at the end of the period,

O_1 =Outflow at the beginning of the period,

O_2 =Outflow at the end of the period,

S_1 =Storage at the beginning of the period,

S_2 =Storage at the end of the period, and

t =Time duration of the period.

In differential form, the inflow (I_t) is expressed as:

$$I_t = O_t + dS/dt\ . \tag{C.2}$$

In natural lakes where storage is a function of outflow at any given elevation, T_s represents the proportionality factor between storage and outflow:

$$S = T_s O\ . \tag{C.3}$$

By substitution, the following form of the equation may be derived. This form is used to compute outflow from one prototype lake increment:

$$O_2 = O_1 + t(I_m - O_1)/\ (T_s + t/2) \tag{C.4}$$

where

I_m =Mean inflow, $(I1 + I2)/2$,

O_1 =Outflow at the beginning of the period,

t =Time duration of the period, and

T_s =Time of storage.

In the computer program, the value $t/(T_s + t/2)$ is evaluated for a specified condition and multiplied by the difference between I_m and O_1 to obtain the change in outflows. The outflow, O_2, computed from the first incremental routing is then saved and converted to initial outflow, O_1 for the next routing period (COE 1987).

Proper characterization of channel routing provides an integrated response of river system entities to hydrometeorological input. Channel routing is accomplished by using either a routing equation for incremental routing or a table that specifies time of storage-discharge relationships (COE 1987). When the following routing equation is used,

$$T_s = KTS/Q^n \tag{C.5}$$

the number of routing phases, the coefficient n, and a KTS value are specified for each channel reach. The derivation of these routing parameters usually begins with values determined from channels with similar characteristics. In the calibration process, these three parameters are adjusted to obtain the best match between the model-predicted and the observed flows (COE 1987).

C.1.2.2 Green River Model

The SSARR model was designed for the portion of the Green River that extends from Flaming Gorge Dam to Jensen, Utah. Six routing equations and two stage-discharge relationships were included in the model for this 93-mi stretch of river. Flow was computed at six locations along the river: Gates of Lodore, Hells Half Mile, Mitten Park, Jones Hole, Rainbow Park, and Jensen (Figure C.1). The stage-discharge relationships included in the model were obtained from a temporary gage installed at Mitten Park and an active U.S. Geological Survey (USGS) gage near Jensen (09261000). The stage-discharge relationships are listed in Table C.9.

Figure C.1 Locations along the Green River where Flow Was Computed with the SSARR Model

Figure C.2 Comparison of Model-Predicted Flows Using Data from Maybell, Colorado, Gage with Measured Flows at Jensen, Utah, April 1 through June 22, 1987

Figure C.3 Comparison of Model-Predicted Flows Using Data from Deer Lodge Park, Colorado, Gage with Measured Flows at Jensen, Utah, April 1 through June 22, 1987

Figure C.4 Comparison of the SSARR Model Results with the Empirical Model Results

A calibrated SSARR model for this segment of the Green River was obtained from Reclamation. To verify the calibration, the model-predicted flows were compared with recorded flows measured at the Jensen gage (09261000) from April 1 through September 30 of water year 1987 and water year 1988. This comparison indicated that the model was well calibrated, except during the spring months when the measured flows were much higher than the predicted flows. Figure C.2 compares the SSARR computed flows with the recorded flows at the Jensen gage. In these SSARR simulations, the recorded flows at the USGS gage near Maybell, Colorado (09251000), were used to represent the flow from the Yampa River. The same comparison is made in Figure C.3, except the recorded flows measured at the gage near Deerlodge Park, Colorado (09260050), were used to include the flow from the Yampa River; this gage is closer to the confluence of the Green River and incorporates the water contribution of the Little Snake River (Figure C.1). This adjustment to the model greatly improved the calibration near Jensen during the spring months (i.e., April through June) when the Yampa River flows discharging to the Green River are high.

Output from the calibrated SSARR model was also compared with the results of the empirical model and is summarized in Section C.1.3 of this appendix. As shown in Figure C.4, the correlation between the two models is good.

The number of routing phases specified for a channel affects the peak and timing response of the hydrograph. As the number of phases increases, with other factors held constant, the peak of the hydrograph decreases and the total time of storage increases. In the calibrated model, the number of routing phases specified for the channels in the river varied from 20 to 40, with the larger routing phase values assigned to channel segments upgradient and the smaller values downgradient of the confluence of the Yampa River. The calibrated SSARR parameters are presented in Table C.10.

The *KTS* and *n* parameters of the routing equation (C.5) were manipulated to obtain the desired time of storage per phase (*Ts*). The calibrated *KTS* parameters, which affect the time of storage linearly, were 300 for all river segments except for the channel between Rainbow Park and Jensen; the calibrated *KTS* value for this segment was 290.

TABLE C.9 Stage-Discharge Relationships Used in the SSARR Model of the Green River

Mitten Park Gage		Jensen Gage[a]	
Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
1.0	452	1.90	770
1.5	1,031	1.99	842
2.0	1,609	2.00	850
2.5	2,188	2.50	1,290
3.0	2,767	3.00	1,830
3.5	3,345	3.50	2,460
4.0	3,924	4.00	3,210
4.5	4,503	4.50	4,100
5.0	5,081	5.00	5,100
5.5	5,660	5.50	6,180
6.0	6,239	6.00	7,430
6.5	6,817	6.50	8,830
7.0	7,396	7.00	10,270
7.5	7,975	7.50	11,830
8.0	8,553	8.00	13,510
8.5	9,132	8.50	15,310
9.0	9,711	9.00	17,110
9.5	10,289	9.50	18,910
10.00	10,868	10.00	20,710
10.45	11,389	10.50	22,610
		11.00	24,510
		11.50	26,510
		12.00	28,510
		12.50	30,510
		13.00	32,510
		13.50	34,760
		14.00	37,010
		14.50	39,260
a Gage 09261000.			

TABLE C.10 Calibrated Parameters Used in the SSARR Modeling for the Green River

	Parameter Value		
River Segment	Number of Routing Phases	*n* Coefficient	*KTS*
Flaming Gorge Dam to Lodore	d30	20	300
Lodore to Hells Half Mile	40	50	300
Hells Half Mile to confluence of the Green and Yampa rivers and Mitten Park	40	50	300
Mitten Park to Jones Hole	20	50	300
Jones Hole to Rainbow Park	25	40	300
Rainbow Park to Jensen USGS gage	20	37	290

The *n* coefficient relates flow to time of storage exponentially, with smaller values of *n* yielding much greater times of storage for a given *KTS*. As shown in Equation C.5, the *n* coefficient is related to time of storage inversely, assuming *n* is positive. The range of the *n* coefficient was between 20 and 50, with the highest values corresponding to segments near the confluence of the Yampa River. The smallest calibrated *n* coefficients are assigned to channels directly downstream of the dam and upstream of the Jensen gage (Table C.10).

The sensitivity analysis evaluated the number of routing phases and the *n* and *KTS* of the routing Equation C.5. The model was more sensitive to changes in the coefficient *n*, relative to the other two parameters. This sensitivity result was expected because *n* represents the exponential in the routing equation.

C.1.3 Multiple Regression Model for the Green River

A multiple regression empirical model was developed to estimate the flow of the Green River near Jensen as a function of releases from Flaming Gorge Reservoir and of flow from the Yampa River. This empirical model was also used to verify the results obtained with the SSARR model (COE 1987).

No hourly discharge data were available for the Jensen gage for water year 1983, a wet year, so no models were developed for that time period. The moderate water year 1987 and dry water year 1989 were each divided into quarters for easier manipulation and because there are differences in Yampa River flows between these points. Each quarter was modeled separately. Flow could not be modeled for the second quarter (winter) of water year 1989 because the gages at Jensen, Utah, and Deerlodge Park, Colorado, were frozen and the data are therefore erroneous.

The model was calibrated by making repeated runs on a data set, with each run using different combinations of dam-release lags. The final result showed that the flow at Jensen depends on only a few dam release lags and on one or two lags of the Yampa River. The coefficients of the dam releases form a distribution about some central dam-release lag (Figures C.5 and C.6). The primary travel time of the release wave can be determined from the coefficients of the lags; the primary travel time is the lag with the largest coefficient.

Comparison plots were created from the mean daily values for the Jensen gage and the Flaming Gorge releases. These plots were used for comparing both the full and adjusted discharge at Jensen to identify the travel time from Flaming Gorge Dam to Jensen and to evaluate the flow of the Green River at the Jensen gage. The monthly plots for full discharge at Jensen show that, during low-flow periods (July through February), it takes one to two days for a water wave to travel from Flaming Gorge Dam to Jensen. It was also determined that the Yampa River has a small influence on the total discharge at Jensen for these periods. During high-flow periods (April through June), the dam releases are completely masked by flows in the Yampa River.

Figure C.5 Lag Distributions for a Moderate Year, 1987

Figure C.6 Lag Distributions for a Dry Year, 1989

To determine the impact of the Yampa River on the flow at Jensen, the Yampa River flow at Deerlodge Park was subtracted from the flow at Jensen. The difference in flow for a user-specified lag time was calculated by Fortran from mean daily values. The adjusted discharge was then plotted with the dam releases. During periods of high flow, the Yampa River accounted for about 50%

of the discharge of the Green River at Jensen; during periods of low flow, the influence of the Yampa River was less than 30%.

The dam release data for the operational scenarios and three water years were used to calculate the coefficient of variation (*Cv*) and the index of variability (I_v). These statistics were then used to compare the stability of the dam operational scenarios with historical releases. The comparison indicated that, with large values of C_v and I_v, the river is more susceptible to bank erosion and aggradation. The results of the historical flow calculations are discussed in Section 3.3.2.2 of this Power Marketing Environmental Impact Statement (EIS). Table C.11 presents values of C_v and I_v for the four operational scenarios. The equations for C_v and I_v are as follows (Gordon et al. 1992):

(C.6)

and

(C.7)

where *s* is the standard deviation of the dam releases, *x* is the mean dam release, x_i is the ith dam release, and *n* is the total number of dam releases.

C.1.4 Sediment Transport Modeling for the Browns Park Reach of the Green River

A mathematical model was developed to evaluate total sediment load because no gaging station is present within the alluvial reach of the Green River through Browns Park. This model was applied to the hydropower operational scenarios to assess their potential impacts on the river.

TABLE C.11 Summary of Coefficient of Variation and Index of Variability for the Operational Scenarios at Flaming Gorge Dam a

	Coefficient of Variation (Cv)					
	Moderate Year (1987)		Dry Year (1989)		Wet Year (1983)	
Operational Scenario	Value	% Diff.	Value	% Diff.	Value	% Diff.
Year-round high fluctuating flows	0.8414	0	0.6841	0	0.6563	0
Seasonally adjusted high fluctuating flows	0.7343	-13	0.8640	26	0.5118	-22
Seasonally adjusted moderate fluctuating flows	0.4875	-42	0.6057	-11	0.4918	-25
Seasonally adjusted steady flows	0.4411	-48	0.5609	-18	0.4860	-26
	Index of Variability (Iv)					
	Moderate Year (1987)		Dry Year (1989)		Wet Year (1983)	
Operational Scenario	Value	% Diff.	Value	% Diff.	Value	% Diff.
Year-round high fluctuating flows	0.8540	0	0.3632	0	0.9215	0
Seasonally adjusted high fluctuating flows	0.7507	-12	0.4695	29	0.7920	-14
Seasonally adjusted moderate fluctuating flows	0.5058	-41	0.4112	13	0.7136	-23
Seasonally adjusted steady flows	0.4811	-44	0.3954	9	0.6982	-24

a % Diff. is the percent difference from year-round high fluctuating flows.

C.1.4.1 Mathematical Model

Total sediment load for a reach was calculated with the Engelund-Hansen method (Engelund and Hansen 1967). This model requires a minimum amount of site-specific information, and it has been demonstrated to give satisfactory results for similar flow systems (Simons and Sentrk 1992; Andrews 1986).

The functional form for the total sediment load, Q_s, is given by the expression

(C.8)

where

U =water velocity = volumetric flow of water (Q) per channel area,

d_{50}=mean size of the sediment,

g =gravitational constant,

r_s =specific weight of sand sediment = $P_s g$ and P_s = density of the sediment,

r =specific weight of water = Pg and P = density of water, and

t_0 =bed shear stress given by the following:

$$t_0 = r\,D\,S \tag{C.9}$$

where

D =depth of the water, and

S =bed slope of the reach.

In the above relationship, the wide-channel approximation is made, that is, the hydraulic radius of the channel is set approximately equal to the depth of water (Garde and Ranga Raju 1985).

C.1.4.2 Site-Specific Values

The following values were used in the sediment transport calculations for this EIS:

d_{50}=0.4 mm (Andrews 1986),

r_s =2.65 x r,

r =62.4 lb/ft^3,

U =water velocity obtained from the HEC-2 flow model results (Yin et al. 1995) for a given Q and a cross section near Swinging Bridge in Browns Park,

D =depth of water obtained from HEC-2 flow model results (Yin et al. 1995) for a given Q and a cross section near Swinging Bridge in Browns Park, and

S =0.0004356 (value obtained from USGS 7-1/2 minute map of the Green River.

Because of the lack of site-specific data, both the bed slope and channel cross section were estimated from USGS 7-1/2 minute maps.

C.1.4.3 Model Results

The cumulative sediment load from the alluvial reach of the Green River in the Browns Park area is shown in Figures C.7, C.8, and C.9 for moderate, dry, and wet years, respectively. The sand load was calculated for year-round high fluctuating flows, seasonally adjusted high fluctuating flows, seasonally adjusted moderate fluctuating flows, and seasonally adjusted steady flows. The fraction of total load as a function of discharge is shown in Figures C.10, C.11, and C.12 for the same water years. Historical sediment loads are discussed in Section 3.2.1.2 and illustrated in Figure 3.17.

Figure C.7 Total Sediment Load for the Green River during a Moderate Year, 1987

Figure C.8 Total Sediment Load for the Green River during a Dry Year, 1989

Figure C.9 Total Sediment Load for the Green River during a Wet Year, 1983

Figure C.10 Fraction of Annual Sediment Load for the Green River during a Moderate Year, 1987

Figure C.11 Fraction of Annual Sediment Load for the Green River during a Dry Year, 1989

Figure C.12 Fraction of Annual Sediment Load for the Green River during a Wet Year, 1983

C.2 ASPINALL UNIT

C.2.1 Release Patterns and Reservoir Elevations

The Aspinall Unit reservoir release patterns and reservoir elevations are discussed in Section 4.2.3.3.1 for two hydropower operational scenarios. For Blue Mesa and Morrow Point reservoirs, the first scenario allows seasonally adjusted high fluctuating flows whereas the second scenario allows only seasonally adjusted steady flows (no hourly fluctuations within a day). Crystal Reservoir would release only seasonally adjusted steady flows within each day under both operational scenarios.

Both operational scenarios are based on USFWS research flows for the Aspinall Unit. Monthly research flows below Crystal Dam were developed by Reclamation for representative moderate (1987), dry (1989), and wet (1983) water years (Harris 1992).

C.2.1.1 Release Patterns

Reservoir release patterns for an average day in each month are summarized in Tables C.12, C.13, and C.14 for the three Aspinall Unit reservoirs. These release patterns were based on the USFWS research flows, and the feasibility of the research flows was confirmed by monthly reservoir operational models for the three representative water years. The model used historical inflows to Blue Mesa Reservoir and side inflows to Morrow Point and Crystal reservoirs (Tables C.15, C.16, and C.17); initial reservoir storages were also historical, except for the 1987 initial storage for Blue Mesa. An initial storage of 660,000 acre-feet, lower than the historical 742,000 acre-feet, was necessary for the proposed Crystal research flows to be feasible. Reservoir operations upstream of Blue Mesa could be modified to provide the lower initial storage.

The feasibility of the operational scenarios on both daily and hourly bases was assessed by developing daily and hourly reservoir operational models to test the reservoir operations by simulating the linked operations of the three Aspinall Unit reservoirs. The daily operational model was validated by simulating historical reservoir operations for 1987, 1989, and 1983. Calculated end-of-month water surface elevations for all three reservoirs were found to deviate generally less than 1 ft from those reported by Reclamation. The model was then used to simulate the seasonally adjusted steady flow scenario. Steady releases from all three reservoirs were feasible for 1987 and 1989, without violating restrictions on short-term water surface fluctuations for Crystal Reservoir. However, shifting Crystal daily releases, but maintaining the average monthly releases, was necessary for 1983.

The hourly operational model is an extension of the daily model and reproduces end-of-day results for the daily model. The hourly model was used to test the feasibility of fluctuating hourly flows for the seasonally adjusted high fluctuating flow scenario. The maximum fluctuations feasible may be limited by the operating constraints for Crystal Reservoir. In wet seasons (April through July), the reservoir surface elevation should not change by more than 0.5 ft in any 24-hour period if the elevation is lower than 6,748 ft. If the elevation is at or above 6,748 ft, the elevation should not change by more than 4 ft in any 24-hour period and by not more than 6 ft in any 48-hour period. In dry seasons (August through March), the reservoir surface elevation should not change by more than 0.5 ft in any 24-hour period if the elevation is lower than 6,733 ft. If the elevation is at least 6,733 ft, the elevation should not change by more than 10 ft in any 24-hour period and by not more than 15 ft in any 48-hour period.

Results from the hourly operational model indicate that the maximum release fluctuations for Morrow Point Reservoir from April through July should be limited to those shown in Table C.18 to comply with constraints on Crystal Reservoir elevation fluctuations. For other months, the fluctuations may be up to power plant capacity. For Blue Mesa Reservoir, the release fluctuations may be up to its power plant capacity (3,700 cfs) in any month when available head permits.

TABLE C.12 Daily Release Patterns for Blue Mesa Reservoir [a]

Month	Release Patterns for Moderate Year, 1987				Release Patterns for Dry Year, 1989				Release Patterns for Wet Year, 1983			
	High Fluctuating Release				High Fluctuating Release				High Fluctuating Release			
	Min. Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	Steady Release (cfs)	Min. Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	Steady Release (cfs)	Min. Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	Steady Release (cfs)
Oct	0	3,700	9	1,570	0	3,700	3	650	0	3,700	7	1,320
Nov	0	3,700	6	1,200	0	3,700	<1	180	0	3,700	8	1,400
Dec	0	3,700	5	1,050	0	3,600	<1	150	0	3,700	8	1,500
Jan	0	3,700	2	500	0	3,700	<1	200	0	3,700	8	1,540
Feb	0	3,700	2	510	0	3,700	<1	250	0	3,700	8	1,470
Mar	0	3,700	2	500	0	3,700	<1	200	0	3,700	8	1,450
Apr	0	3,700	9	1,600	0	3,700	3	760	2,260	3,700	15	3,220
May	0	3,700	14	2,370	0	3,700	4	900	0	3,700	13	2,200
Jun	1,750	3,700	15	3,050	0	3,700	6	1,150	0	3,700	14	2,330
Jul	0	3,700	14	2,350	0	3,700	7	1,300	0	3,700	9	1,550
Aug	0	3,700	10	1,750	0	3,700	7	1,300	0	3,700	6	1,100
Sep	0	3,700	10	1,750	0	3,700	7	1,300	0	3,700	8	1,500

[a] The average annual releases would be 1,520 cfs for the moderate year, 1,710 cfs for the wet year, and 697 cfs for the dry year.

[b] Maximum release of 3,700 cfs assumes full reservoir condition.

TABLE C.13 Daily Release Patterns for Morrow Point Reservoir [a]

Month	Release Patterns for Moderate Year, 1987				Release Patterns for Dry Year, 1989				Release Patterns for Wet Year, 1983			
	High Fluctuating Release				High Fluctuating Release				High Fluctuating Release			
	Min.Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	Steady Release (cfs)	Min. Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	Steady Release (cfs)	Min. Release (cfs)	Max. Release[b] (cfs)	On-Peak Duration (hours)	Steady Release (cfs)
Oct	0	5,300	6	1,700	0	5,300	2	720	0	5,300	5	1,410
Nov	0	5,300	4	1,280	0	4,800	<1	200	0	5,300	5	1,510
Dec	0	5,300	3	1,100	0	4,800	<1	200	0	5,300	5	1,520
Jan	0	5,300	1	570	0	5,270	<1	220	0	5,300	5	1,520
Feb	0	5,300	1	580	0	5,300	<1	270	0	5,300	5	1,540
Mar	0	5,300	1	650	0	5,300	<1	260	0	5,300	5	1,540

Apr	557	2,680	15	1,970	0	2,120	9	970	1,930	4,050	15	3,340
May	1,830	3,420	15	2,890	0	2,120	11	1,090	1,700	3,300	15	2,760
Jun	2,440	3,770	15	3,320	0	2,120	12	1,220	2,120	3,710	15	3,180
Jul	1,070	3,190	17	2,480	0	2,120	14	1,350	780	2,370	15	1,840
Aug	0	5,300	7	1,770	0	5,300	5	1,400	0	5,300	4	1,300
Sep	0	5,300	7	1,820	0	5,300	4	1,300	0	5,300	5	1,510

[a] The annual average releases would be 1,680 cfs for the moderate year, 1,910 cfs for the wet year, and 769 cfs for the dry year.

[b] Maximum release of 5,300 cfs assumes full reservoir condition.

TABLE C.14 Daily Releases for Crystal Reservoir

	Daily Release (cfs)		
Month	Moderate Year, 1987	Dry Year, 1989	Wet Year, 1983
Oct	1,920	960	1,600
Nov	1,430	303	1,600
Dec	1,280	293	1,600
Jan	683	293	1,600
Feb	702	306	1,600
Mar	748	293	1,600
Apr	2,250	1,190	3,500
May	3,580	1,330	3,500
Jun	3,830	1,410	4,600
Jul	2,640	1,420	2,500
Aug	1,920	1,460	1,650
Sep	1,920	1,400	1,650
Annual	1,910	891	2,250

C.2.1.1.1 Seasonally Adjusted Steady Flows

The seasonally adjusted steady flow scenario would have a steady release during each month from Blue Mesa and Morrow Point reservoirs. Varying daily releases would be necessary from Crystal Reservoir for April through July during a wet year (e.g., 1983), but a steady flow would be maintained throughout each day. The release rates are shown in Tables C.15, C.16, and C.17 for moderate, dry, and wet water years, respectively.

C.2.1.1.2 Seasonally Adjusted High Fluctuating Flows

The seasonally adjusted high fluctuating flow scenario can be considered a variation of the seasonally adjusted steady flow scenario. Reservoir release volumes would be the same as the steady flow case during each day, but hourly fluctuations within the day would be allowed. Blue Mesa releases would fluctuate up to 100% of power plant capacity (3,700 cfs) any day except for those months that base releases would be required so that the peaking period could be limited to 15 hours per day. Morrow Point releases would fluctuate up to 100% of power plant capacity (5,300 cfs) for the dry season (August through March) when available head permits and up to 25 to 40%, depending on the year and month, during the wet season (April through July) because of more stringent constraints on the fluctuation of Crystal Reservoir surface elevations. Ramping up and ramping down were assumed to occur in one hour. Ramping up was assumed to start on the hour at a certain hour such that the approximate center of the on-peak period would be at 4:00 p.m. If the peaking period were greater than 15 hours (8 a.m. to 11 p.m.), a base flow would be added. However, if adding a base flow resulted in a peak release greater than the power plant capacity, the maximum fluctuation would be reduced so that the peak release did not exceed the power plant capacity.

TABLE C.15 Reservoir Operations for the Seasonally Adjusted Steady Flow Scenario at the Aspinall Unit during a Moderate Year, 1987 during a Moderate Year, 1987

Reservoir/ Month	Inflow		Side Inflow (cfs)	Release			Evaporation (cfs)	Ending Storage (acre-feet)	Ending Elevation (ft)	Elevation Change	
	acre-feet	cfs		Power (cfs)	Other(cfs)	Total (cfs)				ft	ft/d
***Blue Mesa*[a]**											
Oct	62,539	1,017	0	1,570	0	1,570	8.8	625,462	7,495.61	-4.25	-0.14
Nov	51,278	862	0	1,200	0	1,200	4.2	605,086	7,493.05	-2.56	-0.09
Dec	30,550	497	0	1,050	0	1,050	2.5	570,920	7,488.69	-4.37	-0.14
Jan	27,811	452	0	500	0	500	2.0	567,864	7,488.29	-0.40	-0.01
Feb	28,728	517	0	510	0	510	2.6	568,124	7,488.33	0.03	0.00
Mar	55,524	903	0	500	0	500	4.9	592,603	7,491.47	3.14	0.10
Apr	125,807	2,114	0	1,600	0	1,600	7.8	622,739	7,495.27	3.80	0.13
May	271,476	4,415	0	2,370	0	2,370	14.6	747,592	7,510.23	14.96	0.48
Jun	255,805	4,299	0	3,050	0	3,050	22.8	820,553	7,518.42	8.19	0.27
Jul	97,192	1,581	0	2,350	0	2,350	24.6	771,736	7,512.98	-5.43	-0.18
Aug	64,634	1,051	0	1,750	0	1,750	18.6	727,623	7,507.91	-5.07	-0.16
Sep	44,320	745	0	1,750	0	1,750	15.2	666,907	7,500.70	-7.21	-0.24
***Morrow Point*[b]**											
Oct	96,535	1,570	94	1,700	0	1,700	0.0	112,632	7,154.30	-2.75	-0.09
Nov	71,405	1,200	61	1,280	0	1,280	0.0	111,489	7,152.86	-1.44	-0.05
Dec	64,562	1,050	69	1,100	0	1,100	0.0	112,627	7,154.29	1.44	0.05
Jan	30,744	500	61	570	0	570	0.0	112,061	7,153.58	-0.71	-0.02
Feb	28,324	510	82	580	0	580	0.0	112,744	7,154.44	0.86	0.03
Mar	30,744	500	98	650	0	650	0.0	109,528	7,150.36	-4.08	-0.13
Apr	95,207	1,600	373	1,970	0	1,970	0.0	109,707	7,150.59	0.23	0.01
May	145,726	2,370	534	2,890	0	2,890	2.1	110,439	7,151.52	0.94	0.03
Jun	181,488	3,050	311	3,325	0	3,325	14.3	111,730	7,153.16	1.64	0.05
Jul	144,496	2,350	74	2,480	0	2,480	13.6	107,420	7,147.63	-5.53	-0.18
Aug	107,603	1,750	58	1,770	0	1,770	1.4	109,688	7,150.56	2.93	0.09
Sep	104,132	1,750	44	1,820	0	1,820	0.0	108,124	7,148.55	-2.02	-0.07
***Crystal*[c]**											
Oct	104,529	1,700	210	1,763	156	1,919	0.0	15,276	6,747.04	-1.96	-0.06
Nov	76,165	1,280	135	1,429	0	1,429	0.0	14,443	6,744.02	-3.02	-0.10
Dec	67,636	1,100	152	1,285	0	1,285	0.0	12,413	6,736.29	-7.73	-0.25
Jan	35,048	570	135	683	0	683	0.0	13,766	6,741.50	5.21	0.17
Feb	32,212	580	123	702	0	702	0.0	13,822	6,741.71	0.21	0.01

Mar	39,967	650	147	748	0	748	0.0	16,835	6,752.48	10.77	0.35
Apr	117,223	1,970	275	1,763	489	2,252	0.0	16,418	6,751.05	-1.43	-0.05
May	177,699	2,890	680	1,763	1,815	3,578	0.0	15,926	6,749.34	-1.71	-0.06
Jun	197,851	3,325	507	1,763	2,069	3,832	0.0	15,926	6,749.34	0.00	0.00
Jul	152,489	2,480	164	1,763	872	2,635	0.0	16,480	6,751.26	1.92	0.06
Aug	108,833	1,770	130	1,763	156	1,919	0.0	15,311	6,747.16	-4.10	-0.13
Sep	108,297	1,820	97	1,763	153	1,916	0.0	15,395	6,747.46	0.30	0.01

[a] Starting conditions: storage, 660,000 acre-feet; elevation, 7,499.86 ft. Totals (acre-feet): inflow, 1,115,664; release, 1,100,965; evaporation, 7,793.

[b] Starting conditions: storage, 114,833 acre-feet; elevation, 7,157.05 ft. Totals (acre-feet): inflow, 1,100,965; side inflow, 112,178; release, 1,217,950; evaporation, 1,902.

[c] Starting conditions: storage, 15,829 acre-feet; elevation, 6,749.00 ft. Totals (acre-feet): inflow, 1,217,950; side inflow, 166,679; release, 1,385,063; evaporation, 0.

TABLE C.16 Reservoir Operations for the Seasonally Adjusted Steady Flow Scenario at the Aspinall Unit during a Dry Year, 1989 during a Dry Year, 1989

Reservoir/ Month	Inflow		Side Inflow (cfs)	Release			Evaporation (cfs)	Ending Storage (acre-feet)	Ending Elevation (ft)	Elevation Change	
	acre-feet	cfs		Power (cfs)	Other(cfs)	Total (cfs)				ft	ft/d
Blue Mesa[a]											
Oct	30,258	492	0	650	0	650	6.4	439,014	7,470.52	-1.48	-0.05
Nov	26,684	448	0	180	0	180	3.2	454,796	7,472.82	2.30	0.08
Dec	23,654	385	0	150	0	150	2.0	469,104	7,474.88	2.05	0.07
Jan	27,006	439	0	200	0	200	2.0	483,690	7,476.94	2.06	0.07
Feb	23,941	431	0	250	0	250	2.8	493,591	7,478.32	1.38	0.05
Mar	44,848	729	0	200	0	200	6.2	525,760	7,482.73	4.40	0.14
Apr	96,499	1,622	0	760	0	760	10.8	576,394	7,489.39	6.67	0.22
May	124,997	2,033	0	900	0	900	16.0	645,068	7,498.03	8.64	0.28
Jun	123,561	2,077	0	1,150	0	1,150	21.4	698,926	7,504.53	6.50	0.22
Jul	59,496	968	0	1,300	0	1,300	22.2	677,123	7,501.93	-2.60	-0.08
Aug	56,234	915	0	1,300	0	1,300	17.2	652,366	7,498.93	-3.00	-0.10
Sep	27,920	469	0	1,300	0	1,300	13.6	602,121	7,492.68	-6.25	-0.21
Morrow Point[b]											
Oct	39,967	650	38	720	0	720	0.0	112,021	7,153.53	-2.47	-0.08
Nov	10,711	180	37	200	0	200	0.0	113,033	7,154.80	1.27	0.04
Dec	9,223	150	37	200	0	200	0.0	112,234	7,153.80	-1.01	-0.03

Jan	12,298	200	(15)	220	0	220	0.0	110,082	7,151.07	-2.73	-0.09
Feb	13,884	250	24	270	0	270	0.0	110,304	7,151.35	0.28	0.01
Mar	12,298	200	66	260	0	260	0.0	110,673	7,151.82	0.47	0.02
Apr	45,223	760	207	970	0	970	0.0	110,494	7,151.59	-0.23	-0.01
May	55,339	900	192	1,090	0	1,090	2.1	110,488	7,151.58	-0.01	0.00
Jun	68,430	1,150	102	1,225	0	1,225	14.3	111,244	7,152.55	0.96	0.03
Jul	79,934	1,300	37	1,350	0	1,350	13.8	109,596	7,150.44	-2.10	-0.07
Aug	79,934	1,300	88	1,400	0	1,400	1.4	108,772	7,149.38	-1.06	-0.03
Sep	77,355	1,300	63	1,300	0	1,300	0.0	112,521	7,154.16	4.78	0.16
Crystal[c]											
Oct	44,271	720	186	960	0	960	0.0	13,657	6,741.09	-11.87	-0.38
Nov	11,901	200	98	303	0	303	0.0	13,359	6,739.96	-1.13	-0.04
Dec	12,298	200	92	293	0	293	0.0	13,298	6,739.72	-0.23	-0.01
Jan	13,527	220	73	293	0	293	0.0	13,298	6,739.72	0.00	0.00
Feb	14,995	270	46	306	0	306	0.0	13,853	6,741.83	2.10	0.08
Mar	15,987	260	99	293	0	293	0.0	17,911	6,756.08	14.25	0.46
Apr	57,719	970	224	1,193	0	1,193	0.0	17,971	6,756.27	0.20	0.01
May	67,021	1,090	244	1,334	0	1,334	0.0	17,971	6,756.27	0.00	0.00
Jun	72,893	1,225	183	1,412	0	1,412	0.0	17,733	6,755.49	-0.78	-0.03
Jul	83,008	1,350	64	1,415	0	1,415	0.0	17,671	6,755.29	-0.20	-0.01
Aug	86,083	1,400	43	1,464	0	1,464	0.0	16,380	6,750.92	-4.37	-0.14
Sep	77,355	1,300	66	1,395	0	1,395	0.0	14,654	6,744.79	-6.13	-0.20

[a] Starting conditions: storage, 449,116 acre-feet; elevation, 7,472.00 ft. Totals (acre-feet): inflow, 665,098; release, 504,595; evaporation, 7,498.

[b] Starting conditions: storage, 113,989 acre-feet; elevation, 7,156.00 ft. Totals (acre-feet): inflow, 504,595; side inflow, 52,909; release, 557,058; evaporation, 1,915.

[c] Starting conditions: storage, 16,977 acre-feet; elevation, 6,752.96 ft. Totals (acre-feet): inflow, 557,058; side inflow, 85,783; release, 645,163; evaporation, 0.

TABLE C.17 Reservoir Operations for the Seasonally Adjusted Steady Flow Scenario at the Aspinall Unit during a Wet Year, 1983 during a Wet Year, 1983

	Inflow			Release						Elevation Change	

Reservoir/ Month	acre-feet	cfs	Side Inflow (cfs)	Power (cfs)	Other(cfs)	Total (cfs)	Evaporation (cfs)	Ending Storage (acre-feet)	Ending Elevation (ft)	ft	ft/d
Blue Mesa[a]											
Oct	64,331	1,046	0	1,320	0	1,320	8.9	721,799	7,507.23	-2.02	-0.07
Nov	36,661	616	0	1,400	0	1,400	4.2	674,905	7,501.66	-5.56	-0.19
Dec	29,191	475	0	1,500	0	1,500	2.7	611,698	7,493.89	-7.78	-0.25
Jan	29,301	477	0	1,540	0	1,540	2.0	546,185	7,485.45	-8.43	-0.27
Feb	25,993	468	0	1,470	0	1,470	3.3	490,355	7,477.87	-7.58	-0.27
Mar	42,347	689	0	1,450	0	1,450	5.9	443,183	7,471.13	-6.74	-0.22
Apr	58,197	978	0	3,220	0	3,220	9.5	309,211	7,449.49	-21.65	-0.72
May	164,542	2,676	0	2,200	0	2,200	12.0	337,743	7,454.48	4.99	0.16
Jun	398,810	6,702	0	2,330	0	2,330	22.8	596,551	7,491.97	37.49	1.25
Jul	218,498	3,554	0	1,550	0	1,550	25.2	718,194	7,506.81	14.84	0.48
Aug	123,580	2,010	0	1,100	0	1,100	19.7	772,927	7,513.12	6.31	0.20
Sep	58,040	975	0	1,500	0	1,500	15.8	740,770	7,509.43	-3.68	-0.12
Morrow Point[b]											
Oct	81,164	1,320	81	1,410	0	1,410	0.0	112,214	7,153.77	-0.70	-0.02
Nov	83,306	1,400	37	1,510	0	1,510	0.0	107,870	7,148.22	-5.55	-0.19
Dec	92,231	1,500	37	1,520	0	1,520	0.0	108,915	7,149.57	1.35	0.04
Jan	94,691	1,540	35	1,520	0	1,520	0.0	112,297	7,153.88	4.31	0.14
Feb	81,640	1,470	46	1,540	0	1,540	0.0	110,964	7,152.19	-1.69	-0.06
Mar	89,157	1,450	68	1,535	0	1,535	0.0	109,919	7,150.86	-1.33	-0.04
Apr	191,603	3,220	141	3,345	0	3,345	0.0	110,871	7,152.07	1.21	0.04
May	135,273	2,200	581	2,765	0	2,765	2.1	111,725	7,153.16	1.08	0.03
Jun	138,645	2,330	855	3,180	0	3,180	14.3	111,172	7,152.45	-0.70	-0.02
Jul	95,306	1,550	298	1,840	0	1,840	13.6	110,828	7,152.02	-0.44	-0.01
Aug	67,636	1,100	152	1,300	0	1,300	1.4	107,790	7,148.12	-3.90	-0.13
Sep	89,256	1,500	60	1,510	0	1,510	0.0	110,765	7,151.94	3.82	0.13
Crystal[c]											
Oct	86,697	1,410	180	1,600	0	1,600	0.0	1,488	6,747.79	-2.17	-0.07
Nov	89,851	1,510	83	1,600	0	1,600	0.0	15,072	6,746.30	-1.49	-0.05

Dec	93,461	1,520	83	1,600	0	1,600	0.0	15,256	6,746.97	0.66	0.02
Jan	93,461	1,520	78	1,600	0	1,600	0.0	15,133	6,746.53	-0.44	-0.01
Feb	85,527	1,540	70	1,600	0	1,600	0.0	15,688	6,748.50	1.98	0.07
Mar	94,383	1,535	102	1,600	0	1,600	0.0	17,963	6,756.25	7.75	0.25
Apr	199,041	3,345	153	1,763	1,737	3,500	0.0	17,844	6,755.86	-0.39	-0.01
May	170,013	2,765	739	1,763	1,737	3,500	0.0	18,090	6,756.67	0.81	0.03
Jun	189,223	3,180	1,395	1,763	2,837	4,600	0.0	16,603	6,751.69	-4.98	-0.17
Jul	113,137	1,840	663	1,763	737	2,500	0.0	16,787	6,752.32	0.63	0.02
Aug	79,934	1,300	339	1,650	0	1,650	0.0	16,111	6,749.99	-2.33	-0.08
Sep	89,851	1,510	133	1,650	0	1,650	0.0	15,694	6,748.53	-1.46	-0.05

[a] Starting conditions: storage, 739,179 acre-feet; elevation, 7,509.25 ft. Totals (acre-feet): inflow, 1,249,491; release, 1,239,907; evaporation, 7,993.

[b] Starting conditions: storage, 112,767 acre-feet; elevation, 7,154.47 ft. Totals (acre-feet): inflow, 1,239,907; side inflow, 144,575; release, 1,384,581; evaporation, 1,902.

[c] Starting conditions: storage, 16,103 acre-feet; elevation, 6,749.96 ft. Totals (acre-feet): inflow, 1,384,581; side inflow, 243,142; release, 1,628,131; evaporation, 0.

TABLE C.18 Maximum Allowable Fluctuations for Morrow Point Reservoir Releases for Morrow Point Reservoir Releases

Month	Maximum Fluctuation as Percent of 5,300-cfs Power Plant Capacity		
	Moderate Year, 1987	Dry Year, 1989	Wet Year, 1983
April	40	40	40
May	30	40	30
June	25	40	30
July	40	40	30

C.2.1.2 Reservoir Surface Elevations

End-of-month reservoir elevations and daily elevation changes within each month are shown in Tables C.15, C.16, and C.17 for the seasonally adjusted steady flow scenarios for water years 1987 (moderate), 1989 (dry), and 1983 (wet), respectively. Hourly storage changes and maximum elevation fluctuations during the first day of each month for the seasonally adjusted high fluctuating flow scenario are presented in Table C.19 for water year 1987 (moderate). For each month, the maximum daily fluctuations in elevation for subsequent days would be about the same as the first day.

C.2.2 Reservoir Fluctuation Calculations

To determine fluctuations in daily reservoir pool elevations, a 24-hour reservoir routing model was developed to route the Aspinall unit releases (Tables C.20, C.21, and C.22) through Blue Mesa, Morrow Point, and Crystal reservoirs. The model used is diagrammed in Figure C.13. Mathematically, the model is as follows:

TABLE C.19 Maximum and Minimum Reservoir Surface Elevations on the First Day of the Month under the Seasonally Adjusted High Fluctuating Flow Scenario at the Aspinall Unit for a Moderate Year, 1987

Reservoir/Parameter	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Blue Mesa												
Starting storage (acre-feet)	660,000	625,462	605,086	570,920	567,864	568,124	592,603	622d,739	747,592	820,553	771,736	727,623
Inflow (cfs)	1,017	862	497	452	517	903	2,114	4,415	4,299	1,581	1,051	745
End-of-hour storage (acre-feet)												
1:00 a.m.	660,084	625,533	605,127	570,957	567,907	568,199	592,778	623,103	747,803	820,684	771,823	727,685
2:00 a.m	660,168	625,604	605,168	570,995	567,949	568,273	592,952	623,466	748,013	820,814	771,910	727,746
3:00 a.m.	660,252	625,676	605,209	571,032	567,992	568,348	593,127	623,830	748,224	820,945	771,997	727,808
4:00 a.m.	660,336	625,747	605,250	571,069	568,035	568,423	593,302	624,194	748,435	821,076	772,083	727,869
5:00 a.m.	660,420	625,818	605,291	571,107	568,078	568,497	593,477	624,557	748,645	821,206	772,170	727,931
6:00 a.m.	660,504	625,889	605,332	571,144	568,120	568,572	593,651	624,921	748,856	821,337	772,257	727,992
7:00 a.m.	660,588	625,961	605,374	571,181	568,163	568,646	593,826	625,285	749,067	821,468	772,344	728,054
8:00 a.m.	660,672	626,032	605,415	571,219	568,206	568,721	594,001	625,343	749,116	821,293	772,431	728,116
9:00 a.m.	660,756	626,103	605,456	571,256	568,249	568,796	594,175	625,400	749,166	821,117	772,518	728,177
10:00 a.m.	660,840	626,174	605,497	571,294	568,291	568,870	594,350	625,458	749,215	820,942	772,605	728,239
11:00 a.m.	660,619	626,246	605,538	571,331	568,334	568,945	594,219	625,516	749,265	820,767	772,386	727,994
12:00 Noon	660,397	626,317	605,579	571,368	568,377	569,020	594,088	625,574	749,314	820,592	772,167	727,750
1:00 p.m.	660,175	626,082	605,314	571,406	568,419	569,094	593,957	625,632	749,364	820,417	771,948	727,506
2:00 p.m.	659,954	625,848	605,049	571,443	568,462	569,169	593,826	625,690	749,413	820,242	771,729	727,262
3:00 p.m.	659,732	625,613	604,785	571,175	568,199	568,938	593,695	625,748	749,463	820,067	771,510	727,018
4:00 p.m.	659,510	625,379	604,520	570,906	567,936	568,706	593,564	625,806	749,512	819,892	771,291	726,773
5:00 p.m.	659,288	625,144	604,255	570,638	567,673	568,475	593,433	625,864	749,562	819,716	771,072	726,529
6:00 p.m.	659,067	624,910	603,991	570,601	567,622	568,476	593,302	625,921	749,611	819,541	770,853	726,285
7:00 p.m.	658,845	624,675	603,784	570,638	567,664	568,550	593,170	625,979	749,661	819,366	770,634	726,041
8:00 p.m.	658,623	624,507	603,825	570,675	567,707	568,625	593,039	626,037	749,710	819,191	770,415	725,797
9:00 p.m.	658,651	624,578	603,866	570,713	567,750	568,699	593,098	626,095	749,760	819,016	770,196	725,552
10:00 p.m.	658,735	624,649	603,907	570,750	567,792	568,774	593,273	626,153	749,809	818,841	770,176	725,506
11:00 p.m.	658,819	624,720	603,948	570,787	567,835	568,849	593,448	626,403	749,859	818,897	770,263	725,568
12:00 Midnight	658,903	624,792	603,989	570,825	567,878	568,923	593,623	626,766	750,069	819,028	770,350	725,630
Storage (acre-feet)												
Maximum	660,840	626,317	605,579	571,443	568,462	569,169	594,350	626,766	750,069	821,468	772,605	728,239
Minimum	658,623	624,507	603,784	570,601	567,622	568,124	592,603	622,739	747,592	818,841	770,176	725,506
Elevation (ft)												
Maximum	7,499.96	7,495.72	7,493.12	7,488.76	7,488.37	7,488.46	7,491.69	7,495.77	7,510.51	7,518.52	7,513.08	7,507.98
Minimum	7,499.69	7,495.49	7,492.89	7,488.65	7,488.26	7,488.33	7,491.47	7,495.27	7,510.23	7,518.23	7,512.81	7,507.66
Difference	0.27	0.23	0.23	0.11	0.11	0.14	0.22	0.50	0.28	0.29	0.27	0.32
Morrow Point												
Starting storage (acre-ft)	114,833	112,632	111,489	112,627	112,061	112,744	109,528	109,707	110,439	111,730	107,420	109,688
Side inflow (cfs)	94	61	69	61	82	98	373	534	311	74	58	44
End-of-hour storage (acre-feet)												
1:00 a.m.	114,841	112,637	111,495	112,632	112,068	112,752	109,513	109,600	110,408	111,648	107,425	109,692
2:00 a.m.	114,849	112,642	111,500	112,637	112,075	112,760	109,498	109,493	110,376	111,566	107,430	109,695

3:00 a.m.	114,856	112,647	111,506	112,642	112,081	112,768	109,482	109,386	110,345	111,484	107,434	109,699
4:00 a.m.	114,864	112,652	111,512	112,647	112,088	112,776	109,467	109,279	110,313	111,402	107,439	109,703
5:00 a.m.	114,872	112,657	111,518	112,652	112,095	112,784	109,452	109,171	110,282	111,320	107,444	109,706
6:00 a.m.	114,880	112,662	111,523	112,657	112,102	112,793	109,437	109,064	110,250	111,238	107,449	109,710
7:00 a.m.	114,887	112,667	111,529	112,662	112,108	112,801	109,422	108,957	110,219	111,156	107,454	109,713
8:00 a.m.	114,895	112,672	111,535	112,667	112,115	112,809	109,231	109,025	110,239	111,204	107,458	109,717
9:00 a.m.	114,903	112,677	111,540	112,672	112,122	112,817	109,041	109,092	110,259	111,253	107,463	109,721
10:00 a.m.	114,911	112,682	111,546	112,677	112,129	112,825	108,851	109,159	110,279	111,301	107,468	109,724
11:00 a.m.	115,224	112,687	111,552	112,682	112,136	112,833	108,966	109,226	110,300	111,350	107,779	110,034
12:00 Noon	115,538	112,692	111,557	112,687	112,142	112,841	109,081	109,294	110,320	111,398	107,651	109,905
1:00 p.m.	115,413	113,003	111,869	112,693	112,149	112,849	109,197	109,361	110,340	111,447	107,524	109,777
2:00 p.m.	115,289	112,876	111,742	112,698	112,156	112,857	109,312	109,428	110,360	111,496	107,396	109,648
3:00 p.m.	115,164	112,749	111,616	112,570	112,030	112,733	109,428	109,495	110,380	111,544	107,269	109,519
4:00 p.m.	115,040	112,622	111,489	112,443	111,905	112,609	109,543	109,563	110,401	111,593	107,141	109,391
5:00 p.m.	114,915	112,495	111,363	112,499	111,943	112,510	109,658	109,630	110,421	111,641	107,014	109,262
6:00 p.m.	114,791	112,367	111,245	112,579	112,044	112,592	109,774	109,697	110,441	111,690	106,886	109,134
7:00 p.m.	114,667	112,329	111,498	112,584	112,051	112,600	109,889	109,765	110,461	111,738	106,759	109,005
8:00 p.m.	114,674	112,574	111,504	112,589	112,058	112,608	110,005	109,832	110,481	111,787	107,063	109,209
9:00 p.m.	114,738	112,579	111,510	112,594	112,064	112,617	109,930	109,899	110,502	111,835	107,374	109,518
10:00 p.m.	114,746	112,584	111,515	112,599	112,071	112,625	109,740	109,966	110,522	111,884	107,486	109,629
11:00 p.m.	114,754	112,589	111,521	112,604	112,078	112,633	109,549	109,842	110,542	111,701	107,491	109,633
12:00 Midnight	114,762	112,594	111,527	112,609	112,085	112,641	109,534	109,735	110,510	111,619	107,495	109,636
Storage (acre-feet)												
Maximum	115,538	113,003	111,869	112,698	112,156	112,857	110,005	109,966	110,542	111,884	107,779	110,034
Minimum	114,667	112,329	111,245	112,443	111,905	112,510	108,851	108,957	110,219	111,156	106,759	109,005
Elevation (feet)												
Maximum	7,157.92	7,154.77	7,153.34	7,154.38	7,153.70	7,154.58	7,150.97	7,150.92	7,151.65	7,153.36	7,148.10	7,151.00
Minimum	7,156.84	7,153.92	7,152.55	7,154.06	7,153.38	7,154.15	7,149.49	7,149.62	7,151.24	7,152.43	7,146.77	7,149.68
Difference	1.08	0.85	0.79	0.32	0.32	0.44	1.48	1.30	0.41	0.92	1.33	1.32
Crystal												
Starting storage (acre-feet)	15,829	15,276	14,443	12,413	13,766	13,822	16,835	16,418	15,926	15,926	16,480	15,311
Side inflow (cfs)	210	135	152	135	123	147	275	680	507	164	130	97
Steady release (cfs)	1,919	1,429	1,285	683	702	748	2,252	3,578	3,832	2,635	1,919	1,916
End-of-hour storage (acre-feet)												
1:00 a.m.	15,688	15,169	14,349	12,368	13,718	13,772	16,718	16,330	15,853	15,810	16,332	15,161
2:00 a.m.	15,547	15,062	14,256	12,322	13,670	13,723	16,600	16,241	15,780	15,694	16,184	15,010
3:00 a.m.	15,405	14,955	14,162	12,277	13,622	13,673	16,483	16,153	15,707	15,578	16,036	14,860
4:00 a.m.	15,264	14,848	14,068	12,232	13,575	13,623	16,365	16,065	15,634	15,462	15,889	14,710
5:00 a.m.	15,123	14,741	13,975	12,187	13,527	13,574	16,248	15,977	15,561	15,346	15,741	14,559
6:00 a.m.	14,982	14,634	13,881	12,141	13,479	13,524	16,131	15,888	15,488	15,230	15,593	14,409
7:00 a.m.	14,840	14,527	13,788	12,096	13,431	13,474	16,013	15,800	15,415	15,114	15,445	14,259
8:00 a.m.	14,699	14,420	13,694	12,051	13,383	13,425	16,071	15,843	15,451	15,173	15,297	14,108
9.00 a.m.	14,558	14,314	13,600	12,005	13,335	13,375	16,129	15,886	15,488	15,232	15,149	13,958
10:00 a.m.	14,417	14,207	13,507	11,960	13,287	13,325	16,187	15,930	15,524	15,291	15,001	13,808
11:00 a.m.	14,275	14,100	13,413	11,915	13,240	13,276	16,245	15,973	15,561	15,350	14,854	13,657
12:00 Noon	14,134	13,993	13,319	11,870	13,192	13,226	16,302	16,016	15,597	15,409	15,144	13,945
1:00 p.m.	14,431	13,886	13,226	11,824	13,144	13,176	16,360	16,059	15,634	15,468	15,434	14,233
2:00 p.m.	14,728	14,217	13,570	11,779	13,096	13,127	16,418	16,102	15,670	15,528	15,724	14,520

3:00 p.m.	15,024	14,548	13,914	12,172	13,486	13,515	16,476	16,145	15,707	15,587	16,014	14,808
4:00 p.m.	15,321	14,879	14,259	12,564	13,876	13,903	16,534	16,188	15,743	15,646	16,304	15,096
5:00 p.m.	15,618	15,210	14,603	12,774	14,103	14,267	16,592	16,232	15,780	15,705	16,595	15,383
6:00 p.m.	15,915	15,541	14,939	12,728	14,055	14,217	16,649	16,275	15,816	15,764	16,885	15,671
7:00 p.m.	16,212	15,783	14,846	12,683	14,007	14,168	16,707	16,318	15,853	15,823	17,175	15,959
8:00 p.m.	16,376	15,676	14,752	12,638	13,959	14,118	16,765	16,361	15,889	15,882	17,034	15,914
9:00 p.m.	16,235	15,569	14,658	12,593	13,912	14,068	16,823	16,404	15,926	15,942	16,886	15,764
10:00 p.m.	16,094	15,462	14,565	12,547	13,864	14,019	16,881	16,447	15,963	16,001	16,738	15,614
11:00 p.m.	15,952	15,355	14,471	12,502	13,816	13,969	16,938	16,490	15,999	16,060	16,590	15,463
12:00 Midnight	15,811	15,248	14,378	12,457	13,768	13,919	16,821	16,402	15,926	15,944	16,442	15,313
Storage (acre-feet)												
Maximum	16,376	15,783	14,939	12,774	14,103	14,267	16,938	16,490	15,999	16,060	17,175	15,959
Minimum	14,134	13,886	13,226	11,779	13,096	13,127	16,013	15,800	15,415	15,114	14,854	13,657
Elevation (feet)												
Maximum	6,750.91	6,748.84	6,745.83	6,737.70	6,742.76	6,743.37	6,752.83	6,751.30	6,749.60	6,749.81	6,753.63	6,749.46
Minimum	6,742.88	6,741.95	6,739.45	6,733.75	6,738.95	6,739.07	6,749.65	6,748.90	6,747.53	6,746.46	6,745.52	6,741.09
Difference	8.03	6.89	6.38	3.95	3.81	4.30	3.18	2.40	2.06	3.35	8.11	8.37

TABLE C.20 Bureau of Reclamation Coefficient Tables Used to Calculate Reservoir Elevations

Reservoir	Eb	A	B	C
Blue Mesa	7350.	(14174.00)	1668.82	12.59
	7380.	47203.00	2415.18	14.80
	7400.	101405.00	3000.20	22.13
	7420.	170210.00	2899.79	27.75
	7450.	312210.00	5572.05	29.43
	7470.	435478.00	6767.88	25.68
	7490.	501135.00	7776.96	22.50
	7510.	745605.00	8680.00	26.80
	7519.	829523.00	0.00	0.00
Morrow Point	6770.	0.00	0.00	0.05
	6780.	5.00	1.00	0.15
	6790.	30.00	4.00	0.20
	6800.	90.00	8.00	0.25
	6810.	195.00	13.00	0.40
	6820.	365.00	21.00	0.50
	6830.	625.00	30.70	0.63
	6850.	1490.00	56.00	0.80
	6860.	2131.07	71.39	0.55
	6880.	3781.61	93.09	0.73
	6900.	5931.25	125.13	1.23
	6920.	8911.77	175.79	0.74
	6960.	17120.46	235.21	1.28
	7038.	39833.16	402.63	1.44

Crystal	6670.	0.00	134.00	0.65
	6680.	1405.00	147.00	0.75
	6690.	2950.00	162.00	0.80
	6720.	4650.00	178.00	0.95
	6710.	6525.54	196.00	1.03
	6730.	10870.54	237.70	1.23
	6750.	16115.00	287.00	1.40
	6769.	22044.00	-[a]	0.00

[a] Value missing from table provided by Reclamation. Source: Bureau of Reclamation, Salt Lake City, Utah Office, April 1992; reformatted from electronic transmittal.

TABLE C.21 Elevation Changes in a Moderate Year, 1987 a

Reservoir/ Month	Elevation[b] (ft)		Change in Elevation (ft)		Percent Total Reservoir Change from Flat Releases by Reclamation
	Maximum	Minimum	Daily Change	Total Change from Western Operations	
Blue Mesa					
Oct	7498.1	7498.2	0.2	0.1	49
Nov	7494.8	7495.0	0.2	0.1	37
Dec	7492.6	7492.8	0.2	0.1	61
Jan	7488.6	7488.7	0.1	0.1	11
Feb	7488.2	7488.3	0.1	0.1	1
Mar	7488.3	7488.4	0.1	0.0	82
Apr	7491.4	7491.6	0.2	0.1	65
May	7494.7	7495.1	0.4	0.0	100
Jun	7504.9	7505.0	0.1	0.0	100
Jul	7509.5	7509.6	0.1	0.1	58
Aug	7506.4	7506.6	0.2	0.1	57
Sep	7503.3	7503.5	0.2	0.1	73
Morrow Point					
Oct	7156.8	7157.9	1.1	1.0	8
Nov	7153.9	7154.7	0.8	0.8	5
Dec	7152.5	7153.3	0.8	0.8	5
Jan	7154.0	7154.3	0.3	0.3	6
Feb	7153.3	7153.6	0.3	0.3	9
Mar	7154.1	7154.5	0.3	0.2	30

Apr	7149.4	7150.9	0.6	0.6	0
May	7149.6	7151.0	1.4	1.3	9
Jun	7151.2	7151.6	0.4	0.4	22
Jul	7152.4	7153.3	0.9	0.8	15
Aug	7146.7	7148.0	1.3	1.2	7
Sep	7149.6	7150.9	1.3	1.2	5
Crystal					
Oct	6742.8	6750.9	8.1	8.0	1
Nov	6741.9	6748.8	6.9	6.8	1
Dec	6739.4	6745.8	6.4	6.1	4
Jan	6733.7	6737.6	3.9	3.7	4
Feb	6738.9	6742.7	3.8	3.8	0
Mar	6739.0	6743.3	4.3	3.9	9
Apr	6749.6	6752.8	3.2	3.2	1
May	6748.8	6750.9	2.1	1.7	18
Jun	6747.5	6749.5	2.0	2.0	0
Jul	6746.4	6749.7	3.3	3.2	2
Aug	6745.4	6753.6	8.2	8.0	2
Sep	6741.0	6749.4	8.4	8.4	0

[a] All elevations are for the first day of the month and are reported to the nearest 0.1 ft.

[b] Maximum and minimum reservoir elevations on the first day of the month.

TABLE C.22 Elevation Changes in a Dry Year, 1989 a

Reservoir/ Month	Elevation[b] (ft)		Change in Elevation (ft)		Percent Total Reservoir Change from Flat Releases by Reclamation
	Maximum	Minimum	Daily Change	Total Change from Western Operations	
Blue Mesa					
Oct	7471.9	7472.0	0.1	0.1	29
Nov	7470.5	7470.6	0.1	0.0	100
Dec	7472.8	7472.8	0.0	0.0	100
Jan	7474.8	7474.9	0.1	0.0	93
Feb	7476.9	7477.0	0.1	0.0	72
Mar	7478.3	7478.4	0.1	0.0	100

Apr	7482.7	7482.9	0.2	0.0	100
May	7489.3	7489.6	0.3	0.0	100
Jun	7496.8	7497.0	0.2	0.0	100
Jul	7501.3	7501.4	0.1	0.1	35
Aug	7499.5	7499.7	0.2	0.1	40
Sep	7497.3	7497.5	0.2	0.1	73
Morrow Point					
Oct	7155.8	7156.4	0.6	0.5	15
Nov	7153.4	7153.5	0.1	0.1	37
Dec	7154.7	7154.8	0.1	0.1	26
Jan	7153.5	7153.7	0.2	0.1	46
Feb	7150.9	7151.0	0.1	0.1	6
Mar	7151.2	7151.4	0.2	0.2	9
Apr	7151.4	7152.3	0.9	0.9	0
May	7150.9	7152.0	0.1	0.1	0
Jun	7151.0	7152.2	1.2	1.1	5
Jul	7151.9	7153.2	1.3	1.3	2
Aug	7149.9	7150.9	1.0	1.0	3
Sep	7149.3	7150.2	0.9	0.7	17
Crystal					
Oct	6749.8	6753.8	4.0	0.4	9
Nov	6740.1	6741.5	1.4	1.4	3
Dec	6738.9	6740.4	1.5	1.5	1
Jan	6738.6	6740.2	1.6	1.6	0
Feb	6738.4	6740.3	1.9	1.8	4
Mar	6740.9	6742.7	1.8	1.3	27
Apr	6753.4	6756.8	3.4	3.4	0
May	6753.5	6756.9	3.4	3.4	0
Jun	6753.2	6756.1	2.9	2.9	1
Jul	6752.4	6755.6	3.2	3.2	0
Aug	6750.5	6757.0	6.5	6.4	2
Sep	6745.8	6752.6	6.8	6.6	3

a All elevations are for the first day of the month and are reported to the nearest 0.1 ft. b Maximum and minimum reservoir elevations at the first day of the month.

where

BM =Blue Mesa Reservoir,

MP =Morrow Point Reservoir,

CR =Crystal Reservoir,

storagei=the reservoir storage at the beginning of the ith hour,

sideflowi=is the sideflow into the reservoir during the ith hour,

releasei=the flow through the dam during the ith hour,

inflowi=the steady inflow into Blue Mesa during the ith hour, and

outflowi=the steady outflow from Crystal during the ith hour.

Equations C.10, C.11, and C.12 are coupled with the release terms. The outflow from Blue Mesa Dam during one hour is the inflow to Morrow Point Reservoir during the same hour, whereas the outflow from the dam at Morrow Point is the inflow to Crystal Reservoir. The model input values for initial storage, inflow, sideflow, and outflow were obtained from Aspinall Unit research-flow release patterns (Section C.2.1). The storage value for the beginning of the first hour of a month was taken as the reservoir storage at the end of the preceding month. Sideflows, inflow into Blue Mesa Reservoir, and outflow from Crystal Reservoir were assumed to be constant during the modeled 24-hour period. The dam outflows from Blue Mesa Reservoir and Morrow Point Reservoir were taken as the hourly flows corresponding to the research release patterns. Flow from Crystal Reservoir was assumed to be constant for each day at a rate set by the research release patterns. For this model, evapotranspiration was assumed to be negligible.

Figure C.13

Hourly time steps were used to compute reservoir storage at the end of each hour for a day. The minimum and maximum storage values that occur during this day were used to compute the maximum change in reservoir storage; the storage values at the end of the first hour and at the end of the 24th hour were used to compute the storage change that would occur because of steady operations (i.e., the change that would occur if there were no fluctuations in flow due to power generation).

Reservoir elevations corresponding to the maximum and minimum storage values were determined with a table-lookup function. This lookup function always rounds up (e.g., 0.21 becomes 0.3). The storage-elevation table used by this lookup function was generated in 0.1-ft increments from the Reclamation equation:

where *Alf*, *Blf*, and *Clf* are estimated coefficients from Reclamation for various reservoir levels at facility *f*; *Elf* is the elevation for level *l* at facility *f*; and *EfB* is the base elevation level at facility *f*. The values for A, B, and C are given in Table C.20.

The daily maximum elevation change in a reservoir was computed from the elevations corresponding to the maximum and minimum storage values for the reservoir. The daily cumulative change was calculated by using the difference in storage from the beginning to the end of the day (end of the first hour to the end of the 24th hour). The percent maximum elevation change that would occur if reservoir operations were constant was determined by taking a ratio of the cumulative storage change to the maximum storage change. The value reported as resulting from Western power generation operations in Tables C.21, C.22, and C.23 is subject to roundoff error due to the use of elevation values that were only calculated to the nearest 0.1 ft, the type of lookup function used, and the use of this ratio.

TABLE C.23 Elevation Changes in a Wet Year, 1983 a

Reservoir/ Month	Elevation^b (ft)		Change in Elevation (ft)		Percent Total Reservoir Change from Flat Releases by Reclamation
	Maximum	Minimum	Daily Change	Total Change from Western Operations	

Blue Mesa					
Oct	7504.2	7504.4	0.2	0.1	30
Nov	7502.9	7503.1	0.2	0.1	68
Dec	7499.2	7499.4	0.2	0.0	78
Jan	7493.3	7493.6	0.3	0.1	79
Feb	7485.1	7485.4	0.3	0.1	78
Mar	7477.6	7477.9	0.3	0.1	65
Apr	7470.4	7471.1	0.7	0.0	100
May	7450.0	7450.2	0.2	0.1	60
Jun	7454.5	7455.9	1.4	0.0	100
Jul	7491.9	7492.3	0.4	0.0	100
Aug	7502.8	7502.9	0.1	0.0	98
Sep	7506.5	7506.6	0.1	0.1	48
Morrow Point					
Oct	7153.9	7154.9	1.0	1.0	2
Nov	7153.1	7154.1	1.0	0.8	20
Dec	7147.5	7148.6	1.1	1.0	13
Jan	7148.9	7150.0	1.1	1.0	13
Feb	7153.2	7154.3	1.1	1.0	5
Mar	7151.6	7152.7	1.1	1.1	4
Apr	7150.9	7151.3	0.4	0.4	11
May	7151.5	7152.9	1.4	0.9	34
Jun	7152.3	7153.6	1.3	1.3	1
Jul	7151.5	7153.2	1.7	1.7	1
Aug	7151.8	7152.7	0.9	0.8	14
Sep	7147.6	7148.6	1.0	0.9	12
Crystal					
Oct	6744.9	6751.9	3.0	3.0	1
Nov	6742.2	6749.9	7.7	7.6	1
Dec	6740.7	6748.5	7.8	7.8	0
Jan	6741.4	6749.1	7.6	7.6	0
Feb	6740.9	6748.8	7.9	7.8	1
Mar	6743.0	6750.8	7.8	7.6	3
Apr	6753.4	6756.5	3.1	3.1	0
May	6752.5	6755.3	2.0	1.2	42
Jun	6754.5	6756.7	2.2	2.0	7

Jul	6749.5	6751.9	2.0	2.0	1
Aug	6747.3	6754.0	6.7	6.6	1
Sep	6744.5	6752.0	7.5	7.4	1

[a] All elevations are for the first day of the month and are reported to the nearest 0.1 ft.

[b] Maximum and minimum reservoir elevations at the first day of the month.

C.3 REFERENCES FOR APPENDIX C

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APPENDIX D: ECOLOGICAL RESOURCES

Appendix D contains supplementary materials supporting the ecological resource discussions in Sections 3.4 and 4.2.4. Included are more detailed discussions of impact assessment approaches and wetland resources. Section D.1 lists scientific names and habitat information on all species mentioned in the text, and Section D.2 discusses the approaches used to assess impacts to the ecological resources at Flaming Gorge Dam and the Aspinall Unit. A wetlands assessment is presented in Section D.3; explanations of Federal and state categories of threatened and endangered species and correspondence received from Federal agencies regarding these species are presented in Section D.4. References cited in this appendix are listed in Section D.5.

D.1 LISTS OF SPECIES NAMES

Tables D.1 through D.6 provide information on common and scientific names, habitats, and abundance of species mentioned in Sections 3.4 and Section 4.2.4.

D.2 ECOLOGICAL IMPACT ASSESSMENT METHODOLOGIES FOR FLAMING GORGE DAM AND THEASPINALL UNIT

The impact assessment for Glen Canyon Dam presented in Section 4.2.4.1 was derived from the Glen Canyon Dam EIS (Reclamation 1995). That assessment was based on extensive research conducted as part of the Glen Canyon Environmental Studies begun in 1982. Similar research has not been conducted for either Flaming Gorge Dam or the Aspinall Unit, and assessment of impacts at those facilities required a different approach involving data collection and analysis. Data gathering was focused on collecting existing data from state and Federal agencies, as well as collecting field data to support the assessment. Aerial videography of the Green River during different flows and of the Aspinall Unit reservoirs was performed for this EIS to catalog and quantify resources that could be affected by hydropower operations and, in the case of Flaming Gorge Dam, to determine the relationship of these resources to different flows. Details of the approaches used are presented in the remainder of this section.

D.2.1 Flaming Gorge Dam

D.2.1.1 Multispectral Aerial Videography

Multispectral aerial videography was obtained under different flow conditions for selected segments of the Green River between Flaming Gorge Dam and the gaging station near Jensen, Utah (Figure D.1). A low-flying fixed-wing aircraft was used to collect videography information in red, green, and infrared bands, similar to data collected by Landsat multispectral scanner satellites. Data were collected between May 15, 1992, and June 5, 1992, in order to correspond with the descending portion of peak flows requested by the U.S. Fish and Wildlife Service (USFWS 1992). Videotape was obtained at flows ranging from 780 to 3,960 cfs in the portion of the Green River between Flaming Gorge Dam and the confluence of the Green and Yampa rivers and ranging from 3,980 to 7,960 cfs in the portion of the Green River below the Yampa River (Table D.7).

TABLE D.1 Fish Species in the Lower Colorado River between Glen Canyon Dam and Lake Mead

Common Name[a]	Scientific Name[a]	Origin[b]	Distribution and Commentsc
Clupeidae			
Threadfin shad	*Dorosoma petenense*	Introduced	Rare; common in Lakes Mead and Powell; prefers pelagic zones of reservoirs.
Salmonidae			
Apache trout	*Oncorhynchus apache*	Introduced	Federally threatened, accidental; did not become established; prefers small headwater streams at high elevations.
Cutthroat trout	*O. clarki*	Introduced	Rare; once common, now fished out; prefers cold, clear headwater streams.
Coho salmon	*O. kisutch*	Introduced	Accidental; did not become established; prefers pelagic zones of reservoirs.
Rainbow trout	*O. mykiss*	Introduced	Abundant; most abundant trout species below the dam; prefers pools, eddies, runs, and riffles of streams and lakes with gravel/cobble substrate.
Brown trout	*Salmo trutta*	Introduced	Common; abundant in some reaches and tributaries; prefers deep pools, riffles, and runs with sand/cobble substrate and moderate to fast current.
Brook trout	*Salvelinus fontinalis*	Introduced	Common, especially from dam to Lees Ferry; prefers clear headwater areas and lakes with gravel substrate.
Cyprinidae			
Red shiner	*Cyprinella lutrensis*	Introduced	Rare; accidental, isolated escapees from reservoirs or introduction; prefers backwaters, side channels, and inundated areas with silt, sand, or gravel substrates and shorelines with emergent vegetation.
Common carp	*Cyprinus carpio*	Introduced	Common, but numbers declining; prefers low-water-velocity habitats with silt, sand, or boulder substrate.
Utah chub	Gila atraria	Introduced	Accidental; one record from Lees Ferry; prefers littoral and pelagic zones of reservoirs.
Humpback chub	*G. cypha*	Native	Federally endangered; large population in the Little Colorado River; prefers eddy/run interfaces in deep canyon areas with swift currents and boulder/rubble substrates.
Bonytail chub	*G. elegans*	Native	Federally endangered; extirpated between dam and Lake Mead.
Roundtail chub	*G. robusta*	Native	Federal Category 2; extirpated between dam and Lake Mead; prefers large river channels with boulders and overhanging cliffs; usually in riffles, shallow runs, or eddy/run interfaces.
Virgin spinedace	*Lepidomeda mollispinis*	Introduced	Accidental; one record from Paria River in 1972; prefers gravel- and sand-bottomed flowing pools and runs of fast and usually clear creeks and small rivers.
Golden shiner	*Notemigonus crysoleucas*	Introduced	Rare or accidental; few records; prefers quiet, vegetated waters on lakes, ponds, swamps, backwaters, and pools of creeks and small to medium rivers.
Fathead minnow	*Pimephales promelas*	Introduced	Common or abundant locally in tributaries; in mainstream most abundant in downstream reaches; prefers backwaters and pools with silt/sand substrate.

Woundfin	*Plagopterus argentissimus*	Introduced	Federally endangered; accidental; introduced into Paria River in 1972; did not become established.
Colorado squawfish	*Ptychocheilus lucius*	Native	Federally endangered; extirpated between dam and Lake Mead.
Redside shiner	*Richardsonius balteatus*	Introduced	Accidental; isolated escapee from reservoirs; prefers littoral zones of reservoirs or river backwaters and pools with slow current.
Speckled dace	*Rhinichthys osculus*	Native	Common; associated with tributaries; abundant in lower reaches of the mainstream; prefers shallow, swift runs and riffles with gravel substrate.
Catostomidae			
Bluehead sucker	*Catostomus discobolus*	Native	Common; rare or absent above Nankoweap Basin; prefers deep riffles and shallow runs with gravel or cobble substrate.
Flannelmouth sucker	*Catostomus latipinnis*	Native	Federal Category 2; common; rare or absent above Nankoweap Basin; prefers runs, shorelines, and eddies of mainstem rivers.
Razorback sucker	*Xyrauchen texanus*	Native	Federally endangered; very rare between dam and Lake Mead; prefers backwaters, quiet eddies, and deep runs of large river channels.
Ictaluridae			
Black bullhead	*Ameiurus melas*	Introduced	Rare; occasionally found in tributaries; prefers backwaters with silt/gravel substrate.
Channel catfish	*Ictalurus punctatus*	Introduced	Common; widespread, but locally most common in warm tributaries; prefers deep pools, eddies, shorelines, and runs with silt/gravel/boulder substrate or backwaters with silt/sand substrate.
Centrarchidae			
Green sunfish	*Lepomis cyanellus*	Introduced	Rare; occasional in lower reaches; not established; isolated escapee from reservoirs; prefers slow-moving stream areas or weed beds of warmwater reservoirs and lakes.
Bluegill	*L. macrochirus*	Introduced	Rare; occasional in lower reaches; not established; isolated escapee from reservoirs; prefers shallow, warm lakes and ponds or slow-moving areas of streams with abundant aquatic vegetation.
Largemouth bass	*Micropterus salmoides*	Introduced	Rare; not established; occasional escapee from Lake Mead; prefers clear, quiet waters with aquatic vegetation or littoral zones of reservoirs and lakes.
Percidae			
Walley[e]	*Stizostedion vitreum*	Introduced	Accidental; one record from Lees Ferry, probable escapee from Lake Powell; prefers large streams, rivers, or lakes with moderately deep water.
Cyprinodontidae			
Western plains killifish	*Fundulus zebrinus*	Introduced	Common; rare or absent above Little Colorado River; locally abundant in some tributaries; prefers shallow backwaters with silt/sand substrate.
Poeciliidae			
Mosquitofish	*Gambusia affinis*	Introduced	Accidental; prefers vegetated drainage ditches, backwaters, and oxbows containing aquatic vegetation.
Percichthyidae			
Striped bass	*Morone saxatilis*	Introduced	Rare; occasional in lower reaches; not established; isolated escapee from reservoirs; prefers pelagic zones of reservoirs.

a All common and scientific names are from the American Fisheries Society's *Common and Scientific Names of Fishes*

(AFS 1991).
b Native = a species or subspecies naturally occurring in the Colorado River below Glen Canyon Dam; Introduced = a species or subspecies that has been introduced into the Colorado River below Glen Canyon Dam.
c Abundant = occurring in large numbers and consistently collected in a designated area; Common = occurring in moderate numbers and frequently collected in a designated area; Rare = occurring in low numbers either in a restricted area or having a sporadic distribution over a larger area; Accidental = one or two specimen records, isolated releases of bait, relatively unsuccessful introductions, or occasional individuals entering from Lake Powell or Lake Mead; Extirpated = formerly present in the Grand Canyon but now locally extinct.

Sources: AFS (1991); Maddux et al. (1987); Carothers and Brown (1991); Minckley (1991); Reclamation (1995).

TABLE D.2 Fish Species in the Green River from Flaming Gorge Dam to Jensen, Utah

Common Name[a]	Scientific Name[a]	Origin[b]	Distribution and Comments[c]
Salmonidae			
Cutthroat trout	*Oncorhynchus clarki*	Introduced and native	Common from dam to Little Hole; decreases to Echo Park; stocked in tailwaters; prefers cold, clear headwater streams; includes the Colorado River, Snake River, and Bear Lake subspecies.
Rainbow trout	*O. mykiss*	Introduced	Abundant from dam to Browns Park; common from Browns Park to Echo Park; rare below Echo Park; stocked in tailwaters; prefers pools, eddies, runs, and riffles of streams and lakes with gravel/cobble substrate.
Kokanee salmon	*O. nerka*	Introduced	Rare; probable escapees from reservoir where stocked; prefers pelagic zones of reservoirs.
Mountain whitefish	*Prosopium williamsoni*	Native	Rare or incidental below dam; common in the upper Yampa River; prefers runs with swift water and gravel/rubble substrate.
Brook trout	*Salvelinus fontinalis*	Introduced	Common from tailrace; decreases in abundance to Echo Park; stocked in tailwaters; prefers clear headwater areas and lakes with gravel substrate.
Brown trout	*Salmo trutta*	Introduced	Rare in tailrace; becomes more common downstream in Browns Park area; prefers deep pools, riffles, and runs with sand/cobble substrate and moderate to fast current.
Cyprinidae			
Red shiner	*Cyprinella lutrensis*	Introduced	Abundant from Lodore to Jensen; rare above Lodore; common in lower Yampa River; prefers backwaters, side channels, and inundated areas with silt, sand, or gravel substrates and shorelines with emergent vegetation.
Common carp	*Cyprinus carpio*	Introduced	Rare above Browns Park; common from Browns Park to Echo Park; abundant from Echo Park to Jensen; prefers low-water- velocity habitats with silt, sand, or boulder substrates.
Utah chub	*Gila atraria*	Introduced	Rare from the dam to Echo Park; incidental in the lower Yampa; prefers littoral and pelagic zones of reservoirs.
Humpback chub	*G. cypha*	Native	Federally endangered; rare from Lodore to Jensen; rare in the lower Yampa; prefers eddy/run interfaces in deep canyon areas with swift currents and boulder/rubble substrate.
Bonytail chub	*G. elegans*	Native	Federally endangered; historically present in the upper Green River and at the confluence of the Green and Yampa rivers; last verified specimen from the upper Green River Basin collected in 1979 from the lower Yampa River; prefers eddies and runs in canyon areas with swift current and steep

			walls.
Roundtail chub	*G. robusta*	Native	Federal Category 2; abundant from Browns Park to Island Park; abundant in Yampa; prefers large river channels with boulders and overhanging cliffs; usually in riffles, shallow runs, or eddy/run interfaces.
Sand shiner	*Notropis stramieneus*	Introduced	Common around Echo Park and lower Yampa River; rare below Echo Park; prefers shallow runs and backwaters with silt/sand substrate.
Fathead minnow	*Pimephales promelas*	Introduced	Rare from dam to Browns Park; common from Browns Park to Jensen; prefers backwaters and pools with silt/sand substrate.
Colorado squawfish	*Ptychocheilus lucius*	Native	Federally endangered; absent above Lodore; rare from Lodore to Jensen; rare in the lower Yampa; adults prefer deep runs, eddies, and large backwaters with silt/boulder substrate; juveniles and young-of-the-year prefer backwaters with silt/sand substrate.
Redside shiner	*Richardsonius balteatus*	Introduced	Rare from dam to Lodore; common around Echo Park and Yampa River; prefers littoral zones of reservoirs or river backwaters and pools with slow current.
Speckled dace	*Rhinichthys osculus*	Native	Rare from dam to Echo Park; common from Echo Park to Jensen; prefers shallow, swift runs and riffles with gravel substrate.
Creek chub	*Semotilus atromaculatus*	Introduced	Rare between Browns Park and Jensen; common around Echo Park; prefers riffles, runs, and pools with rubble/cobble substrate.
Catostomidae			
Utah sucker	*Catostomus ardens*	Introduced	Rare; prefers reservoirs and areas of slow to rapid current in streams.
White sucker	*C. commersoni*	Introduced	Rare or incidental; common in the Yampa River; prefers gravel/ cobble substrate; prefers creeks and small to medium rivers but also occurs in a wide range of habitats from headwater streams to large lakes.
Bluehead sucker	*C. discobolus*	Native	Rare above Lodore; common from Lodore to Jensen; prefers deep riffles and shallow runs with gravel or cobble substrates.
Flannelmouth sucker	*C. latipinnis*	Native	Federal Category 2; rare above Lodore; common from Lodore to Jensen; prefers runs, shorelines, and eddies of mainstem rivers.
Mountain sucker	*C. platyrhynchus*	Native	Rare around Echo Park; prefers cool, clear streams with gravel/cobble substrate.
Razorback sucker	*Xyrauchen texanus*	Native	Federally Endangered; rare from Lodore to Jensen; spawns in lower Yampa; prefers backwaters, quiet eddies, and deep runs of large river channels.
Ictaluridae			
Black bullhead	*Ameiurus melas*	Introduced	Absent or incidental from dam to Split Mountain; incidental in upper Yampa River; rare or incidental in the Green River below Split Mountain; prefers backwaters with silt/gravel substrate.
Channel catfish	*Ictalurus punctatus*	Introduced	Rare from dam to Echo Park; common from Echo Park to Jensen; prefers deep pools, eddies, shorelines, and runs with silt/gravel/boulder substrate or backwaters with silt/sand substrate.
Centrarchidae			
Green sunfish	*Lepomis cyanellus*	Introduced	Rare from Echo Park to Jensen; rare in the lower Yampa River; prefers slow-moving stream areas or weed beds of warmwater reservoirs and lakes.
Bluegill	*L. macrochirus*	Introduced	Incidental at Echo Park; prefers shallow, warm lakes and ponds or slow-moving areas of streams with abundant aquatic vegetation.
Smallmouth	*Micropterus*	Introduced	Rare from Echo Park to Jensen; prefers clear, fast-flowing runs and

bass	*dolomieui*		flowing pools with gravel/rubble substrate.
Largemouth bass	*M. salmoides*	Introduced	Incidental in the lower Yampa River; prefers clear, quiet waters with aquatic vegetation or littoral zones of reservoirs and lakes.
Percidae			
Walleye	*Stizostedion vitreum*	Introduced	Rare from Echo Park to Jensen; incidental in lower Yampa River; prefers large streams, rivers, or lakes with moderately deep water.
Esocidae			
Northern pike	*Esox lucius*	Introduced	Incidental; rare in the Yampa; prefers pools with silt, gravel, or sand/rubble substrate and shallow vegetated areas of lakes.
Cottidae			
Mottled sculpin	*Cottus bairdi*	Native	Rare from dam to Browns Park and below Echo Park; common around Echo Park and lower Yampa River; prefers riffles and deep runs with gravel, rubble, or boulder substrate.

a All common and scientific names are from the American Fisheries Society's *Common and Scientific Names of Fishes* (AFS 1991).
b Native = a species or subspecies naturally occurring in the Upper Green River Basin; Introduced = a species or subspecies that has been introduced into the Upper Green River Basin.
c Abundant = occurring in large numbers and consistently collected in a designated area; Common = occurring in moderate numbers and frequently collected in a designated area; Rare = occurring in low numbers either in a restricted area or having a sporadic distribution over a larger area; Incidental = occurring in very low numbers and known only from a few collections.

Sources: AFS (1991); Tyus et al. (1982); Haines and Tyus (1990); Karp and Tyus (1990).

TABLE D.3 Fish Species in the Aspinall Unit Reservoirs, Gunnison River, Colorado

Common Name[a]	Scientific Name[a]	Origin[b]	Distribution and Comments[c]
Salmonidae			
Cutthroat trout	*Oncorhynchus clarki*	Native	Rare or incidental; restricted to the reservoirs; prefer cold, clear headwater streams.
Coho salmon	*O. kisutch*	Introduced	Common; restricted to the reservoirs; stocked; prefers pelagic zones of reservoirs.
Rainbow trout	*O. mykiss*	Introduced	Abundant; stocked in reservoirs and the upper Gunnison River; prefers pools, eddies, runs, and riffles of streams and lakes with gravel/cobble substrate.
Kokanee salmon	*O. nerka*	Introduced	Abundant; stocked in reservoirs and the upper Gunnison River; prefers pelagic zones of reservoirs.
Brown trout	*Salmo trutta*	Introduced	Common in the reservoirs and the river; prefers deep pools, riffles, and runs with sand/cobble substrate and moderate to fast current.
Brook trout	*Salvelinus fontinalis*	Introduced	Rare or incidental; restricted to the reservoirs; stocked; prefers cold, clear headwater streams and lakes with gravel substrate.
Lake trout	*S. namaycush*	Introduced	Rare; restricted to the reservoirs; prefers deep, cold water in reservoirs.
Cyprinidae			

Fathead minnow	*Pimephales promelas*	Introduced	Rare or incidental; prefers shallow nearshore areas with silt/sand substrate.
Speckled dace	*Rhinichthys osculus*	Native	Rare to common; prefers shallow, nearshore areas with gravel substrate.
Catostomidae			
Longnose sucker	*Catostomus catostomus*	Introduced	Common; prefers clear, cold water with gravel substrate.
White sucker	*C. commersoni*	Introduced	Common; prefers gravel/cobble substrate; prefers creeks and small to medium rivers but also occurs in a wide range of habitats from headwater streams to large lakes.
Bluehead sucker	*C. discobolus*	Native	Rare; prefers deep riffles and shallow runs with gravel and cobble substrates; in the reservoirs occurs along nearshore areas with gravel or cobble substrate.
Flannelmouth sucker	*C. latipinnis*	Native	Federal Category 2; rare; prefers nearshore areas with gravel or cobble substrate.
Esocidae			
Northern pike	*Esox lucius*	Introduced	Incidental; one record from Blue Mesa Reservoir; in reservoirs prefers shallow, vegetated areas with silt/gravel or sand/rubble substrate.
Cottidae			
Mottled sculpin	*Cottus bairdi*	Native	Rare to common; in lakes and reservoirs prefers shallow margins with gravel, rubble, or boulder substrate.

a All common and scientific names are from the American Fisheries Society s *Common and Scientific Names of Fishes* (AFS 1991).

b Native = a species or subspecies naturally occurring in the upper reaches of the Gunnison River and the Aspinall Reservoirs; Introduced = a species or subspecies that has been introduced into the upper reaches of the Gunnison River and the Aspinall Reservoirs.

c Abundant = occurring in large numbers and consistently collected in a designated area; Common = occurring in moderate numbers and frequently collected in a designated area; Rare = occurring in low numbers either in a restricted area or having a sporadic distribution over a larger area; Incidental = occurring in very low numbers and known only from a few collections.

Sources: AFS (1991); Van Buren and Burkhard (1981); Stanford and Ward (1982); Tyus et al. (1982); Woodling (1985); Hebein (1992); Rose (1992).

TABLE D.4 Common Names, Scientific Names, and Habitats of Terrestrial Plant and Animal Species below Glen Canyon Dam, Arizona a

Common Name	Scientific Name	Habitat
Plants		
Apache plume	*Fallugia paradoxa*	Upper riparian zone
Arrowweed	*Pluchea sericea*	Upper riparian zone
Bulrush	*Scirpus validus*	Lower riparian zone
Catclaw acacia	*Acacia greggii*	Upper riparian zone
Cattail	*Typha domingensis, T.*	Lower riparian zone

	latifolia	
Common reed	*Phragmites australis*	Lower riparian zone
Desert broom	*Baccharis* spp.	Upper riparian zone
Grand Canyon flaveria	*Flaveria macdougallii*	Upland
Horsetail	*Equisetum hyemale*	Lower riparian zone
Netleaf hackberry	*Celtis reticulata*	Upper riparian zone
Plantain	*Plantago* spp.	Lower riparian zone
Redbud	*Cercis occidentalis*	Upper riparian zone
Rush	*Juncus* spp.	Lower riparian zone
Scouring rush	*Equisetum laevigatum*	Lower riparian zone
Sedge	*Carex* spp.	Lower riparian zone
Spikerush	*Eleocharis* spp.	Lower riparian zone
Tamarisk	*Tamarix ramosissima*	Upper riparian zone
Western honey mesquite	*Prosopis glandulosa*	Upper riparian zone
Willow	*Salix* spp.	Lower riparian zone
Invertebrates		
Kanab ambersnail	*Oxyloma haydeni kanabensis*	Marsh in upper riparian zone
Amphibians and Reptiles		
Red-spotted toad Chuckwalla	*Bufo punctatus Sauromalus obesus*	Upper and lower riparian zones, open shoreline Upland, upper riparian zone
Side-blotched lizard	*Uta stansburiana*	Upland, upper and lower riparian zones, open shoreline
Birds		
American coot	*Fulica americana*	Lower riparian zone, open water
Bald eagle	*Haliaeetus leucocephalus*	Open water, upper riparian zone
Bell's vireo	*Vireo bellii*	Upper riparian zone
Belted kingfisher	*Ceryle alcyon*	Open water, upper riparian zone
Black-chinned hummingbird	*Archilochus alexandri*	Upper riparian zone
Black-crowned night heron	*Nycticorax nycticorax*	Open water, upper and lower riparian zones
Bufflehead	*Bucephala albeola*	Open water, lower riparian zone
Canada goose	*Branta canadensis*	Open water, upper and lower riparian zones
Common yellowthroat	*Geothlypis trichas*	Lower and upper riparian zones
Common merganser	*Mergus merganser*	Open water, lower riparian zone
Common goldeneye	*Bucephala clangula*	Open water, lower riparian zone
Great blue heron	*Ardea herodias*	Open water, upper and lower riparian zones
Green-winged teal	*Anas crecca*	Open water, lower riparian zone
Killdeer	*Charadrius vociferus*	Lower riparian zone
Loggerhead shrike	*Lanius ludovicianus*	Upland, upper riparian zone
Mallard	*Anas platyrhynchos*	Open water, lower riparian zone

Mexican spotted owl	*Strix occidentalis lucida*	Upland, upper riparian zone
Northern goshawk	*Accipiter gentilis*	Upland, upper riparian zone
Osprey	*Pandion haliaetus*	Open water, upper riparian zone
Peregrine falcon	*Falco peregrinus*	Open water, upper and lower riparian zones, upland
Ruddy duck	*Oxyura jamaicensis*	Open water, lower riparian zone
Snowy egret	*Egretta thula*	Open water, upper and lower riparian zones
Southwestern willow flycatcher	*Empidonax traillii extimus*	Upper riparian zone
Spotted sandpiper	*Actitis macularia*	Lower riparian zone
Violet-green swallow	*Tachycineta thalassina*	Open water, upper and lower riparian zones, upland
White-faced ibis	*Plegadis chihi*	Lower riparian zone, open water
White-throated swift	*Aeronautes saxatalis*	Open water, upper and lower riparian zones, upland
Yellow-breasted chat	*Icteria virens*	Upper riparian zone
Mammals		
Bighorn sheep	*Ovis canadensis*	Upland, upper and lower riparian zones
Brush mouse	*Peromyscus boylii*	Upland, upper and lower riparian zones
Mule deer	*Odocoileus hemionus*	Upland, upper riparian zone
Pinyon mouse	*Peromyscus truei*	Upland, upper riparian zone
Southwestern river otter	*Lutra canadensis sonora*	Open water, upper and lower riparian zones
Spotted bat	*Euderma maculatum*	Upland, open water, upper and lower riparian zones

a See Figure 3.25 for representation of habitats and their relationship to river flow. Habitats presented are those in which the species are most commonly found.

TABLE D.5 Common Names, Scientific Names, and Habitats of Terrestrial Plant and Animal Species below Flaming Gorge Dam, Utah and Colorado a

Common Name	Scientific Name	Habitat
Plants		
Box elder	*Acer negundo*	Upper riparian zone
Bulrush	*Scirpus* spp.	Lower riparian zone
Cattail	*Typha latifolia*	Lower riparian zone
Common reed	Phragmites australis	Lower riparian zone
Coyote willow	*Salix exigua*	Lower riparian zone
Dogbane	*Apocynum cannabinum*	Upper riparian zone
Douglas-fir	*Pseudotsuga menziesii*	Upland
Field horsetail	*Equisetum arvense*	Lower riparian zone
Fremont cottonwood	*Populus fremontii*	Upper riparian zone
Giant whitetop	*Lepidium latifolium*	Upper riparian zone
Golden aster	*Heterotheca* spp.	Upper riparian zone

Ownbey thistle	*Cirsium ownbeyi*	Upper riparian zone
Pinyon pine	*Pinus edulis*	Upland
Ponderosa pine	*Pinus ponderosa*	Upland
Rabbitbrush	*Chrysothamnus* spp.	Upper riparian zone
Rush	*Juncus* spp.	Lower riparian zone
Russian olive	*Elaeagnus angustifolia*	Upper riparian zone
Sagebrush	*Artemisia* spp.	Upland
Scouring rush	*Equisetum* spp.	Upper and lower riparian zones
Sedge	*Carex* spp.	Lower riparian zone
Shore buttercup	*Ranunculus cymbalaria*	Lower riparian zone
Silverweed	*Potentilla anserina*	Lower riparian zone
Sow thistle	*Sonchus* spp.	Upper and lower riparian zones
Spikerush	*Eleocharis palustris*	Lower riparian zone
Squawbush	*Rhus trilobata*	Upper riparian zone
Sweet clover	*Melilotus* spp.	Upper riparian zone
Tamarisk	*Tamarix ramosissima*	Upper riparian zone
Thistle	*Cirsium* spp.	Upper riparian zone
Utah juniper	*Juniperus osteosperma*	Upland
Ute ladies-tresses	*Spiranthes diluvialis*	Upper riparian zone
Western goldenrod	*Solidago occidentalis*	Upper and lower riparian zones
Western mugwort	*Artemisia ludoviciana*	Upper riparian zone
Wild licorice	*Glycyrrhiza lepidota*	Upper riparian zone
Wyoming big sagebrush	*Artemisia tridentata*	Upland
Amphibians and Reptiles		
Woodhouse's toad	*Bufo woodhousei*	Upper and lower riparian zones, open shoreline
Fence lizard	*Sceloporus undulatus*	Upland, upper and lower riparian zones
Gopher snake	*Pituophis melanoleucus*	Upland, upper riparian zone
Utah milk snake	*Lampropeltis triangulum taylori*	Upland, upper riparian zone
Western smooth green snake	*Opheodrys vernalis blanchardi*	Upland, upper riparian zone
Birds		
American widgeon	*Anas americana*	Open water, lower riparian zone
American redstart	*Setophaga ruticilla*	Upper riparian zone
American coot	*Fulica americana*	Lower riparian zone, open water
Bald eagle	*Haliaeetus leucocephalus*	Open water, upper riparian zone
Black-chinned hummingbird	*Archilochus alexandri*	Upper riparian zone
Canada goose	*Branta canadensis*	Open water, upper and lower riparian zones
Common goldeneye	*Bucephala clangula*	Open water, lower riparian zone
Gadwall	*Anas strepera*	Open water, lower riparian zone
Great blue heron	*Ardea herodias*	Open water, lower and upper riparian zones
Greater sandhill crane	*Grus canadensis tabida*	Lower riparian zone, open water

Green-winged teal	*Anas crecca*	Open water, lower riparian zone
Killdeer	*Charadrius vociferus*	Open shoreline, lower riparian zone
Lazuli bunting	*Passerina amoena*	Upland, upper riparian zone
Lewis's woodpecker	*Melanerpes lewis*	Upland, upper riparian zone
Loggerhead shrike	*Lanius ludovicianus*	Upland, upper riparian zone
Long-billed curlew	*Numenius americanus*	Lower riparian zone, open shoreline
Mallard	*Anas platyrhynchos*	Open water, lower riparian zone
Mexican spotted owl	*Strix occidentalis lucida*	Upland, upper riparian zone
Northern goshawk	*Accipiter gentilis*	Upland, upper riparian zone
Osprey	*Pandion haliaetus*	Open water, upper riparian zone
Peregrine falcon	*Falco peregrinus*	Open water, upper and lower riparian zones, upland
Red-tailed hawk	*Buteo jamaicensis*	Upland, upper riparian zone
Redhead	*Aythya americana*	Open water, lower riparian zone
Spotted sandpiper	*Actitis macularia*	Open shoreline, lower riparian zone
Swainson's hawk	*Buteo swainsoni*	Upland, upper riparian zone
Whooping crane	*Grus americana*	Lower riparian zone, open water
Western yellow-billed cuckoo	*Coccyzus americanus occidentalis*	Upper riparian zone
Western snowy plover	*Charadrius alexandrinus nivosus*	Open shoreline, lower riparian zone
Willow flycatcher	*Empidonax traillii*	Upper riparian zone
Wilson's warbler	*Wilsonia pusilla*	Upper riparian zone
Yellow-breasted chat	*Icteria virens*	Upper riparian zone
Mammals		
Bighorn sheep	*Ovis canadensis*	Upland, upper and lower riparian zones
Coyote	*Canis latrans*	Upland, upper riparian zone
Deer mouse	*Peromyscus maniculatus*	Upland, upper and lower riparian zones
Dwarf shrew	*Sorex nanus*	Upland, upper and lower riparian zones
Elk	*Cervus elaphus*	Upland, upper riparian zone
Moose	*Alces alces*	Upper and lower riparian zones
Mule deer	*Odocoileus hemionus*	Upland, upper riparian zone
Pronghorn	*Antilocapra americana*	Upland, upper riparian zone
Ringtail	*Bassariscus astutus*	Upland, upper riparian zone
River otter	*Lutra canadensis*	Open water, lower and upper riparian zones
Spotted bat	*Euderma maculatum*	Upland, open water, upper and lower riparian zones

a See Figure 3.25 for representation of habitats and their relationship to river flow. Habitats presented are those in which the species are most commonly found.

TABLE D.6 Common Names, Scientific Names, and Habitats of Terrestrial Plant and Animal

Species in the Vicinity of the Aspinall Unit Reservoirs, Gunnis on River, Colorado a

Common Name	Scientific Name	Habitat
Plants		
Aspen	*Populus tremuloides*	Upland
Bebb willow	*Salix bebbiana*	Lower riparian zone
Black sagebrush	*Artemisia nova*	Upland
Black Canyon gilia	*Gilia penstemonoides*	Cliffs
Blue grama	*Bouteloua gracilis*	Upland
Bottlebrush squirreltail	*Sitanion hystrix*	Upland
Box elder	*Acer negundo*	Upper riparian zone
Colorado desert-parsley	*Lomatium concinnum*	Upland
Coyote willow	*Salix exigua*	Lower riparian zone
Douglas-fir	*Pseudotsuga menziesii*	Upland
Gambel oak	*Quercus gambelii*	Upland
Geyer willow	*Salix geyeriana*	Lower riparian zone
Gunnison milkvetch	*Astragalus anisus*	Upland
Hanging garden sullivantia	*Sullivantia purpusii*	Cliffs
Horsetail	*Equisetum* spp.	Lower riparian zone
Mountain big sagebrush	*Artemisia tridentata*	Upland
Narrowleaf cottonwood	*Populus angustifolia*	Upper riparian zone
Needlegrass	*Stipa* spp.	Upland
Pacific willow	*Salix lasiandra*	Lower riparian zone
Pinyon pine	*Pinus edulis*	Upland
Rocky Mountain juniper	*Juniperus scopulorum*	Upland
Rocky Mountain thistle	*Cirsium perplexans*	Upland
Sandberg bluegrass	*Poa sandbergii*	Upland
Sedge	*Carex* spp.	Lower riparian zone
Serviceberry	*Amelanchier* spp.	Upland
Sierra corydalis	*Corydalis caseana brandegei*	Upland
Spikerush	*Eleocharis* spp.	Lower riparian zone
Sweetclover	*Melilotus* spp.	Upper riparian zone
Thinleaf alder	*Alnus tenuifolia*	Upper riparian zone
Wheatgrass	*Agropyron* spp.	Upland
White fir	*Abies concolor*	Upland
Amphibians and Reptiles		
Striped chorus frog	*Pseudacris triseriata*	Open water, lower riparian zone
Leopard frog	*Rana pipiens*	Open water, lower riparian zone
Tiger salamander	*Ambystoma tigrinum*	Open water, lower and upper riparian zones
Sagebrush lizard	*Sceloporus graciosus*	Upland, upper and lower riparian zones

Eastern fence lizard	*Sceloporus undulatus*	Upland
Bullsnake	*Pituophis melanoleucus*	Upland, upper and lower riparian zones
Western garter snake	*Thamnophis elegans*	Upland, upper and lower riparian zones
Smooth green snake	*Opheodrys vernalis*	Upland, upper and lower riparian zones
Birds		
American widgeon	*Anas americana*	Open water, lower riparian zone
Bald eagle	*Haliaeetus leucocephalus*	Open water, upper riparian zone
Blue-winged teal	*Anas discors*	Open water, lower riparian zone
Canada goose	*Branta canadensis*	Open water, lower and upper riparian zones
Common goldeneye	*Bucephala clangula*	Open water, lower riparian zone
Golden eagle	*Aquila chrysaetos*	Upland
Great blue heron	*Ardea herodias*	Open water, lower and upper riparian zones
Greater sandhill crane	*Grus canadensis tabida*	Lower riparian zone, open water
Green-winged teal	*Anas crecca*	Open water, lower riparian zone
Killdeer	*Charadrius vociferus*	Open shoreline, lower riparian zone
Lazuli bunting	*Passerina amoena*	Upland, upper riparian zone
Loggerhead shrike	*Lanius ludovicianus*	Upland, upper riparian zone
Mallard	*Anas platyrhynchos*	Open water, lower riparian zone
Northern goshawk	*Accipiter gentilis*	Upland, upper riparian zone
Northern pintail	*Anas acuta*	Open water, lower riparian zone
Northern shoveler	*Anas clypeata*	Open water, lower riparian zone
Peregrine falcon	*Falco peregrinus*	Open water, lower and upper riparian zones, upland
Prairie falcon	*Falco mexicanus*	Upland
Red-tailed hawk	*Buteo jamaicensis*	Upland, upper riparian zone
Song sparrow	*Melospiza melodia*	Upper riparian zone
Spotted sandpiper	*Actitis macularia*	Open shoreline, lower riparian zone
White-faced ibis	*Plegadis chihi*	Lower riparian zone, open water
Whooping crane	*Grus americana*	Lower riparian zone, open water
Yellow warbler	*Dendroica petechia*	Upper and lower riparian zones
Mammals		
Beaver	*Castor canadensis*	Open water, upper and lower riparian zones
Bighorn sheep	*Ovis canadensis*	Upland, upper and lower riparian zones
Dusky shrew	*Sorex obscurus*	Upland, upper and lower riparian zones
Elk	*Cervus elaphus*	Upland, upper riparian zone
Least chipmunk	*Eutamias minimus*	Upland, upper riparian zone
Meadow vole	*Microtus pennsylvanicus*	Upland, upper riparian zone
Mule deer	*Odocoileus hemionus*	Upland, upper riparian zone
River otter	*Lutra canadensis*	Open water, upper and lower riparian zones
Spotted bat	*Euderma maculatum*	Upland, open water, upper and lower riparian zones

a See Figure 3.25 for representation of habitats and their relationship to river flow. Habitats presented are those in which the species are most commonly found.

After videography was collected, images were catalogued in order to identify river segments that had been videotaped at three or four different flow levels, including the highest and lowest flows obtained. The number of flows at which a particular site was successfully videotaped depended, in part, on weather conditions (e.g., cloud cover) during data collection flights. After these segments were identified (Table D.7), the appropriate images were captured and transferred to a computer format by using commercially available hardware and software.

Argonne National Laboratory ecologists examined the images and identified and digitized selected features. The features quantified in all images from each river segment included the area of the riparian zone, the surface area of the river, and the number and size of backwater areas. The relationships between discharge and these habitat features were used to predict habitat conditions under each of the hydropower operational scenarios (Hlohowskyj and Hayse 1995; LaGory and Van Lonkhuyzen 1995).

D.2.1.2 Methodology for Assessment of Impacts to Aquatic Ecology

Evaluation of impacts to the aquatic ecology of the Green River was restricted to the area between Flaming Gorge Dam and the U.S. Geological Survey (USGS) gage station near Jensen, Utah. A Biological Opinion issued by the USFWS (1992) has placed restrictions on operations of the dam that limit impacts in areas downstream of the gage. The portion of the Green River between the dam and Jensen can be divided into two distinct regions in terms of the fish they support: (1) the region upstream of the Yampa River, which is dominated by trout species, and (2) the region downstream of the Yampa River, which is dominated by native species (including four Federal endangered species) and introduced species (not including trout) (see Section 3.4.2.1.

TABLE D.7 Approximate River Flows during Multispectral Aerial Videography on the Green River

	Flows (cfs) on Date of Videography			
Videography Sitesa	5/15/92	5/17/92	5/20/92	6/5/92
Red Canyon Tailwaters	3,823	2,427	1,442	778
Little Hole	3,961	2,493	N/Ab	795
Taylor Flat/Upper Browns Park	3,953	2,578	1,544	813
Lower Browns Park	3,942	2,679	1,602	815
Echo Park	7,950	7,211	6,394	4,052
Island Park/Rainbow Park	7,714	7,412	6,468	3,976
Jensen Gage Station	7,963	7,556	N/A	4,472

a See Figure D.1 for location of videography sites.
b Videography not available.

adjusted high fluctuations, seasonally adjusted moderate fluctuations, and seasonally adjusted steady flow. The factors evaluated were changes that would occur to seasonal discharge levels and patterns, daily fluctuations, desiccation periods, aquatic habitats, and the aquatic food base that supports these fish. The evaluation methods and assumptions are summarized below; greater detail is provided in Hlohowskyj and Hayse (1995).

D.2.1.2.1 Green River Upstream of the Yampa River Discharge Levels, Daily Fluctuations, and Seasonal Patterns

Information about discharge levels, daily fluctuations in flow, and seasonal hydrological patterns in the upper portion of the Green River was obtained from descriptions of the operational scenarios and hydrological modeling (Section 4.2.3.2.1). For evaluation of impacts to biota, the assumption was made that the areas of concern in the Green River upstream of the Yampa River would experience daily fluctuations in discharge similar to the fluctuations in releases from Flaming Gorge Dam. Dam release patterns for each of the operational scenarios are presented in Section 4.2.3.2.1.

Aquatic Habitats in the Upper Portion of the Green River

Aerial videography (Section D.2.1.1) of the upper portion of the Green River was used to determine the relationship between the inundated area and flow. The videographic information was used with data on the daily minimum and maximum flows under each of the operational scenarios to delineate the aquatic habitat into (1) a permanently wetted zone, (2) a seasonally wetted zone, and (3) a fluctuation zone. The permanently wetted zone is that area that would be inundated throughout the year and is determined by the minimum flow that would occur in a given year. This zone was assumed to provide the most suitable conditions for a rich aquatic food base and was assumed to include the most suitable sites for successful reproduction by trout and other fish species. In the upper portion of the Green River, algae production is supported at all depths, because the high degree of water clarity allows sunlight to penetrate to the bottom in all areas. The seasonally wetted zone is the area that would be inundated throughout the day for some portion of the year, but would become exposed during other periods of the year. Such areas were generally considered to be less productive and less suitable for successful reproduction by fish than the permanently wetted area. The fluctuation zone refers to the portion of the aquatic habitat that is subjected to daily flooding and exposure. Such areas would typically be less productive than seasonally wetted areas, with the level of production depending on the number of hours of exposure.

Impacts to the Aquatic Food Base

The principal components of the aquatic food base in the Green River downstream of Flaming Gorge Dam are the green alga cladophora, the amphipod gammarus, and periphytic diatoms. A large proportion of the diet of trout in the upper portion of the Green River is composed of cladophora and the amphipods and other invertebrates supported by cladophora. Cladophora and its attached diatoms are the most important primary producers within the aquatic food base, and cladophora serves as an indicator of productivity in the upper portion of the Green River.

Since cladophora production decreases as the length of daily exposure to the air increases (Usher et al. 1987), it was assumed that the production of cladophora would be highest in permanently wetted zones and lowest in fluctuation zones with daily exposures of 1 to 12 hours. Areas with exposure times greater than 12 hours were considered unsuitable for sustaining a cladophora-based community. The production of cladophora and associated biota in the seasonally wetted zone was assumed to be intermediate to production in the other two zones. In addition, the time of the year and the number of consecutive days that seasonally wetted areas were present were considered in evaluating the potential for food production; inundation during cold periods and inundation for less than a month would probably not be conducive to high levels of cladophora production.

Impacts to Trout

In the Green River, successful reproduction by trout is limited primarily by the availability of suitable spawning sites and successful hatching of eggs once they are spawned. The critical period for successful reproduction extends from the spawning of eggs through the emergence of the fry. Areas of aquatic habitat that are exposed to the air between spawning and the emergence of young trout are of little value for reproduction, and the presence of such areas could reduce overall success of spawning by wasting the efforts of reproductively mature females that use those areas. The critical periods for successful reproduction extend from early October to late May for trout that spawn in the fall (brown and rainbow trout), and from March through mid-July for trout that spawn in the spring (rainbow and brook trout) (Modde et al. 1991). All the operational scenarios provide the same amount of permanently wetted zone, and it was assumed that the number of available spawning sites in this zone would be similar. If the seasonally wetted zone was inundated throughout the period of spawning and egg development for trout, that zone was considered capable of providing additional habitat for reproduction. The assumption also was made that smaller fluctuations would provide a more constant environment for developing eggs than large fluctuations, since the quality of a redd site can be affected by water velocity.

An important factor for maintenance of the trout fishery downstream of Flaming Gorge Dam is the overwinter survival of the fish that are stocked each spring. The current management practice is to stock hatchery-reared trout that are about 6 in. long, with the goal of having those fish reach 12 in. by the end of the year. It has been demonstrated that trout smaller than 12 in. at the end of the year are more likely to die during the winter than larger trout (Modde et al. 1991). Therefore, increasing growth rates during the warmer period of the year could increase the proportion of the trout population that survives the winter. To survive the winter, many trout depend upon energy reserves accrued during warmer periods of the year. Excessive activity during the winter can result in mortality if it causes these energy reserves to fall below critical levels. Since fluctuations in flow have been observed to increase the movements of trout, the potential for overwinter mortality would increase with increasing fluctuations.

D.2.1.2.2 Green River Downstream of the Yampa River Discharge Levels, Daily Fluctuations, and Seasonal Patterns

Information about discharge levels, daily fluctuations in flow, and seasonal hydrological patterns in the lower portion of the Green River also was obtained from descriptions of the operational scenarios and hydrological modeling (Section 4.2.3.2.1). These predictions of discharge levels and patterns in the lower portion of the river took into account the average seasonal inflow from the Yampa River. The major areas of interest downstream of the Yampa River (i.e., Island Park, Rainbow Park, and the area near the Jensen gaging station) were presumed to experience similar flow regimes because of their distance from the dam and the similarity of topography. Hydrological models predicted that under any of the operational scenarios, flows would not differ by more than about Ä80 cfs among these sites during any part of the year. The predicted annual patterns of flow for the Rainbow Park and Jensen gage stations are provided in Section 4.2.3.2.1.

Backwater Habitats in the Lower Portion of the Green River

Backwaters constitute one of the most important resources for the native fish (including endangered species) that inhabit the Green River downstream of the Yampa River. Backwaters are defined as areas of little or no current that are either narrowly connected (connected backwaters) or unconnected (isolated backwaters) from the main channel. Water temperatures are commonly warmer in backwaters than in the main channel during spring, summer, and fall. Juveniles of many native fish species in the Green River rely upon backwaters as nursery areas after hatching. Young fish inhabiting backwater areas that are flooded and drained regularly can be subjected to thermal shock from the inflow of cooler water during flooding or they can be drawn into the main channel during backwater draining. Once in the main channel, young fish are subject to colder water temperatures, which reduce growth rates, and to increased predation by larger fish inhabiting the main channel. In addition, backwaters that are not flooded and drained regularly can attain a greater biomass of food organisms, thus benefitting feeding by younger fish (Grabowski and Hiebert 1989). Investigations by Pucherelli et al. (1990) and aerial videography collected specifically to evaluate impacts of the operational scenarios presented in this document (Section D.2.1.1) were used to quantify the relationships between flows and the number and surface area of backwaters in the lower Green River. These relationships were then used to predict effects of the operational scenarios on backwaters. Although no link has been demonstrated between backwater area and the quality of backwaters as nursery habitats for fish, the stability of backwater areas is thought to play an important role in nursery habitat quality (USFWS 1992; Reclamation 1995). The greater the magnitude and frequency of daily fluctuation in backwater size, the less suitable the backwater as a nursery habitat. For the analyses in the EIS, the assumption was made that predicted daily change in backwater area is an indicator of backwater habitat quality. Thus, a large fluctuation in backwater area on a daily basis is assumed to result in low backwater habitat quality, while smaller daily fluctuations reflect a higher quality. Other factors important in determining backwater quality include water temperature, depth, and substrate type. These factors were not evaluated in these analyses.

Impacts to Native Fish Species

The impacts of hydropower operations on native fish species in the Green River were assessed by evaluating potential effects on reproduction and the survival of larval, juvenile, and adult fish.

Reproduction of native fish is restricted primarily to areas downstream of Echo Park, presumably because of the cold water temperatures upstream of that point. A large proportion of fish larvae collected from the Green River between the Yampa River and Jensen were those of native species (Haines and Tyus 1990). Therefore, production of larvae in the Green River does not appear to be the limiting factor in recruitment of young to adult populations of native fish, and this production would be expected to remain about the same under all the operational scenarios, especially for species that spawn in the Yampa River.

After hatching, the larvae of many of the native fish enter the main channel of the Green River and are transported downstream. At downstream sites, many of the larvae move into backwaters, where they grow until winter. The survival of young fish in backwaters depends on a number of factors, including the quality of backwaters and the magnitude and frequency of flooding and draining that occurs during the nursery period, a period that is critical to the continued existence of endangered fish species in the Green River (USFWS 1992). Since the nursery period for most of the native fish in the river is from July through December, backwater habitat quality (as a function of stability) during this period was used as an indicator of the survival of larval and juvenile fish. The assumptions were made that lower backwater habitat quality during this period would reduce survival, while the presence of higher quality backwater habitats would improve survival.

Increasing backwater habitat stability was also assumed to enhance populations of introduced fish, which may compete with native fish for food resources or prey on larval and juvenile native fish (Kaeding and Osmundson 1988; Haines and Tyus 1990; Karp and Tyus 1990; Tyus and Beard 1990; Minckley et al., 1991; Reclamation 1995). Slow-water habitats such as backwaters are used by juveniles and adults of a number of introduced fish species present in the upper Green River (Table D.2), including the common carp, fathead minnow, sand shiner, redside shiner, and black bullhead. Tyus et al. (1982) discuss species distributions within the Green River, and Pflieger (1975), Smith (1979), and Woodling (1985) discuss habitat preferences. Quiet water habitats are also preferred by the green sunfish, bluegill, and northern pike. The two former species are omnivorous forms that will feed on larval fish, while the latter species eats fish exclusively. For the assessment in this EIS, it was assumed that as backwater habitats become more stable under the seasonally adjusted flow scenarios, the quality of these habitats should increase for introduced fish as well as for the native species.

Survival of adult and juvenile fish during the winter can also be decreased by fluctuations in flow. In order to survive the winter, many fish species depend upon energy reserves accrued during warmer periods of the year. Excessive activity during the winter can kill fish if that activity causes these energy reserves to fall below critical levels. Since fluctuations in flow increase the movements of some Green River fish (Valdez and Masslich 1989), the potential for overwinter (December through March) survival was assumed to decrease as fluctuations in flow increased.

D.2.1.3 Methodology for Assessment of Impacts to Riparian Vegetation

This section describes the approach used to identify the types of impacts to riparian vegetation that would result from shifts in flow regimes for the Flaming Gorge Dam hydropower operational scenarios. Aerial videography was obtained for the Green River to determine riparian areas inundated at different flows (as described in Section D.2.1.1). Three-band (red, green, infrared) videography was collected during May and June 1992. Images were obtained at four locations along the river (approximately 1 mi of river length at each) between the dam and the Yampa River. Riparian area (defined here as the area of vegetation and substrate between upland vegetation and water) and water surface areas were identified, and acreage was calculated. Changes in the size of the riparian area at different flows were calculated in units of acres per mile (LaGory and Van Lonkhuyzen 1995).

Species composition and elevation data were obtained along 38 transects on the Green River between Flaming Gorge Dam and Split Mountain Canyon (82 mi below the dam) during June 1992 (LaGory and Van Lonkhuyzen 1995). Dam releases during this period were about 800 cfs; thus, river levels approximated those associated with low flow. Transects extended perpendicular to the river from the edge of the water to the upper edge of the riparian zone.

Riparian areas were divided into upper and lower zones relative to their position above the river (Figure 3.25). The upper riparian zone was that portion of the riparian area above the elevation of typical maximum river flow (4,200 cfs for the Green River below Flaming Gorge Dam). Operational scenarios featuring maximum flows higher than 4,200 cfs would result in inundation and potential drowning of some existing upper riparian zone vegetation. Lower maximum flows under different operational scenarios would result in the expansion of the upper riparian zone to lower elevations. Although the vegetation at the upper boundary of the zone that became established before construction of the dam would experience lower soil moisture levels under reduced flows, it was assumed that this vegetation would survive for 50 years or more, well beyond the 15-year period relevant to this Power Marketing EIS. Several factors were evaluated to assess the potential for expansion of upper riparian zone vegetation to lower elevations. It was assumed that this vegetation could not colonize or survive on substrates that were continuously or daily inundated for a month or more each year. The spring peak flows required by the Biological Opinion for Flaming Gorge Dam (USFWS 1992) were not considered to be of sufficient duration to prevent vegetation survival. Flow velocity during the spring peak was not considered to be sufficient to remove rooted plants.

The lower riparian zone is located between minimum river flow (800 cfs for the Green River) and typical maximum flow (Figure 3.25). The vegetation in this zone is adapted to intermittent inundation by fluctuating flow levels during the growing season (May 1 through September 30). The intermittent saturation from flow fluctuations sustain soil-moisture levels without drowning vegetation. Lower riparian zone vegetation could respond rather quickly (within several years) to changes in the moisture regime. Continuous inundation (i.e., nonfluctuating high flows) for a month or more during the growing season was considered sufficient to kill existing vegetation by drowning if the water was greater than 1 ft deep. Additionally, if a period of two months or more of exposure occurred during the growing season (i.e., without inundation due to fluctuating flows), it was assumed that existing vegetation would die back because of drought stress. If the exposure followed at least two months of current maximum flow levels, drought-intolerant vegetation would be replaced with more drought-tolerant species. A decrease in maximum flows during the growing season was assumed to reduce the amount of existing vegetation by killing plants at higher elevations. Therefore, the total amount of lower riparian zone vegetation would be directly related to the width of the fluctuating zone during the growing season. A shift in the location of the fluctuation zone would result in loss of some existing vegetation and simultaneous replacement with new vegetation at a different elevation. Such a situation could result in no net change in the area of the lower riparian zone once equilibrium to the new flow regime was achieved. However, a seasonal shift would cause alternate drowning and exposure, resulting in a net loss of vegetation. Spring-peak flows were not considered to be of sufficient duration to drown lower riparian zone vegetation.

Results of the assessments are summarized in Section 4.2.4.2.2. More detailed results are presented in Section D.3 and LaGory and Van Lonkhuyzen (1995).

D.2.2 Aspinall Unit

D.2.2.1 Methodology for Assessment of Impacts to Aquatic Ecology

Potential impacts to the aquatic ecology of the Aspinall Unit were evaluated only for the area between the upstream end of Blue Mesa Reservoir and Crystal Dam. Only this area was evaluated because releases from Crystal Dam would be steady (i.e., would not be controlled to produce hydropower under either of the operational scenarios analyzed). Therefore, this analysis of impacts focuses on fish in the three Aspinall Unit reservoirs (Blue Mesa, Morrow Point, and Crystal). The daily changes in reservoir elevation attributable to hydropower operations were examined to evaluate the potential impacts to kokanee salmon and trout from the two hydropower operational scenarios (seasonally adjusted steady flows and seasonally adjusted high fluctuating flows). The methods and assumptions used in that evaluation are summarized here.

The hourly change in reservoir elevation under each operational scenario was calculated on the basis of the volume of water to be released (see Section 4.2.3.3 and Appendix C for details). Because the volume of water to be released during a day would be the same under both operational scenarios, beginning- and end-of-day reservoir elevations would be similar. Thus, the seasonally adjusted steady flow operational scenario would result in a linear increase or decrease in reservoir during the day, while the seasonally adjusted high fluctuating flows operational scenario would result in a nonlinear change in reservoir elevation during the day.

The difference in the potential for entrainment of kokanee salmon through the penstocks of the Aspinall Unit facilities was evaluated by examining how far the preferred depths of kokanee salmon would be above the penstock intakes throughout the day under each operational scenario. In the summer, when adult kokanee salmon seek cold water, the preferred depths of these fish in Blue Mesa Reservoir are between 50 and 100 ft, and the preferred depths in Morrow Point Reservoir are between the surface and 40 ft.

Evaluation of impacts to growth, condition, and habitat availability of the operational scenarios was also based upon examination of differences in daily changes in reservoir elevation. This approach took into account the shoreline surface area that would be inundated and exposed on a daily basis and the amount of benthic food resources that could be affected. The major source of food for kokanee salmon is zooplankton, which is assumed to be unaffected by the fluctuations in reservoir elevation attributable to hydropower operations.

D.2.2.2 Methodology for Assessment of Impacts to Riparian Vegetation

Multispectral aerial videography for the Aspinall Unit reservoirs was used to determine the amount of riparian vegetation present. The videography was obtained from a low flying fixed-wing aircraft during May, June, and October 1992. Information was collected in red, green, and infrared bands similar to those collected by Landsat multispectral scanner satellites. The taping, which was conducted for four flow releases from the Aspinall Unit dams, covered an area that included each reservoir and dam. Images of the half-mile section of riverine habitat at the headwaters of Crystal Reservoir, 11 locations along Blue Mesa Reservoir, 6 locations along Morrow Point Reservoir, and 6 locations along Crystal Reservoir were captured, transferred to a computer format, and analyzed (Figure D.2). Riparian areas were identified, and the area of coverage was calculated. The amount of riparian vegetation was calculated in units of acres per mile.

Aspinall Unit reservoir levels were calculated from Bureau of Reclamation storage volumes and a reservoir routing model (Section 4.2.3.3.1). Stage changes were used to determine which types of plant communities would be affected by different water levels and to what extent they would be inundated (see Section D.2.1.3 for approach used to assess impacts to riparian vegetation). Results of the assessments are summarized in Section 4.2.4.3.2; more detailed results are presented in Section D.3 of this appendix.

D.3 WETLANDS ASSESSMENT

This wetlands assessment has been prepared to comply with Executive Order 11990, *Protection of Wetlands*. The assessment focuses on the potential impacts to wetlands that could result from implementation of the various hydropower operational scenarios considered in this EIS for Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit. Each of the commitment-level alternatives considered could use any of the hydropower operational scenarios considered here; thus, the impacts of these alternatives would essentially be the same with regard to associated hydropower impacts.

The analysis presented in Section 4.1.1.1 indicates that certain commitment-level alternatives would be more likely than others to result in the construction of new power plants, and this new construction also could result in impacts to wetlands. The types of impacts to wetlands possible include (1) disturbance (e.g., dredge or fill) during construction, (2) discharge of materials (intentional or inadvertent) to any adjacent wetlands during operation of the power plant, (3) inundation of wetlands, or (4) alterations of hydrology. Any such impacts would depend on the location and characteristics of new power plants and would not necessarily be a function of the projected number of new power plants. Since the locations of any new power plants cannot be determined at this time, it is not possible to assess these potential indirect impacts to wetlands. Any such action would require an environmental review that would consider impacts to wetlands before construction.

Wetland delineations (delineation of jurisdictional wetlands following U.S. Army Corps of Engineers [COE] methods [COE 1987]) have not been performed for any of the areas considered in this EIS. As a conservative approach, all riparian vegetation considered here is assumed to meet the Corps of Engineers definition of wetlands, (i.e., "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions@ [COE 1987]). To be considered a wetland under this definition, an area must possess the following characteristics: (1) a predominance of plant species typically adapted to saturated soil conditions; (2) hydric soils; and (3) periodic or permanent inundation or soil that is saturated to the surface at some time during the growing season (COE 1987). It is assumed that all riparian vegetation in these areas possess these characteristics, although jurisdictional wetlands probably do not occupy the entire riparian zone, especially the upper riparian zone. Any wetlands above the riparian zone would, by definition, not be dependent hydrologically on river flow or reservoir water level and, thus, would not be affected by any of the operational scenarios under consideration.

D.3.1 Glen Canyon Dam

D.3.1.1 Description of Riparian Vegetation below Glen Canyon Dam

Riparian vegetation occurs within the approximately 290 mi of river corridor between Glen Canyon Dam and the headwaters of Lake Mead. This riparian habitat, which would be considered wetland under the USFWS wetlands classification system (Cowardin et al. 1979; Table D.8) and is here assumed to meet the COE criteria for wetland, is the largest protected riparian corridor in the western United States (Anderson and Ruffner 1987). Before Glen Canyon Dam was completed in 1963, two zones of riparian vegetation occurred along the Colorado River in the Glen Canyon and Grand Canyon corridors (Anderson and Ruffner 1987; Reclamation 1988). Closest to the river, in the area exposed to annual scouring floods, ephemeral herbaceous and short-lived woody species became established between floods. Above this elevation (approximately the 90,000-cfs level), the plant community consisted of long-lived shrubs and trees that depended on occasional elevated flows to provide suitable substrates, nutrients, and groundwater necessary for growth and reproduction (Anderson and Ruffner 1987; Reclamation 1988). This ?old high-water zone@ community was dominated by western honey mesquite, catclaw acacia, apache plume, redbud, and netleaf hackberry (Anderson and Ruffner 1987). The upper limit of the old high-water zone was apparently determined by soil-moisture levels and soil depth (Reclamation 1988).

TABLE D.8 Wetland Classification of Riparian Habitats of the Colorado River Corridor below Glen Canyon Dam a

Vegetation Type	Common Plant Species	Wetland Type[b]
Upper riparian zone		
Pre-dam origin	Western honey mesquite, catclaw acacia, apache plume, redbud, netleaf hackberry	Palustrine, broad-leaved deciduous scrub-shrub, intermittently flooded
Post-dam origin	Tamarisk, desert broom, willows, arrowweed	Palustrine, broad-leaved deciduous scrub-shrub, intermittently flooded
Lower riparian zone	Sedges, bulrush, rushes, cattail, scouring rush, common reed	Palustrine, persistent emergent, regularly or irregularly flooded

a All areas may not meet the COE definition of jurisdictional wetlands (COE 1987).

b Wetland types are from Cowardin et al. (1979). *Palustrine* = wetlands dominated by trees, shrubs, or persistent emergents; *scrub-shrub* = dominated by woody vegetation less than 20 ft tall; *emergent* = dominated by erect, rooted, herbaceous plants present for most of the growing season; *persistent* = plants remain standing until the beginning of the next growing season; *nonpersistent* = plants fall to the surface before the next growing season; *intermittently flooded* = substrate usually exposed but with variable periods of inundation and unpredictable, possibly long periods between inundations; *regularly flooded* = substrate alternately inundated and exposed at least once daily; *irregularly flooded* = substrate alternately inundated and exposed less often than daily.

Riparian vegetation in the old high-water zone has remained relatively stable since 1963 (Pucherelli 1986) and occupies about 1,870 acres between the dam and Lake Mead (Reclamation 1995). Typical old-high water zone species reproduce in both the old high-water zone and below, but the greater survival of seedlings closer to the river suggests an eventual shift of the community closer to the river's edge (Anderson and Ruffner 1987).

One of the most noticeable changes in the river corridor that resulted from construction of Glen Canyon Dam was the establishment of long-lived riparian vegetation closer to the river. This new community, termed the ?new high-water zone,@ consists of woody and perennial herbaceous species that grow in the old ephemeral zone at and above the 31,500-cfs level (Carothers and Brown 1991) and occupy about 1,320 acres between the dam and Lake Mead (Reclamation 1995). Establishment of these species at lower elevations resulted from the elimination of the large annual floods that previously removed vegetation below the 90,000-cfs level. The new high-water zone is dominated by a mix of native and nonnative species, including tamarisk, desert broom, willows, and arrowweed (Pucherelli 1986).

In the wet year of 1983, flows in excess of 90,000 cfs occurred below the dam (Reclamation 1990; Stanford and Ward 1991). This flood and others in the subsequent wet years of 1984 to 1986 significantly reduced (by about 49%) plant cover in the new high-water zone (Pucherelli 1986; Stevens and Waring 1986; Brian 1987). The lack of floods since 1986 has allowed vegetation in the new high-water zone to begin recovery.

In contrast to the adverse effects of flooding on new high-water zone vegetation, the 1983 flood resulted in a slight increase in plant cover in the old high-water zone, presumably because of an increase in soil moisture and replenishment of nutrients (Brian 1987). Occasional floods of this magnitude appear to be necessary for the long-term maintenance of this community (Pucherelli 1986; Brian 1987; Carothers and Brown 1991).

Below the upper riparian zone is the area affected by fluctuating flows from the dam. This lower riparian zone is comparable to the old flood zone in that periodic scouring and inundation prevent colonization by many long-lived plant species. However, within the lower riparian zone, marsh vegetation (mostly cattail and bulrush) has colonized some protected beaches, backwater areas, and tributary mouths where fine sediments have accumulated (Carothers and Brown 1991). Common marsh species include sedges, bulrush, rushes, cattail, scouring rush, and common reed.

Approximately 1,100 marshes are present along the river corridor. The total marsh area is about 62 acres (Reclamation 1995). Marshes become progressively more common but smaller downstream of Lees Ferry. In the upper canyon, marshes occur only along wide reaches. In the lower canyon, marshes occur in both wide and narrow reaches and are more common than they are nearer the dam because of the increased amount of sediment available for colonization of wetland plants.

The number of small marshes has increased since institution of interim flows in August 1991, especially in backwater areas at the 20,000-cfs level (Wegner 1992). Above that level, marshes appear to be drying out because of the reduction in water levels under interim flows.

D.3.1.2 Impacts to Riparian Vegetation below Glen Canyon Dam

Table D.9 summarizes impacts to riparian vegetation under the nine operational scenarios considered in the Glen Canyon Dam EIS (Reclamation 1995). Operational scenarios differ considerably in the expected amount of impact to wetlands. Most of these differences exist between the various fluctuating flow scenarios and steady flow scenarios. These differences are discussed below.

Continuation of historical operations (defined as no-action operations in the Glen Canyon Dam EIS) would not result in impacts to existing wetlands because the extent and nature of this vegetation in the river corridor are primarily a function of these historical operations. Riparian vegetation has increased in abundance due to the elimination or reduction in annual flooding that occurred with construction of the dam. With this reduction, riparian vegetation became established at lower elevations determined by the maximum flows (32,000 cfs) that occurred during historical operations.

TABLE D.9 Summary of Impacts of Hydropower Operational Scenarios on Riparian Vegetation below Glen Canyon Dam a

Operational Scenarios	Upper Riparian Zone	Lower Riparian Zoneb
Continuation of historical operations	No impact; no net change in area.	No impact; no net change in area.
Maximum power plant capacity	No impact to slight adverse impact (0-9% decrease in area).	Same as above.
Restricted high fluctuating flows	Slight benefit (15-35% increase in area).	Same as above.
Moderate fluctuating flows	No impact to slight benefit (0-12% increase in area with habitat-maintenance flows).	Either no impact or a slight adverse impact; either no net change or a decrease in area.
Modified low fluctuating flows	Same as above.	Same as above.
Interim low fluctuating flows	Moderate benefit (30-47% increase in area).	Same as above.
Existing monthly volume steady flows	Large benefit (45-65% increase in area).	Slight adverse impact; decrease in area.
Seasonally adjusted steady flows	No impact to slight benefit (0-12% increase in area with habitat-maintenance flows).	Same as above.
Year-round steady flows	Large benefit (63-94% increase in area).	Same as above.

a The terms *slight, moderate,* and *large* are used to convey the importance of the impact. These relative terms were not included in the Glen Canyon Dam EIS but have been added on the basis of a review of the findings presented in that EIS. They represent the professional judgment of the authors of this Power Marketing EIS and have been added to provide consistency in treatment among facilities.
b Area coverage cannot be predicted but would likely be similar for all scenarios (Reclamation 1995).

Source: Adopted from Reclamation (1995).

Under operations at maximum power plant capacity, a slight increase in maximum flow would reduce the area available for upper riparian zone vegetation. Some additional shoreline area would be regularly inundated by the higher flows, and any upper zone plants in this area would be lost. These losses would represent up to 9% of the upper riparian zone. In addition, the small (5%) increase in maximum flows would increase the fluctuation zone, thus slightly increasing the area available for colonization by lower zone plants. However, this increase is not expected to result in a substantial change from current conditions.

The restricted high fluctuation operational scenario would have the same maximum flow as historical operations but would feature some reduction in fluctuation to protect resources. Reductions in fluctuations are expected to result in an increase of 15-35% in upper zone vegetation. Existing lower zone vegetation would be wetted at approximately the same frequency and thus would be maintained.

The moderate fluctuation operational scenario would result in reduced daily fluctuations that could increase the area of upper riparian zone vegetation by 23-40%, but annual habitat-maintenance flows should prevent any such increase. The 29% decrease in maximum flow would decrease the fluctuation zone, and thus could decrease the area available for lower riparian zone vegetation.

Under the modified and interim low fluctuation operational scenarios, a zone between the 20,000- and 31,500-cfs levels would no longer be periodically inundated. The substantial (37%) reductions in maximum flows under these operational scenarios could result in up to a 47% increase in the area of upper riparian zone vegetation. However, the annual habitat-maintenance flows of the modified low fluctuation scenario should prevent any such increase. Lower zone vegetation would continue to occupy sites below the 20,000-cfs stage. Existing lower zone vegetation above this stage would not be wetted regularly by fluctuating flows and would be gradually replaced by upper riparian zone vegetation.

The greatly reduced maximum flows under the existing monthly volume steady flow operational scenario would increase the area available for upper riparian zone plants by about 45-65%. The zone between the 16,300- and 31,500-cfs stages would no longer be inundated by fluctuating flows. These reductions in fluctuations are expected to favor upper riparian zone vegetation over lower zone vegetation. Lower zone plants above the 16,300-cfs level would lose their water supply, and those below this level would be inundated for extended periods, including most of the growing season. The lack of a daily fluctuation zone and the occurrence of only minor monthly fluctuations during the growing season would greatly reduce the representation of typical lower zone species. Monthly changes in flow could allow some of these species to become established between the elevations of 13,000- and 15,000-cfs flows, but no vegetation would be expected below the elevation of 13,000-cfs flows because this area would be continuously inundated for most of the growing season.

Under seasonally adjusted steady flows, the area between the elevations of 18,000- and 31,500-cfs flows would no longer be periodically inundated, which could result in a 38-58% increase in the area of upper riparian zone vegetation, but annual habitat-maintenance flows would prevent such an increase. The seasonal variation in steady flows is expected to be detrimental to lower riparian zone plants. Under this operational scenario, existing lower zone plants would either (1) lose their water supply for five months when flows are at 9,000 cfs or less (October, November, December, August, September); (2) be partially inundated for five months when flows range from 11,000 to 12,500 cfs (January through April, July); or (3) be completely inundated for two months when flows are at 18,000 cfs (May and June). The timing of complete inundation followed by complete exposure during the growing season would be particularly detrimental, and it is assumed that a loss of vegetation would occur. Some lower riparian zone vegetation could be reestablished around the 18,000-cfs level. Because of the seasonal changes in flow, however, some of these plants could occur between the 12,000- and 18,000-cfs levels. No vegetation would be expected below the 12,000-cfs level because this area would be inundated for most of each year.

The year-round steady flow operational scenario would result in steady flows of about 11,400 cfs and would result in a 63-94% increase in the area of upper riparian zone vegetation. Existing vegetation below the elevation of 11,400-cfs flows would be under water year-round, while those above this level would be dry, resulting in a reduction in existing lower riparian zone vegetation. Any of this vegetation that persisted would be located around the elevation of 11,400-cfs flows.

D.3.2 Flaming Gorge Dam

D.3.2.1 Description of Riparian Vegetation below Flaming Gorge Dam

Riparian vegetation occurs along most of the 93 mi of the Green River corridor between Flaming Gorge Dam and Jensen, Utah. Riparian vegetation is absent only in the few areas where sheer rock walls abut the river. Table D.10 summarizes information on the characteristics of the riparian vegetation along the river. Since the construction of Flaming Gorge Dam, the characteristic seasonal flow pattern has been replaced by a shift in monthly releases to meet irrigation demands (higher flows in summer) and relatively large daily fluctuations to produce hydropower (Section 3.3.2.1). Below the confluence with the Yampa River, flows in the Green River are strongly influenced by flows from the unregulated Yampa and, as a result, take on a more natural flow regime that includes high spring flows.

Before construction of Flaming Gorge Dam, the vegetation along the river occupied two distinct zones (Fischer et al. 1983). Nearest the river, flooding occurred each year during high spring flows, and plants in this flood zone were predominantly annuals or scour-tolerant perennials such as wild licorice, dogbane, and sedges. Dominant species above the flood zone included box elder, squawbush, Fremont cottonwood, and coyote willow (Holmgren 1962). After construction of the dam, woody riparian vegetation permanently colonized much of the old flood zone and formed a more stable riparian corridor. Species that spread by underground stems, such as wild licorice, common reed, and scouring rush, have formed dense stands along the shoreline in some areas and appear to be gradually making the channel narrower and deeper with steep banks. Riparian vegetation above the high water line, including pre-dam woody riparian vegetation, is estimated to occupy about 13.2 acres per mile.

TABLE D.10 Wetland Classification of Riparian Habitats of the Green River Corridor below Flaming Gorge Dam a

Vegetation Type	Common Plant Species	Wetland Type[b]
Upper riparian zone		
Pre-dam origin	Cottonwood, box elder, sweet clover, grasses	Palustrine, broad-leaved deciduous, forested, intermittently flooded
Post-dam origin	Box elder, tamarisk, grasses, wild licorice, giant whitetop, scouring rush	Palustrine, broad-leaved deciduous, scrub-shrub, intermittently flooded
Lower riparian zone	Cattail, bulrush, coyote willow, rushes, common reed, scouring rush, spikerush	Palustrine, persistent emergent, regularly or intermittently flooded

a All areas may not meet the COE definition of jurisdictional wetlands (COE 1987).
b Wetland types are from Cowardin et al. (1979). Terms are defined in Table D.8 with the exception of *forested* = dominated by woody vegetation at least 20 ft tall.

Between Flaming Gorge Dam and Jensen, the Green River alternately flows through narrow canyons and broad valleys that are relatively distinct in terms of riparian vegetation. The major areas are Red Canyon, Browns Park, Canyon of Lodore, Whirlpool Canyon, Island and Rainbow Parks, and Split Mountain Canyon. These areas are described below.

The riparian zone in Red Canyon occurs on a predominantly rocky substrate (mostly cobble and boulder) and is relatively narrow (less than 100 ft wide). Riparian vegetation extends up to 25 ft above the low-water level (800-cfs level). Above the normal high-water line (4,200 cfs), grasses, scouring rush, giant whitetop, wild licorice, and a variety of woody species (including box elder, coyote willow, and squawbush) are common. Individual ponderosa pine occur near the river in some areas. Tamarisk is uncommon except for stands at Little Hole and near Red Creek.

Through Browns Park, the river meanders within a broad, open floodplain of mostly sand, silt, and gravel. The riparian zone is relatively broad (up to 200 ft wide) except in a few areas (e.g., Swallow Canyon) and extends to 15 ft above the low-water level. Above the high-water line, grasses, sedges, coyote willow, wild licorice, and sow thistle are common; tamarisk forms occasional dense stands at higher elevations throughout Browns Park. Some relatively large cottonwood groves occur on high terraces above the river, particularly downstream of Swinging Bridge (30 mi below the dam). Few young cottonwoods are present, apparently because the dam eliminated the periodic floods needed for seedling establishment (Bureau of Land Management [BLM] 1990). Steep cutbanks are common in lower Browns Park, and in some areas almost all banks are cut and severely eroded.

Within the Canyon of Lodore, many of the canyon walls are nearly vertical, with narrow talus slopes at the base or occasionally with cliffs descending directly into the water; substrates within the riparian zone vary from sand to gravel, cobble, or boulder. Although the riparian zone within the canyon is generally more narrow than in Browns Park because of the restricting canyon walls, it can be up to several hundred feet wide near the confluence of tributary streams. Riparian vegetation extends up to 35 ft above the low-water level. Grasses, scouring rush, box elder, and tamarisk are prevalent above the high-water line. Box elder groves occur throughout the canyon but are largest near the confluence with tributaries. Small tamarisk stands are common throughout the canyon.

The species found in the riparian zone within Whirlpool Canyon are similar to those in the Canyon of Lodore, but unvegetated sandy beaches are more common and riparian vegetation is further above the normal river level because of the greater seasonal variations in flow below the Yampa River. Tamarisk is very common below the old high-water line (Fischer et al. 1983).

In Island and Rainbow Parks, the Green River again flows through a wide floodplain with predominantly sand and silt substrate. Islands and backwaters are abundant throughout this section of river. The riparian zone is relatively wide (several hundred feet in areas) and extends up to 20 ft above the water level. Riparian vegetation is similar to that in Browns Park, and large stands of cottonwood, box elder, or tamarisk are common on high terraces.

Below Rainbow Park, the Green River enters Split Mountain Canyon, which has steep, rocky walls and a narrow riparian zone. The vegetation is similar to that found in the Canyon of Lodore except that cottonwoods are more frequent than box elder. Below Split Mountain Canyon, the topography is flatter and the river has steep cutbanks and a high terrace. Tamarisk is a dominant riparian species on the upper terrace throughout the area. Russian olive is also common.

Marshes occur in the lower riparian zone along the Green River between the dam and Jensen. Marshes occur in backwater areas, side channels, on vegetated islands, and in low, flat, sandy or silty areas on the inside curves of the river where the current slows and sediments are deposited. The greatest abundance of marsh vegetation is between the 2,000- and 3,000-cfs levels. Marshes also occur occasionally along the channel margin in protected areas, such as downstream of protruding rocks or cliffs. Marshes are most abundant in lower Browns Park and Island Park, where the river meanders extensively and many backwaters and side channels exist. Common species in marshes are cattail, bulrush, rush, common reed, scouring rush, and spikerush. In the Canyon of Lodore, common reed is the most common marsh species, while cattails are less common. The lower riparian zone (between the elevations of 800- and 4,200-cfs flows), where most marshes occur, occupies about 5.3 acres per mile along the river (LaGory and Van Lonkhuyzen 1995).

D.3.2.2 Impacts to Riparian Vegetation below Flaming Gorge Dam

Changes in river flow under each operational scenario during a moderate water year (October 1 through September 30) are presented in Figure D.3. This figure shows the seasonal patterns in flow under each operational scenario and the expected shifts in riparian vegetation zones that would result. Operational scenarios would differ considerably in their expected impact to riparian vegetation, as summarized in Table D.11. These impacts are discussed below and in LaGory and Van Lonkhuyzen (1995).

As discussed in Section D.3.2.1, the abundance of riparian vegetation has increased along the Green River because of the elimination or reduction of annual flooding following construction of Flaming Gorge Dam. With this reduction, riparian vegetation became established at lower elevations determined by the maximum flows that occurred during previous operations. With the year-round high fluctuation operational scenario, the area of upper riparian zone vegetation above the high-water line would decrease by 5% because maximum releases of 4,700 cfs under this operation scenario would be slightly greater than the historical maximum flow of 4,200 cfs. The extent of the fluctuation zone would increase slightly (13%). The zone would continue to support existing marsh vegetation and other lower riparian zone vegetation and additional areas could become available for these species.

With seasonally adjusted high fluctuations, maximum flows would be 4,700 cfs, slightly higher than historical levels, for most of the year (from November 1 until July 10 in moderate water years) (Figure D.3). From July 10 to October 1, maximum flows would be reduced from 4,700 cfs to around 3,000 cfs. However, any upper riparian zone vegetation that colonized this area during this period would be inundated and killed by the higher maximum flows that would occur for the greater part of the year. The extent of upper riparian zone vegetation under this operational scenario is, therefore, expected to decrease by 5%. However, the area available for lower zone vegetation would be increased by 13% because, for several months of the growing season, the fluctuation zone would extend higher than historical levels.

Maximum daily release would be variable under seasonally adjusted moderate fluctuations. For two months of the growing season, maximum flows would reach 4,700 cfs, thus reducing the area of upper riparian zone vegetation by 5%. Otherwise, maximum flows would generally be lower than under either year-round high fluctuations or seasonally adjusted high fluctuations (Figure D.3). However, upper riparian zone vegetation is not expected to expand to lower elevations because reductions in maximum flow either would occur outside of the growing season (lower flows between October 1 and January 31) or would only occur during part of the growing season (lower flows between July 1 and September 30). Thus, upper zone vegetation would either not be able to respond to reductions in flow or would be drowned when higher flows occurred from May 1 to June 30.

TABLE D.11 Summary of Impacts of Hydropower Operational Scenarios on Riparian Vegetation below Flaming Gorge Dam a

Operational Scenarios	Upper Riparian Zone	Lower Riparian Zone
Year-round high fluctuating flows	Slight adverse impact to existing vegetation; 5% decrease in area; species most likely to decrease is box elder.	Slight benefit; 13% increase in area available for lower riparian zone vegetation; species most likely to increase are Canada thistle, carex, common reed, coyote willow, juncus, and scouring rush.
Seasonally adjusted high fluctuating flows	Same as above.	Same as above.
Seasonally adjusted moderate fluctuating flows	Same as above.	Moderate adverse impact; area available for lower zone vegetation decreases by about 40%; species most likely to decrease are cattail, common spikerush, field horsetail, juncus, and scirpus.
Seasonally adjusted steady flows	Slight benefit; 8% increase as high-water line lowered to around the 3,400-cfs level; species most likely to increase are tamarisk, giant whitetop, golden aster, box elder, and artemisia.	Large adverse impact; area available for lower zone vegetation decreases by about 74%; species most likely to decrease are cattail, common spikerush, field horsetail, juncus, and scirpus.

a The terms *slight*, *moderate*, and *large* are used to convey the importance of the impact. These relative terms were determined after the analysis of the impacts was completed and represent the professional judgment of the analyst.

Under seasonally adjusted moderate fluctuations, lower riparian zone vegetation (including marshes) would be affected by the seasonal shifting in location of the fluctuation zone (between about 2,400- and 4,700-cfs levels from November through January and April through May; and 1,000- and 2,000-cfs levels from mid July to September 30) (Figure D.3).

This shifting would inhibit the establishment or maintenance of stable marshes and result in a decrease of 40% in the area available for this vegetation. Lower zone plants that germinated in the lower fluctuation zone prevalent for most of the growing season would be under water for most of the year and would not persist. No vegetation is expected to occur below about the 2,400-cfs level because this area would be inundated for eight months each year (November through June).

With seasonally adjusted steady flows, daily fluctuations in flow would be eliminated, and only seasonal fluctuations would occur (Figure D.3). Although the maximum release during the year would be the same as the daily maximum achieved each day under year-round high fluctuations, this peak flow would not occur long enough to prevent establishment of upper riparian zone plants at lower elevations. It is expected that upper riparian zone species could become established down to approximately the elevation of 3,400-cfs flows (which would occur early in the growing season). Establishment of upper riparian zone plants down to this new high-water line would represent an increase in this vegetation type of about 1.1 acres per mile; this represents an increase of about 8%.

The lack of daily fluctuations in flow and the wide seasonal variation would greatly reduce the area available for marsh and other lower zone plants under seasonally adjusted steady flows (Figure D.3). Because there would be no fluctuation zone, this vegetation would probably be limited to areas wetted by tributary streams or seeps and the area between the elevations of 2,400- and 3,400-cfs flows. This latter area would be wetted during much of the growing season and would not be inundated for more than a few weeks at a time. No vegetation or only short-lived annual plants are expected to occur below the 2,400-cfs level because this area would be inundated for eight months each year (November through June).

D.3.3 Aspinall Unit

D.3.3.1 Description of Riparian Vegetation at the Aspinall Unit

The Aspinall Unit reservoirs occupy areas that for the most part had been canyon and gorge or, in sections of Blue Mesa Reservoir, somewhat wider steep-walled valleys. Little of the original riparian zone escaped inundation upon completion of the Aspinall Unit dams. At normal reservoir levels, most riparian vegetation occurs along the tributaries of the reservoirs rather than along the reservoir itself. Table D.12 summarizes the characteristics of the riparian vegetation that occurs in the area.

Areas surrounding Blue Mesa Reservoir are moderately to steeply sloped. Little riparian vegetation of any kind grows along the reservoir, either above or below the normal high-water line (only about 0.03 acre per mile of shoreline and 0-10 ft wide), and in most areas upland vegetation or bare rock occurs down to the water. Some areas do, however, support woody riparian vegetation, mainly near the confluences with tributaries. Vegetation found in such areas includes narrowleaf cottonwood, coyote willow, Bebb willow, Geyer willow, Pacific willow, thinleaf alder, and sweet clover. Approximately 10 acres of marsh (dominated by sedges) occurs where the Gunnison River enters the upstream end of Blue Mesa Reservoir, between South Beaver Creek and Beaver Creek. This marsh receives water when reservoir elevations are relatively high (around 7,510 ft MSL), and water enters the marsh through a road embankment consisting of boulders and fill material.

TABLE D.12 Wetland Classification of Riparian Habitats of the Aspinall Unit Reservoirs a

Vegetation Type	Common Plant Species	Wetland Type[b]
Upper riparian	Box elder, narrowleaf cottonwood,	Palustrine, broad-leaved deciduous, scrub-shrub,

zone	coyote willow	intermittently flooded
Lower riparian zone	Sedges, spikerush, horsetail, grasses	Palustrine, persistent or nonpersistent emergent, seasonally or regularly flooded

a All areas may not meet the COE definition of jurisdictional wetlands (COE 1987).
b Wetland types are from Cowardin et al. (1979). Terms are defined in Table D.8 with the exception of *seasonally flooded* = substrate inundated for extended periods early in the growing season but exposed by the end of the growing season.

Morrow Point Reservoir is surrounded by steep rocky slopes. Little riparian vegetation of any kind occurs along the reservoir. Much of the northern shore consists of unvegetated rocky cliffs, and in other areas upland vegetation is found down to the high-water line. Vegetation does not exist between the high- and low-water lines because of repeated exposure and inundation. Pine Creek, Curecanti Creek, Blue Creek, and Round Corral Creek, tributaries to Morrow Point Reservoir, support riparian areas containing narrowleaf cottonwood, willow, and thinleaf willow near the reservoir.

Crystal Reservoir also is surrounded by steep rocky slopes. The upper riparian zone is dominated by box elder, narrowleaf cottonwood, and coyote willow for about 0.5 mi below Morrow Point Dam, where the flow is essentially riverine. Here the riparian zone is 0-13 ft wide. In this riverine section, where daily fluctuations have ranged from 0 to 5,300 cfs during moderate water years (Section 3.3.3.1), some lower riparian zone vegetation (e.g., spikerush, horsetail, and grasses) occurs within the fluctuation zone. Farther downstream, no distinct riparian zone occurs. Woody riparian vegetation, including box elder, narrowleaf cottonwood, and willow, grows along the shore where Crystal Creek enters the reservoir.

D.3.3.2 Impacts to Riparian Vegetation at the Aspinall Unit

Because only a limited amount riparian vegetation occurs along any of the reservoirs of the Aspinall Unit, the potential for impact from the two operational scenarios considered here is greatly reduced. Table D.13 summarizes the limited impacts that could occur.

TABLE D.13 Summary of Impacts of Hydropower Operational Scenarios on Riparian Vegetation along the Aspinall Unit Reservoirs

Operational Scenarios	Upper Riparian Zone	Lower Riparian Zone
Seasonally adjusted high fluctuating flows		
Blue Mesa Reservoir	No impact on existing vegetation (including marsh in upper end) because fluctuations would be within historical range.	No impact; little vegetation exists in zone along reservoir.
Morrow Point Reservoir	Same as above.	No impact; little vegetation exists in zone along reservoir.
Crystal Reservoir	Slight benefit; expansion of zone in headwaters down to 3,800-cfs level; represents increase of about 0.1 acre.	Slight adverse impact; about 0.4 acre of lower zone vegetation lost.
Seasonally adjusted steady flows		
Blue Mesa Reservoir	No impact on existing vegetation (including marsh in upper end) because fluctuations would be within historical range.	No impact; little vegetation exists in zone along reservoir.
Morrow Point	Same as above.	No impact; little vegetation exists in zone along reservoir.

Reservoir		
Crystal Reservoir	Slight benefit; expansion of zone in headwaters down to 3,325-cfs level; represents increase of about 0.2 acre.	Slight adverse impact; about 0.6 acre of lower zone vegetation lost.

With seasonally adjusted high fluctuations, monthly variation in reservoir elevations at Morrow Point and Crystal reservoirs would be within the historical range of elevations (Section 4.2.3.3.1). Because upper riparian zone vegetation currently exists only above this range, both along the shorelines and at tributary mouths, changes in reservoir elevation resulting from hydropower operations should not affect this existing vegetation. New riparian vegetation would be unlikely to develop because of the wide range in inundation during the year. At Blue Mesa Reservoir, the monthly high-water elevation in a moderate water year would be somewhat higher than the historical monthly high-water elevation resulting from Reclamation operations. However, the influence of hydropower on Blue Mesa Reservoir elevations would not increase levels above historical levels. Consequently, no impacts to the marsh in the upper reach of the reservoir are expected to result from hydropower operations.

With seasonally adjusted high fluctuations, some expansion of upper riparian zone vegetation could occur along the headwaters of Crystal Reservoir (tailwaters of Morrow Point Dam) as fluctuations in flow would be reduced in this riverine section during three months (May through July) of the growing season. During this period, flows would fluctuate daily below 3,800 cfs (Section 4.2.3.3.1), and upper riparian zone vegetation could expand downward to this new high-water line. Such an increase would represent a vertical expansion of about 1 ft (ranging from 0.2 to 1.7 ft throughout the half-mile reach) by this vegetation type. Reduction in the fluctuation zone in this reach would result in a decrease in the limited amount of lower riparian zone vegetation that now occurs there. Under this operational scenario, this vegetation would be limited to the area between the 1,800- and 3,800-cfs levels, which represents a vertical range of about 1.6 ft (ranging from 0.2 to 3.1 ft throughout a half-mile section). Vegetation below the 1,800-cfs level (2.2 ft above the current low-water line, ranging from 0.1 to 4.9 ft) would be eliminated because of extended periods of inundation. About 0.4 acre of lower zone vegetation could be lost under the seasonally adjusted high fluctuation operational scenario.

Seasonally adjusted steady flows could result in some expansion of upper riparian zone vegetation along the headwaters of Crystal Reservoir because fluctuations in flow would be reduced in this riverine section during the growing season. Whereas historical releases from Morrow Point ranged from 0 to 5,300 cfs, under seasonally adjusted steady flows, releases would range from 1,770 to 3,325 cfs (Section 4.2.3.3.1). This difference would represent a drop in stage of about 1.3 ft (ranging from 0.2 to 2.4 ft), and upper riparian zone vegetation would be expected to extend down to this new high-water line, representing an increase of 0.2 acre. The fluctuation zone (and potentially all of the lower zone vegetation) in the headwaters of Crystal Reservoir would be eliminated under the seasonally adjusted steady flow operational scenario. Vegetation below the 3,325-cfs level (3.5 ft above the low-water line, ranging from 0.2 to 7.4 ft) would be eliminated because of monthly changes in inundation and exposure. About 0.6 acre of lower zone vegetation could be lost under this operational scenario.

D.3.4 Conclusions

Impacts of the various hydropower operational scenarios follow a distinct trend at the three facilities studied. Impacts to upper riparian zone vegetation would range from slight adverse impacts to a large benefit, with steady flows tending to create the greatest benefit. Impacts to lower riparian zone vegetation would range from slight benefits to moderate adverse impacts. Generally, lower maximum flows during the growing season would increase the areas of upper riparian zone vegetation. Reduced daily fluctuations would tend to decrease the areas of lower zone vegetation.

D.4 THREATENED AND ENDANGERED SPECIES

This section provides definitions of species-listing categories for the Federal Government and the states of Arizona, Colorado, and Utah (Sections D.4.1 through D.4.4). Correspondence with the U.S. Fish and Wildlife Service and state agencies regarding the presence of listed species within the areas of the facilities considered in this EIS is reproduced in Section D.4.5.

D.4.1 Federal Listing Categories

Federal categories of protected species are defined as follows:

- *Endangered*: Any species that is in danger of extinction throughout all or a significant portion of its range.
- *Threatened*: Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.
- *Category 1 (C1)*: Taxa for which the U.S. Fish and Wildlife Service has on file enough substantial information on biological vulnerability and threat(s) to support proposals to list them as endangered or threatened species. Proposed rules have not yet been issued because this action is precluded by other listing activity. Development and publication of proposed rules on Category 1 taxa are anticipated, however.
- *Category 2 (C2)*: Taxa for which information now in the possession of the U.S. Fish and Wildlife Service indicates that proposing to list as endangered or threatened is possibly appropriate, but for which conclusive data on biological vulnerability and threat are not currently available to support proposed rules.
- *Category 3:* Taxa that once were considered for listing as threatened or endangered but are no longer under such consideration. Taxa in Category 3 are not current candidates for listing. Reasons for losing candidacy include extinction (Category 3A), determination that the taxa are not a valid species (3B), and determination that the species is common or well protected (3C).

D.4.2 State of Arizona

Plant species in Arizona are protected under the Arizona Native Plant Law, administered by the Arizona Department of Agriculture. The law establishes the following protection categories:

- *Highly Safeguarded:* Species whose prospects for survival in the state are in jeopardy or which are in danger of extinction throughout all or a significant portion of their range, and those species which are likely in the foreseeable future to become jeopardized or in danger of extinction.
- *Salvage Restricted:* Species which are not in the highly safeguarded category but are nevertheless subject to a high potential for damage by theft or vandalism.
- *Export Restricted:* Species which are not in the highly safeguarded category but are nevertheless subject to over-depletion if their exportation from the state is permitted.
- *Salvage Assessed:* Species which are neither in the highly safeguarded category or salvage restricted categories but nevertheless have a sufficient value if salvaged to support the cost of salvage requirements.
- *Harvest Restricted:* Species which are not in the highly safeguarded category but are subject to excessive harvesting or over-cutting because of the intrinsic value of their byproducts, fiber, or woody parts.

The Arizona Game and Fish Department maintains a list of threatened native wildlife in the state. The following listing categories are used:

- *Endangered:* Species extirpated from Arizona since the mid-1800s or for which extinction or extirpation is highly probable without conservation efforts.
- *Threatened:* Animal species whose continued presence in Arizona could be in jeopardy in the near future. Serious threats have been identified and populations are (a) lower than they were historically or (b) extremely local and small.
- *Candidate:* Species with known or suspected threats, but for which substantial population declines from historical levels have not been documented.

D.4.3 State of Colorado

Plant species in Colorado are not protected by statute, but several lists of species of special concern are maintained, depending on rarity in the state (Colorado Natural Areas Program 1991). The lists are as follows:

- *List 1:* Federal threatened or endangered plant species and species that are rare throughout their range. This includes species that are extinct.
- *List 2:* Plant species that are rare or extirpated from Colorado but are relatively common elsewhere within their range.
- *List 3:* Plant species which appear to be rare but for which conclusive information is lacking.
- *List 4:* Plants of limited distribution or special interest that appear secure at this time.

The Colorado Department of Natural Resources maintains the following listing categories for animals:

- *Endangered:* Any species or subspecies of native wildlife whose prospects for survival or recruitment within Colorado are in jeopardy.
- *Threatened:* Any species or subspecies of wildlife which is not in immediate jeopardy of extinction but is vulnerable because it exists in such small numbers or is so extremely restricted throughout all or a significant portion of its range that it may become endangered.
- *Special Concern:* A native species or subspecies which has been threatened or endangered or could become threatened or endangered due to low population levels.

D.4.4 State of Utah

The state of Utah uses the following species listing categories:

- *Endangered:* Any species, subspecies or subpopulation that is threatened with extinction resulting from very low or declining numbers, alteration and/or reduction of habitat, detrimental environmental changes, or any combination of the above. Continued survival is unlikely without implementation of special measures.
- *Threatened:* Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.
- *Sensitive:* Any species which, although still occurring in numbers adequate for survival, has been greatly depleted or occurring in limited areas and/or numbers due to a restricted or specialized habitat. A management program, including protection or habitat manipulation, is needed.

D.4.5 Correspondence Regarding Listed Species

The following pages contain copies of correspondence with Federal and state officials concerning the presence and status of listed species.

Coorespondence Letter 1

Coorespondence Letter 2

Coorespondence Letter 3

D.5 REFERENCES FOR APPENDIX D

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APPENDIX E: COMMENTS AND RESPONSES

E.1 INTRODUCTION

E.1.1 Public Participation

The draft EIS was filed with the U.S. Environmental Protection Agency (EPA) on April 1, 1994, and a notice of the availability of the document for public review was published in the *Federal Register* on March 28, 1994 (59 Fed. Reg. 14,417, March 28, 1994). Press releases regarding the availability of the document were mailed beginning March 25, 1994. At the same time, the project newsletter, *EIS Update*, announcing both the availability of the draft EIS and the schedule for public informational hearings, was circulated to a large mailing list (approximately 2,100 individuals). Copies of the draft and supporting materials were made available to the public in the following locations:

· **Arizona**

- Flagstaff Public Library, Flagstaff
- Page Public Library, Page
- Phoenix Public Library, Phoenix
- Western Area Power Administration, Phoenix Area Office, Phoenix

· **Colorado**

- Denver Public Library, Denver
- Montrose Public Library, Montrose
- Western Area Power Administration Loveland Area Office, Loveland

· **New Mexico**

- General Library, University of New Mexico, Albuquerque

· **Utah**

- Salt Lake City Public Library, Salt Lake City
- Uintah County Library, Vernal

· **Washington, D.C.**

- U.S. Department of Energy, FOI Reading Room, Forrestal Building

In total, 362 copies of the draft EIS were mailed to members of Congress, Federal and state agencies, local governments, utilities and electric power entities, other interest groups, private citizens, and libraries. In addition, public informational hearings, where public comments on the draft EIS were accepted, were held in the following locations: (1) Denver, Colorado, on April 11, 1994; (2) Albuquerque, New Mexico, on April 12, 1994; (3) Salt Lake City, Utah, on April 18, 1994; (4) Flagstaff, Arizona, on April 26, 1994; and (5) Phoenix, Arizona, on April 27, 1994.

E.1.2 Comments

Comments from the public were received in the form of correspondence, hearing testimony, and written hearing submittals. Forty-one comment documents and transcribed testimonies were received and were assigned identification numbers (1-41). These documents were reviewed and divided into 444 individual comments, each containing a single theme or concern. Each comment was assigned a number, and an individual response was prepared. The comment documents are reproduced in Section E.4 of this appendix, and the responses are presented in Section E.5.

While every comment received a response, not every line of every document was considered part of a comment. Sections of the comment documents that did not deal directly with the EIS were not considered comments and did not receive individual responses. For example, each comment document usually had some introductory material that was not a comment on the EIS. These sections required no specific response and were not marked as comments. Each comment was considered individually in the context of the comment document, and a response was produced. In cases where comments were very similar or identical to comments made in other comment documents, the reader was referred to a previous response. Where necessary, the text of the final EIS has been modified to reflect the concerns of the commenter. Cases when changes were made in the text of the EIS as a result the comment are noted in the response to that comment.

Some comment documents included comments on documents other than the EIS itself. Included were comments on the Glen Canyon Dam Operations EIS, biological opinions produced by the U.S. Fish and Wildlife Service, transcripts of testimony presented to congressional committees on related issues, and comments on documents referenced in the EIS. While all attachments to all comment documents were read and considered by the EIS authors in revising the EIS, these attachments were not divided into individual comments unless the comments were on the technical memorandums written by EIS staff as part of the research for this EIS.

In general, comments on the technical memorandums were handled in one of two ways: (1) comments on points that affected the presentation in the EIS received a full response; (2) comments that had no direct bearing on the EIS did not receive a response, but were considered when preparing revisions of those technical memorandums.

E.2 HOW TO USE THIS VOLUME

Individual comments and the responses to them were assigned corresponding numbers. These numbers consist of two parts. The first part is the number of the document and the second is the number of the individual comment. Thus, comment number 5-1 refers to comment 1 of document 5. Each numbered comment document is the submittal of a single individual or organization, whether received as written correspondence or oral testimony. Spoken and written materials from the same person at the same hearing were considered a single comment document. On the other hand, a single organization sometimes combined the comments of more than one person into a single comment package. Such packages, under a single cover letter, were assigned a single comment document number. The author of the cover letter is listed as the author in the finding guide below (Table E.1).

Two indexes are provided to aid in locating individual comment documents. The first (Table E.1) lists individual commenters and organization representatives by last name, the organization represented (if any), the comment document number, and the page on which the reproduction of the document begins. The second index (Table E.2) is arranged by organization. This index lists organization name, the name of the individual submitting the comments, the comment document number, and the number of the page where the reproduction of the document begins. All comment documents are reproduced in numerical order in Section E.4.

To find a response to a specific comment, note the comment number listed in the margin of the document. Then turn to Section E.5. The response will have the same number as the comment.

E.3 SUMMARY OF COMMENTS AND RESPONSES

This section presents an overview of the comments received, highlighting those comments made by more than one individual or organization or those that were considered of major concern. Individual technical comments and specific responses to those comments are not presented in this summary, but instead are presented in Sections E.4 (comments) and E.5 (responses).

Forty-one comment documents were received by Western, including 23 from utilities and electric power entities, 3 from water and irrigation organizations, 2 from Federal agencies, 4 from state agencies, 5 from local government agencies, 2 from interest groups, and 2 from individuals. Not surprisingly, the comments reflect the particular interests of the groups and individuals represented. For example, utilities and electric power entities noted that there was little difference between the power marketing alternatives presented with regard to their effect on natural resources, and urged that the commitment-level alternative resulting in the most inexpensive power be chosen. On the other hand, groups concerned with the natural environment noted that statistically there was no difference in the socioeconomic effects of the alternatives considered on a regional scale and urged that a hydropower operational scenario that minimized fluctuations in releases, and was thus most like natural flows, be adopted at each facility.

TABLE E.1 Index of Commenters

Commenter	Representing	Document Number	Comments	Responses
Aitken, Gary A.	Strawberry Electric Service District Payson, Utah	28	E-283	E-496
Albrecht, Carl R.	Garkane Power Association, Inc. Richfield, Utah	32	E-333	E-519
Allum, John	Platte River Power Authority Fort Collins, Colorado	4	E-37	E-460
Ashby, Stanenly H.	Roosevelt Irrigation District Buckeye, Arizona	41	E-457	E-524
Barber, Brad T.	Governor's Office of Planning and Budget, State of Utah Salt Lake City, Utah	3	E-27	E-460
Barrett, Clifford	Colorado River Energy Distributors Association Salt Lake City, Utah	6 24	E-49 E-113	E-460 E-468
Bingham, Thomas Kip	City of Safford Safford, Arizona	38	E-449	E-523
Bowler, R. Leon	Dixie - Escalante Rural Electric Association, Inc. Beryl, Utah	36	E-445	E-523
Chatfield, Norman V.	Self St. George, Utah	1	E-23	E-459
Christensen, Chesley R.	Mt. Pleasant City Corporation Mt. Pleasant, Utah	17	E-95	E-464
Curtis, Michael A.	Arizona Municipal Power Users' Association Phoenix, Arizona	23	E-111	E-467
Duffin, Vaughn H.	Self St. George, Utah	2	E-25	E-459
Eyre, F. Danny	Bridger Valley Electric Association Mountain View, Wyoming	26	E-279	E-496
Falbo, Joe A.	Maricopa Water District Waddell, Arizona	22	E-109	E-467
Galvin, Denis P.	U.S. Department of the Interior National Park Service Washington, D.C.	31	E-309	E-498
Gibbs, William	Lehi City Corporation Lehi, Utah	29	E-285	E-496

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Gold, Leonard S.	Ak-Chin Indian Community Tempe, Arizona	39	E-453	E-524
Highers, David L.	Plains Electric Generation and Transmission Cooperative, Inc. Albuquerque, New Mexico	25	E-277	E-495
Hoskinson, Gene E.	City of Truth or Consequences Truth or Consequences, New Mexico	13	E-87	E-463
Jacquot, Jon F.	Public Service Commission The State of Wyoming Cheyenne, Wyoming	19	E-101	E-466
James, Leslie	Salt River Project Phoenix, Arizona	30	E-287	E-497
Jensen, T.C.	Grand Canyon Trust Flagstaff, Arizona	35	E-339	E-520
Justice, R.D.	Electrical District #7 of the County of Maricopa and the State of Arizona Waddell, Arizona	33	E-335	E-519
Keyes, Conrad G., Jr.	International Boundary and Water Commission, United States and Mexico El Paso, Texas	8	E-63	E-462
Knutson, Peter C.	Tri-State Generation and Transmission Association, Inc. Denver, Colorado	21	E-107	E-467
Lucy, Dick	Utah Municipal Power Agency Spanish Fork, Utah	5	E-48	E-460
Lynch, Robert S.	Irrigation & Electrical Districts Association of Arizona and CREDA Phoenix, Arizona	11 12	E-78 E-83	E-462 E-463
McNeil, Carolyn S.	Intermountain Consumer Power Association Sandy, Utah	16	E-93	E-464
Merrill, Gary O.	Murray City Power Department Murray, Utah	14	E-89	E-463
Michaelis, Clifford C.	Bountiful City Light and Power Bountiful, Utah	15	E-91	E-464
Moody, Tom	Grand Canyon River Guides	10	E-70	E-462
Onstad, David	Arizona Power Authority Phoenix, Arizona	9	E-68	E-462
Romney, Wm. Kent	Page Electric Utility Page, Arizona	27	E-281	E-496
Sheldon, George	Plains Electric Generation and Transmission Cooperative, Inc. Albuquerque, New Mexico	7	E-57	E-461
Shields, John W.	State Engineer's Office The State of Wyoming Cheyenne, Wyoming	18	E-97	E-464
Sweeney, James R.	Electrical District No. 4, Pinal County Eloy, Arizona	40	E-455	E-524
Tenney, Q.L.	Electrical District No. 3 Stanfield, Arizona	34	E-337	E-496
Woehlecke, William D.	Electrical District No. 5, Pinal County Red Rock, Arizona	37	E-447	E-523

TABLE E.2 Index of Organizations Represented by Commenters

Organization	Commenter	Document Number	Comments	Responses
Ak-Chin Indian Community Tempe, Arizona	Leonard S. Gold	39	E-453	E-524

Arizona Municipal Power Users' Association Phoenix, Arizona	Michael A. Curtis	23	E-111	E-467
Arizona Power Authority Phoenix, Arizona	David Onstad	9	E-68	E-462
Arizona State Clearinghouse Phoenix, Arizona	Manager	20	E-105	E-467
Bountiful City Light and Power Bountiful, Utah	Clifford C. Michaelis	15	E-91	E-464
Bridger Valley Electric Association Mountain View, Wyoming	Danny F. Eyre	26	E-279	E-496
City of Truth or Consequences Truth or Consequences, New Mexico	Gene E. Hoskinson	13	E-87	E-463
Colorado River Energy Distributors Association (CREDA) Salt Lake City, Utah	Clifford Barrett	6 24	E-49 E-113	E-460 E-468
CREDA and Irrigation & Electrical District Association of Arizona Phoenix, Arizona	Robert S. Lynch	11	E-78, 83	E-462
Dixie - Escalante Rural Electric Association, Inc. Beryl, Utah	R. Leon Bowler	36	E-445	E-523
Electrical District #7 of the County of Maricopa and the State of Arizona Waddell, Arizona	R.D. Justice	33	E-335	E-519
Electrical District No. 3 Stanfield, Arizona	Q.L. Tenney	34	E-337	E-496
Electrical District No. 4, Pinal County Eloy, Arizona	James R. Sweeney	40	E-455	E-524
Electrical District No. 5, Pinal County Red Rock, Arizona	William D. Woehlecke	37	E-447	E-523
Garkane Power Association, Inc. Richfield, Utah	Carl R. Albrecht	32	E-333	E-519
Governor's Office of Planning and Budget, State of Utah Salt Lake City, Utah	Brad T. Barber	3	E-27	E-460
Grand Canyon River Guides	Tom Moody	10	E-70	E-462
Grand Canyon Trust Flagstaff, Arizona	T.C. Jensen	35	E-339	E-520
Intermountain Consumer Power Association Sandy, Utah	Carolyn S. McNeil	16	E-93	E-464
International Boundary and Water Commission, United States and Mexico El Paso, Texas	Conrad G. Keyes, Jr.	8	E-63	E-462
Irrigation & Electrical Districts Association of Arizona Phoenix, Arizona	Robert S. Lynch	11 12	E-78 E-83	E-462 E-463
Lehi City Corporation Lehi, Utah	William L. Gibbs	29	E-285	E-496
Maricopa Water District Waddell, Arizona	Joe A. Falbo	22	E-109	E-467
Mt. Pleasant City Corporation Mt. Pleasant, Utah	Chesley R. Christensen	17	E-95	E-464
Murray City Power Department Murray, Utah	Gary O. Merrill	14	E-89	E-463
National Park Service Washington, D.C.	Denis P. Galvin	31	E-309	E-498
Page Electric Utility Page, Arizona	Wm. Kent Romney	27	E-281	E-496
Plains Electric Generation and Transmission Cooperative, Inc. Albuquerque, New Mexico	David Highers George Sheldon	7 25	E-277 E-57	E-461 E-495
Platte River Power Authority Fort Collins, Colorado	John Allum	4	E-37	E-460
Public Service Commission The State of Wyoming Cheyenne, Wyoming	Jon F. Jacquot	19	E-101	E-466

Roosevelt Irrigation District Buckeye, Arizona	Stanley H. Ashby	41	E-457	E-524
Safford, City of Safford, Arizona	Thomas Kip Bingham	38	E-449	E-523
Salt River Project Phoenix, Arizona	Leslie James	30	E-287	E-497
Strawberry Electric Service District Payson, Utah	Gary A. Aitken	28	E-283	E-496
Tri-State Generation and Transmission Association, Inc. Denver, Colorado	Peter C. Knutson	21	E-107	E-467
U.S. Department of the Interior National Park Service Washington, D.C.	Denis P. Galvin	31	E-309	E-498
Utah Governor's Office of Planning and Budget	Brad T. Barber	3	E-27	E-460
Utah Municipal Power Agency Spanish Fork, Utah	Dick Lucy	5	E-48	E-460
Wyoming Public Service Commission Cheyenne, Wyoming	Jon F. Jacquot	19	E-101	E-466
Wyoming State Engineer's Office Cheyenne, Wyoming	John W. Shields	18	E-97	E-464

E.3.1 Identification of a Preferred Alternative

Comment Summary: Many commenters expressed concern that Western did not identify a preferred commitment-level alternative in the EIS. Most of these commenters were Western customers and recommended that Western select commitment-level alternative 1, a high-capacity, high-energy alternative. These commenters thought that such an alternative would enable customers to maintain needed flexibility. One commenter suggested that first an operational scenario be chosen that protected downstream natural environments, and then a corresponding commitment-level alternative be chosen. Another commenter questioned whether the electrical purchases that would be required to meet a high commitment level would exceed Western's legal authority.

Response: Since publication of the draft EIS, Western has identified commitment-level alternative 1 as the preferred alternative and has indicated this choice where appropriate throughout the EIS. This alternative has also been incorporated into Western's proposal to implement replacement capacity requirements of the Grand Canyon Protection Act. The suggestion that an operational scenario be chosen first appears to be based on the assumption that such a selection would drive the choice of a commitment level. However, hydropower operations are only weakly linked to commitment levels. This weak relationship allows a decoupling of the selection of a commitment level and establishment of hydropower operations at Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit. Any capacity or energy lost through reduction in hydropower production could be regained through purchases from utilities, although this reduction in hydropower generation could have economic effects. In the Record of Decision for the EIS, Western will select a commitment level to achieve a balanced mix of purposes, including the fewest associated environmental impacts practicable. Western will also choose hydropower operational scenarios that are protective of downstream resources. Western has determined that all alternatives evaluated in the EIS, including the preferred alternative, are lawful.

E.3.3 Use of the Glen Canyon Dam EIS and other Studies

Comment Summary: There was some concern that the EIS relied too heavily on the work of others that some commenters considered inconclusive or scientifically unsound, including the *Glen Canyon Dam Operations EIS*, U.S. Fish and Wildlife Service biological opinions, and other studies.

Response: The EIS drew upon a number of sources for information, including both work done by others and research done specifically for the EIS. In all cases, the best available data were used. For the effects below Glen Canyon Dam, Western did not conduct any of its own research, but instead relied on the Glen Canyon Dam Environmental Studies and the Glen Canyon Dam EIS. These studies provide the most comprehensive information available for this facility. Because less information was available for the areas below Flaming Gorge Dam and in the vicinity of the Aspinall Unit, Western conducted research in these areas for the EIS. While the impact projections presented in the EIS have some underlying uncertainties, they represent our best understanding of the consequences of the hydropower operational scenarios evaluated. Where uncertainties exist, they are clearly stated in the EIS.

E.3.4 Geographic Scale of the Socioeconomic Analysis

Comment Summary: A number of commenters were concerned that the geographic scale of analysis, which showed only minor economic effects at the subregional level, masked real and significant potential impacts on the local level.

Response: The EIS utilized a regional scale of analysis for a number of reasons. The scale has overall benefit to policy makers, but, more importantly, the fact that the regional impacts of changes in retail electricity rates would be small is not a result of the scale of analysis. There are four reasons why changes in Western customer rates do not have significant regional impacts (1) the insignificance of Western sales compared to total power sales in each subregion, (2) the composition of sales by customer class by Western customer utilities, (3) the relative unimportance of electricity costs for industrial and commercial activity, as well as a part of residential consumption of goods, and (4) the size of the economy in which Western's power is sold. Additional analysis examining the effects of each alternative at the local level has been added to Section 4.1.1.4 for the two counties with high reliance on Western power. Even for these extreme cases, impacts on retail rates would be slight.

E.3.5 Consideration of the Impacts of Capacity Replacement in the EIS

Comment Summary: A number of comments dealt with the impacts of replacing power that would no longer be available to Western's customers under some scenarios. Particular concern was raised with regard to replacing generating capacity at Glen Canyon Dam. The loss of hydropower capacity under many alternatives would require Western's customers to replace that capacity through construction of new capacity or increased purchases. Commenters noted a lack of specificity in the consideration of potential environmental effects from these activities, including the potential irreversible commitments of fossil fuel.

Response: Although Western has more hydropower capacity than would be marketed on a long-term firm basis under each of the alternatives, replacement of lost capacity is a valid concern. Even though much of the affected area currently has excess capacity, some Western customers may eventually need to replace power marketed on a firm basis. Customers that need to replace lost hydropower capacity may either construct new capacity or purchase power derived from other sources by Western. A technical memorandum by Veselka et al. (1994) discusses Western's need to augment SLCA/IP resources, and Western is currently investigating ways to replace lost Glen Canyon Dam capacity.

Because the secondary economic impacts of the construction of new capacity would offset to some extent changes in retail electricity rates, estimates of overall regional impacts included in the EIS are somewhat conservative. As noted in the EIS, the construction or purchase of replacement capacity would have environmental effects. The extent of those effects, including the potential commitment of fossil fuel, cannot be measured until specific replacement plans have been formulated. Any new construction would require a separate environmental review.

E.3.6 Demand Side Management and Conservation and Renewable Energy

Comment Summary: The discussion of demand side management (DSM) and conservation and renewable energy programs were topics of comment. One commenter suggested that the use of generic DSM-related costs be avoided since this would lead to the underestimation of DSM impacts. The use of identical DSM options for all alternatives was also questioned. The lack of emphasis on conservation as a means for addressing lost production capacity was questioned, as was the absence of a discussion of non-price-induced conservation programs.

Response: Because DSM programs in place at various utilities are not uniform, the analyses presented in the EIS reduced the significance of the impacts of DSM programs on utility capacity expansion and thus results in conservative estimates of the impacts of each alternative. DSM analysis showed that each alternative and operational scenario had very little impact on DSM programs and, therefore, on hourly loads. Language has been added to the EIS including conservation as a means of addressing lost capacity. This topic is considered in more detail in Western's EPAMP EIS. Non-price-induced conservation programs were not considered because of lack of information on their nature and their applicability to Western customer utilities.

E.3.7 Inclusion of Nonuse Values in the EIS

Comment Summary: The validity of attempting to assign nonuse values to natural resources and particularly the use of the contingent valuation method was challenged on the basis that the method is too subjective to produce meaningful results. One commenter felt that while nonuse values were significant, they had been undervalued for recreation.

Response: While it is true that the use of nonuse valuation in economic analyses is still somewhat controversial, the studies from which data were used for the EIS have undergone peer review and were found to be of high quality. No attempt has been made to estimate the magnitude of the effects of changes in nonuse values, but a reasonable lower bound on nonuse values based on completed studies has been suggested.

E.3.8 Air Emissions Inventory and Projections

Comment Summary: It was noted that contrary to statements in the EIS, the data presented on air resources actually indicate large changes in air pollutant emissions that are related to the different commitment-level alternative/supply option cases. The assertion that reduced flow fluctuation would decrease air pollution was questioned, although it was pointed out that decreasing trends in SO2 and TSP emissions were observed in the data presented in Appendix B as flow fluctuation is reduced. Comments on the air resources technical memorandum suggested that outdated emissions data may have been used for the analysis of air quality and visibility.

Response: The EIS was revised to reflect the absolute change in air pollutant emissions related to the commitment-level alternative/supply option cases. These differences in air pollutant emissions are not expected to result in significant regional air quality impacts, because of the large area over which increased emissions would be released. Section 4.2.2 was revised to show more clearly how reduced flow fluctuation would result in lowered emissions. The emissions data used in the analysis were the most current data available at the time the EIS was prepared. Even with updated emissions data, the results should be within the same order of magnitude as those presented in the EIS.

E.3.9 Size of the Affected Environment for Flaming Gorge Dam

Comment Summary: One commenter felt that the affected environment for Flaming Gorge Dam should be extended to include the Green River between Jensen and Ouray, Utah, because this reach of the river is particularly important to endangered fish.

Response: Jensen was selected as the downstream limit of the affected area on the Green River, because the U.S. Fish and Wildlife Service Biological Opinion for Flaming Gorge Dam considers flow compliance at Jensen as protective of downstream habitat. Thus, hydropower operations that complied with the biological opinion would not affect endangered fish below Jensen. By definition, these areas would not be part of the affected environment.

E.3.10 Inclusion of Hydropower Operational Scenarios with Flows Exceeding Maximum Operating Capacity

Comment Summary: One commenter requested that the EIS consider a hydropower operational scenario for Flaming Gorge Dam that featured flows in excess of operating capacity (i.e., 4,700 cfs). Such high flows could be used to manage sediment along the Green River and would benefit relict riparian communities, especially cottonwoods, that depended on these high flows for regeneration.

Response: Inclusion of such a hydropower operational scenario would not be appropriate because such releases are outside of Western's control. The EIS does not examine all effects of dam operations because not all of these effects are attributable to hydropower operations. Text has been added to the EIS to clarify the scope of the EIS. Occasional high flows have been added to the list of potential mitigation measures in Section 4.4 of the EIS.

E.3.11 Understatement of the Benefits of Fluctuating Flows on Aquatic Resources

Comment Summary: Several comments were made that the assessments for impacts to aquatic ecological resources understated or ignored the benefits of fluctuating flows. Included in these comments were statements that cold water had the largest adverse effect on endangered fish and that fluctuating flows increased the availability of food (particularly cladophora) and inhibited competition and predation from non-native fish species.

Response: The EIS acknowledges that hydropower operation (i.e., fluctuating flows) is not the sole factor affecting aquatic habitat and discusses a number of other factors, including cold water temperatures. As discussed in Appendix D, it is unclear what effect steady flows would have on non-native fish and, in turn, what effect these species would have on endangered species. The impact assessments in the EIS reflects this uncertainty. Despite the fact that fluctuating flows could increase the amount of cladophora in the drift, which serves as food for trout, the adverse effect that these fluctuations have on cladophora production would tend to reduce overall productivity of the aquatic food base. Thus, the effects of fluctuations on this aspect of aquatic ecology would be considered adverse.

E.3.12 Understatement of the Benefits of the Seasonally Adjusted Steady Flow Operational Scenario to Ecological Resources below Flaming Gorge Dam

Comment Summary: Several comments stated that the assessments in the EIS consistently understated the benefits of a steady flow operational scenario. Specifically mentioned were benefits to endangered fish species and trout that could result from elimination of daily fluctuations and benefits to riparian vegetation and wildlife that would result from the seasonal adjustment to a more natural flow regime.

Response: No empirical data are available for the seasonally adjusted steady flow scenario at Flaming Gorge Dam. The impact assessments presented in the EIS represent the professional judgment of the EIS authors based on a thorough review of the available information including information collected specifically for this EIS. Factors other than hydropower operations affect downstream resources, and although reducing hourly fluctuations would result in some benefit, it is unlikely that large benefits to ecological resources would be possible. Other dam-related effects, such as reduction in sediment load and water temperature, have a greater effect on water quality than do fluctuations. Even with fluctuations eliminated, these alterations would continue to adversely affect aquatic ecology. Although establishment of a more natural flow regime in the Green River could result in benefits to some terrestrial resources, such benefits would only result with reinstatement of periodic floods well above power plant capacity (e.g., 7,000 cfs). Such large releases would be necessary to redistribute sediments, renew beaches, and maintain elevated riparian vegetation. The spring peak of the seasonally adjusted steady flow scenario (4,700 cfs) would be far less than the annual spring floods that occurred before construction of the dam and would probably not provide substantial benefit to these resources.

E.4 COMMENT DOCUMENTS

NOT AVAILIABLE

E.5 RESPONSES TO COMMENTS

Responses to Norman Chatfield, St. George, Utah (Comment Document 1)

Response 1-1: The CRSP dams were built for the provision of water and electrical power to the arid West. However, they are also intended to do this in a manner that is compatible with environmental values. Western and Reclamation must make decisions regarding marketing and power plant operations that strike the appropriate balance between economic development and environmental preservation.

Response 1-2: Over the past 20 years, few changes in the shoreline have occurred along the Colorado River between the dam and Lees Ferry and downstream of the Paria River. This stability is due to the fact that the dam has effectively removed sediment input from the reach to Lees Ferry, and the clear water discharged from the reservoir has removed most of the fine grain sediment immediately below the dam. Downstream of the Paria River, sufficient sediment enters the system from that river and from the Little Colorado River to make changes to the shoreline small. Between Lees Ferry and the Paria River, dam operations have an impact on the shoreline. Higher levels of fluctuations enhance erosion and promote changes to the shoreline; more steady flows have reduced erosion rates. Because of variable water years and dam release schedules, long-term effects of dam operations, while occurring, may be difficult to discern without detailed studies.

Response 1-3: Comment noted.

Responses to Vaughn H. Duffin, St. George, Utah (Comment Document 2)

Response 2-1: Comment noted.

Response 2-2: Full analysis of the baseline economic impacts of recreation below the Flaming Gorge and Aspinall dams is undertaken in the EIS. Because no changes in use rates are predicted to occur with any of the alternatives, they would have no impact on the recreational economy in the area. This conclusion is fully discussed in the EIS and in supporting documentation.

Response 2-3: In preparing the EIS, we attempted to avoid jargon and instead to use simple language to make the document as readable as possible. However, many of the issues associated with this EIS are particularly complex and difficult to understand regardless of the language used. For this reason, summary tables that clearly present the results of the various analyses are provided throughout the text.

Response to Brad T. Barber, Utah State Planning Coordinator, Salt Lake City, Utah (Comment Document 3)

Response 3-1: Comment noted.

Responses to John Allum, Platte River Power Authority, Fort Collins, Colorado (Comment Document 4)

Response 4-1: Western received written comments from this organization (see responses 24-1 to 24-175).

Response 4-2: When the EIS was prepared, information was gathered from a large number of sources, including federal and state agencies responsible for management of affected resources, scientists working in affected areas, published and unpublished scientific literature, existing NEPA documents, and original field data collected specifically for the EIS. With regard to the assessment of the impacts of Glen Canyon Dam, Western did no research of its own but instead relied on the findings presented in the Glen Canyon Dam EIS. Those findings were based on extensive long-term research of that system. While it is true that the impact projections have some underlying uncertainties, the assessments presented in Western's Power Marketing EIS represent our best understanding of the consequences of the hydropower operational scenarios evaluated. In many sections of the EIS, these uncertainties are clearly stated and used to qualify impact projections. Ongoing and planned studies should permit refinement of dam operations to maximize benefit to environmental resources.

Response 4-3: Comment noted.

Response 4-4: Western has identified commitment-level alternative 1 as the preferred alternative. Moreover, this alternative is incorporated into Western's proposal to implement the replacement capacity requirements of the Grand Canyon Protection Act.

Response to Dick Lucy, Manager of Power Operations, Utah Municipal Power Agency, Spanish Fork, Utah (Comment Document 5)

Response 5-1: See response 4-2.

Responses to Cliff Barrett, Executive Director, Colorado River Energy Distributors Association, Salt Lake City, Utah (Comment Document 6)

Response 6-1: Western received written comments from this organization (see responses 24-1 to 24-175).

Response 6-2: See response 4-2.

Response 6-3: Comment noted.

Response 6-4: See response 4-4.

Response 6-5: Western received written comments from this organization (see responses 24-1 to 24-175).

Response 6-6: See response 4-2.

Response 6-7: Although hydropower operations appear to be only weakly linked to commitment levels, it is ultimately through the hydropower operations employed that downstream national resources are affected. For this reason, a direct examination of these operational effects was considered the most appropriate approach to an examination of potential environmental effects. In addition, Western wishes to comply with the court order issued by Federal Judge Greene that requires Western's EIS to examine the environmental impacts of its marketing criteria; the impacts of its marketing criteria on dam operations; and the impacts of dam operations on environmental resources, including endangered fish species.

Response 6-8: See response 6-4.

Responses to George Sheldon, Plains Electric Generation and Transmission Cooperative, Inc., Albuquerque, New Mexico (Comment Document 7)

Response 7-1: Western received written comments from this organization (see responses 25-1 to 25-3).

Response 7-2: See response 4-2.

Response 7-3: Although hydropower operations appear to be only weakly linked to commitment levels, it is ultimately through the hydropower operations employed that downstream natural resources are affected. For this reason, a direct examination of these operational effects was considered the most appropriate approach to an examination of potential environmental impacts.

Response 7-4: Western has identified commitment-level alternative 1 as the preferred alternative. Moreover, this alternative is incorporated into Western's proposal to implement the replacement capacity requirements of the Grand Canyon Protection Act.

Response to Conrad G. Keyes, Jr., Principal Engineer, Planning, International Boundary and Water Commission, El Paso, Texas (Comment Document 8)

Response 8-1: Western will begin consultation with the U.S. International Boundary and Water Commission and, in cooperation with the Bureau of Reclamation, continue to comply with existing laws and obligations to the government of Mexico.

Responses to David Onstad, Administrator, Arizona Power Authority, Phoenix, Arizona (Comment Document 9)

Response 9-1: Western received written comments from this organization (see responses 24-1 to 24-175).

Response 9-2: See response 4-2.

Response 9-3 Comment noted.

Response 9-4: See response 4-4.

Responses to Tom Moody, Grand Canyon River Guides (Comment Document 10)

Response 10-1: Comment noted.

Response 10-2: Western's commitment of electrical power is not entirely analogous to the commitment of Colorado River Basin water under various water compacts. Western's commitment of electrical power under long-term firm contract is made up of power from hydroelectric power plants and purchases from other utilities. Although the water in the Colorado River is in limited supply, electrical power is not.

Responses to Bob Lynch, CREDA, and Irrigation & Electrical Districts Association of Arizona, Phoenix, Arizona (Comment Document 11)

Response 11-1: Western received written comments from this organization (see responses 12-1 to 12-4 and 24-1 to 24-175).

Response 11-2: See response 4-2.

Response 11-3 Comment noted.

Response 11-4: Western is interested in providing flexibility to its customers. Currently, as a response to operational constraints at most of the SLCA/IP power plants, Western is engaged in discussions with its customers about the possibility of Western's making purchases on the customers' behalf. Through this public process, Western is attempting to increase flexibility for its customers.

Response 11-5: Western and its customers must rely less on hydroelectric capacity than has been the case in the past. In the last few years, constraints on the operations of the SLCA/IP power plants have reduced dependable firm capacity.

Responses to Robert Lynch, Assistant Secretary/Treasurer, Irrigation & Electrical Districts Association of Arizona, Phoenix, Arizona (Comment Document 12)

Response 12-1: Comment noted.

Response 12-2: Western's preferred alternative, commitment-level alternative 1, is a "high capacity, high energy" alternative, in large part for the reasons articulated by the commenter.

Response 12-3: The EIS discusses the effects of water temperature on humpback chub in the Colorado River below Glen Canyon Dam. The EIS acknowledges the role of water temperature in expanding the range of the humpback chub in the main stem of the Colorado River and discusses the importance of water temperatures to humpback chub reproduction and distribution in the main stem of the river. The impact analysis presented in the EIS takes into account these effects. Issues related to modifications of the dam, such as the addition of multilevel intake structures and temperature curtains, are outside the scope of the EIS.

Response 12-4: The analyses and conclusions presented in the EIS are based on the latest information and evaluations available and include consideration of the effects of cold water temperatures on the potential benefits of each operational scenario. A review and revision based on the June 17 memorandum from the Bureau of Reclamation to the U.S. Fish and Wildlife Service is not warranted.

Response to Gene E. Hoskinson, Joint Utility Director, City of Truth or Consequences, New Mexico (Comment Document 13)

Response 13-1: See response 4-4.

Responses to Gary O. Merrill, Assistant General Manager, Murray City Power Department, Murray, Utah (Comment Document 14)

Response 14-1: Comment noted.

Response 14-2: See response 4-2.

Response 14-3: See response 4-4.

Responses to Clifford C. Michaelis, Director, Bountiful City Light and Power, Bountiful, Utah (Comment Document 15)

Response 15-1: Comment noted.

Response 15-2: See response 4-2.

Response 15-3: See response 4-4.

Responses to Carolyn S. McNeil, General Manager, Intermountain Consumer Power Association, Sandy, Utah (Comment Document 16)

Response 16-1: Comment noted.

Response 16-2: See response 4-2.

Response 16-3: See response 4-4.

Responses to Chesley R. Christensen, Mayor and ICPA Representative, Mt. Pleasant City Corporation, Mt. Pleasant, Utah (Comment Document 17)

Response 17-1: Comment noted.

Response 17-2: See response 4-2.

Response 17-3: See response 4-4.

Responses to John Shields, Interstate Streams Engineer, Wyoming State Engineer's Office, Cheyenne, Wyoming (Comment Document 18)

Response 18-1: See response 4-4.

Response 18-2: The modifiers "slight," "moderate," and "large" were used to qualify adverse impacts and benefits to present the reader with some idea of the importance of the projected impacts. Text has been added to the EIS describing how these terms were used. There is no numerical cutoff between these levels of impacts because they represent relative rather than absolute levels of impacts and would vary from resource to resource. In Chapter 4, text that describes the types of impacts that would occur accompanies statements of relative impact levels. Wherever possible, actual predicted changes in a resource are presented as well (see, for instance, projected changes in riparian coverage in Table 4.24). Only in summary tables, such as in Section S.8 and 2.3.4, are relative impact projections not accompanied by explanatory text.

Response 18-3: Although hydropower operations appear to be only weakly linked to commitment levels, it is ultimately through the hydropower operations employed that downstream natural resources are affected. For this reason, a direct examination of these operational effects was considered the most appropriate approach to an examination of potential environmental impacts. It is incorrect to state that little effort was expended in quantifying socioeconomic impacts. Socioeconomic impacts were examined thoroughly, and the results of socioeconomic analyses are summarized in the EIS. More extensive details on the approach and findings are presented in the supporting technical memorandums that were produced for the EIS and are referenced therein.

Response 18-4: Although the results of the regional analysis indicate that the impact of changes in retail electricity rates from each alternative would be small, this situation is not because of the geographic scale at which the analysis was undertaken. Four factors determine the magnitude of the impact of each alternative in each subregion: (1) the importance of Western power in each subregion (reliance of Western customers on Western power and the size of power sales by Western customer utilities compared with power sales by all utilities), (2) the composition of sales by customer class by Western customer utilities, (3) the importance of electricity as a factor input to regional industrial and commercial activity and as a part of the "basket of goods" consumed by residential customers, and (4) the size of the economy of the area in which Western power is sold. The relative importance of each of these factors in each subregion is discussed in detail in the supporting technical documentation (Allison and Griffes 1995). Because each of the 195 counties constituting the 9 subregions used in the analysis receives power from Western, aggregating the effects of each alternative and supply option at the county level (where impacts on individual utility service districts could be measured) to the subregional level averages the impact of each alternative and supply option across all utilities in each of the subregions. Aggregation to the subregional level does not, therefore, have the effect of minimizing the impact of each alternative and supply option. This would be the case, for example, if the analysis were to measure the impacts of each alternative and supply option in a subregion containing a large number of counties, only one of which contained a utility receiving Western power. The impact of each alternative at the regional rather than at the individual utility level is presented in the EIS to facilitate decision making. In order to examine the impacts of each alternative and supply option at the local level for an extreme case, however, additional analysis was undertaken for two counties containing Western customer utilities with high reliance on Western power and also experiencing larger retail rate increases as a result of the alternatives and supply options. The analysis found impacts on the local economy of each county to be only of minor significance. The results are presented in Section 4.1.1.4, with additional discussion of the analysis found in Allison and Griffes (1995).

Because it is clear that many of the counties receiving Western power have only a small number of different economic activities, the EIS also considers the impact of changing rates on irrigated agriculture, which is a significant user of electricity for water pumping. The analysis of agricultural impacts considered the effects of changes in rates on agricultural revenues, both at the state level and for counties where the local utility relied heavily on Western power and where agriculture was a significant contributor to local income. Changes in revenues from seven crops were found to be small at the state level, with revenues at the county level decreasing by more than 5% for only one crop in two of the counties analyzed. The results of the analysis are presented in Section 4.1.1.4.2, with additional discussion found in the supporting technical documentation (Edwards et al. 1995).

Response 18-5: Although production decisions made at the level of the individual farm vary according to local physical and economic conditions, the analysis of the impact of changes in electricity rates requires the use of models that allow evaluations at a more general level. These models are based on a number of key assumptions without which it would not be possible to predict the behavior of the agriculture sector over different time horizons. Once these assumptions are made, the models produce results that allow policymakers to base their decisions on an overall understanding of how farmers as a whole respond to changes in the farm economy. A crucial assumption is that farmers will search for combinations of inputs and farming techniques, such as dryland agriculture, that will maximize profits in the long term, usually assumed to be a period of five or more years. In the long term, farmers may switch to dryland agriculture with a change in the cost of certain factor inputs, such as electricity. In the short term, however, farmers do not have the ability to make this switch, and most farmers will have to suffer losses as a result. The impact of different responses to changing conditions over different time horizons was an important part of the modeling done for the EIS.

Response 18-6: See response 4-2.

Response to Jon F. Jacquot, Engineering Supervisor, Public Service Commission,Cheyenne, Wyoming (Comment Document 19)

Response 19-1: The impacts to socioeconomics and natural resources of various commitment-level alternatives are evaluated and presented in the EIS. Included is an evaluation of the impacts of replacing capacity lost as a result of changes in hydropower operations. The preferred alternative is identified in Chapter 2 of the EIS.

Response to Manager, Arizona State Clearing House, Phoenix, Arizona (Comment Document 20)

Response 20-1: Comment noted.

Responses to Frank R. Knutson, General Manager, Tri-State Generation and Transmission Association, Inc., Denver, Colorado (Comment Document 21)

Response 21-1: Comment noted.

Response 21-2: See response 4-4.

Response 21-3: In preparing the EIS, we gathered information from a large number of sources, including federal and state agencies responsible for management of affected resources, scientists working in affected areas, published and unpublished scientific literature, existing NEPA documents, and original field data collected specifically for the EIS. Much of the information regarding the effects of Glen Canyon Dam was derived from the Glen Canyon Dam EIS; Western did not conduct its own research of that facility.

Responses to Joe A. Falbo, General Manager, Maricopa Water District, Waddell, Arizona (Comment Document 22)

Response 22-1: Comment noted.

Response 22-2: See response 4-4.

Responses to Michael A. Curtis, Executive Secretary, Arizona Municipal Power Users' Association, Phoenix, Arizona (Comment Document 23)

Response 23-1: See response 4-4.

Response 23-2: One of the goals of the EIS is to identify all of the potential impacts of the commitment-level alternatives and operational scenarios. There is sufficient theoretical justification and consensus among economists with respect to the validity of the concept of nonuse values to assume that nonuse values might be affected by one or more of the operational scenarios. However, there has been no attempt to estimate the actual magnitude of such effects (i.e., changes in nonuse values) within the EIS. Rather, data from previous studies have been used to present what those studies suggest constitutes a reasonable lower bound on the nonuse values associated with the resource. While there is also some debate over the strengths and weaknesses of the contingent valuation method, it is also recognized as the only means of developing estimates of nonuse values at this time. In summary, the discussion of nonuse values and the corresponding estimates of their potential magnitude presented in the EIS are considered useful and are therefore retained.

Response 23-3: Comment noted.

Response 23-4: Although hydropower operations appear to be only weakly linked to commitment levels, it is ultimately through the hydropower operations employed that downstream natural resources are affected. For this reason, a direct examination of these operational effects was considered the most appropriate approach to an examination of potential environmental effects. In preparing the EIS, we gathered information from numerous sources, including federal and state agencies responsible for management of affected resources, scientists working in affected areas, published and unpublished scientific literature, existing NEPA documents, and original field data collected specifically for the EIS. Western did no research of its own in assessing the impacts of Glen Canyon Dam but instead relied on the findings presented in the Glen Canyon Dam EIS. Those findings were based on extensive long-term research of that system. While it is true that the impact projections have some underlying uncertainties, the assessments presented in Western's Power Marketing EIS represent our best understanding of the consequences of the hydropower operational scenarios evaluated. The EIS acknowledges that nonoperational effects, such as temperature and sediment reduction, have had large impacts on natural resources. The assessments of hydropower effects presented in the EIS take these impacts into account.

Responses to Clifford Barrett, Executive Director, Colorado River Energy

Distributors Association, Salt Lake City, Utah (Comment Document 24)

The comment letter from Clifford Barrett of the Colorado River Energy Distributors Association (CREDA) included a number of attachments containing comments of documents other than the Power Marketing EIS. While all of the comments were considered in the drafting of the final EIS, only those attachments that commented directly on documents produced for this EIS have been answered in detail (see responses 24-3 and 24-4). As a result, only some of the attachments have been divided into individual comments for a specific response.

Response 24-1: Comment noted.

Response 24-2: Although hydropower operations appear to be only weakly linked to commitment levels, it is ultimately through the hydropower operations employed that downstream natural resources are affected. For this reason, a direct examination of these operational effects was considered the most appropriate approach to an examination of potential environmental effects. In preparing the EIS, we gathered information from numerous sources, including federal and state agencies responsible for management of affected resources, scientists working in affected areas, published and unpublished scientific literature, existing NEPA documents, and original field data collected specifically for the EIS. Western did no research of its own in assessing the impacts of Glen Canyon Dam but instead relied on the findings presented in the Glen Canyon Dam EIS. Those findings were based on extensive long-term research of that system. While it is true that the impact projections have some underlying uncertainties, the assessments presented in Western's Power Marketing EIS represent our best understanding of the consequences of the hydropower operational scenarios evaluated.

Response 24-3: The documents referenced in the comment are not part of the EIS and were not written by authors of the EIS. It would, therefore, be inappropriate to respond here to specific comments concerning those documents. However, these comments have been considered in revising the EIS.

Response 24-4: See responses 24-6 to 24-140 regarding Attachment 6 and responses 24-141 to 24-175 regarding Attachment 7. Attachment 8 presents general comments on the use of nonuse values in socioeconomic analyses. These general comments have been noted and taken into consideration as appropriate in revising the EIS.

Response 24-5: See response 4-4.

Response 24-6: We agree that operational scenarios differ in their environmental impacts and that losses in hydropower operational capacity would result in a need for additional generating capacity. Measures to provide that additional capacity could, in turn, have environmental impacts on other resources or attributes. We disagree, however, that the commitment level chosen by Western will not have an environmental impact. Impacts have been identified to a wide variety of environmental resources or attributes and are discussed in the EIS. The comment appears to be based on an assumption that the magnitude of environmental impact is directly related to the amount of generation capacity as determined by demand. That assumption ignores the importance of the location of generation facilities and the technology used to meet capacity needs in determining impact magnitude.

Response 24-7: Specific responses are provided to the detailed comments presented in Attachment 7. See responses 24-141 through 24-175. Although hydropower operations appear to be only weakly linked to commitment levels, it is ultimately through the hydropower operations employed that downstream natural resources are affected. For this reason, a direct examination of these operational effects was considered the most appropriate approach to an examination of potential environmental impacts. The results of this assessment will be valuable in establishing operational regimes that are protective of natural resources downstream of those hydroelectric facilities that provide much of the power marketed by Western.

Response 24-8: Comment noted.

Response 24-9: See response 6-7.

Response 24-10: A study was conducted to determine the relationship between Western's power-marketing program and hydropower operations. This study determined that the relationship between hydropower operations and long-term firm commitments for capacity and energy was weak. Regardless of the relationship between commitment-level alternatives and hydropower operations, it is ultimately through the hydropower operations employed that downstream natural resources are affected. A direct examination of these operational effects was considered the most appropriate approach to an examination of potential environmental effects.

Response 24-11: Section 2.3.4.1, including Table 2.6, provides a summary of the impacts of hydropower operational scenarios at the three facilities under consideration in the EIS. That section refers to the more detailed discussion of impacts, with supporting references, provided in Section 4.2 of the EIS.

Response 24-12: Western did no research of its own to assess the impacts of Glen Canyon Dam operations, but relied instead on the findings presented in the Glen Canyon Dam EIS. The Glen Canyon Dam EIS was based on a great deal of research and was itself subject to public review and comment. By incorporating the findings in the final Glen Canyon Dam EIS, the Power Marketing EIS incorporates the results of that public review process.

Response 24-13: See response 23-2. In addition, as is indicated in Section 3.1.2 of the EIS, the estimate of the lower bound on nonuse values is not based on the HBRS, Inc., study of nonuse values for the environment below Glen Canyon Dam that is currently underway. Rather, this estimate and the estimate for the lower bound on nonuse values for the environment below Flaming Gorge Dam, are based on previous studies that were subsequently published in the open scientific literature.

Response 24-14: The text in Section 3.1.3 has been revised to show the correct reliance numbers.

Response 24-15: The descriptions of the effects of the 1983 and 1984 floods are presented to provide context for the description of the affected environment below Glen Canyon Dam. Speculation on what would occur if other flow scenarios had occurred during this period would be inappropriate.

Response 24-16: Conclusions presented in this EIS were extracted from those given in the Glen Canyon Dam EIS; separate analyses were not performed. However, as stated in the Glen Canyon Dam EIS, the Lake Mead delta is a function of water level and sediment load transported. In the short term (the time base for this Power Marketing EIS), sediment loads could be affected by dam operations, and the deltas could be affected accordingly. In the long term (50 years ? the time base for some of the Glen Canyon Dam EIS calculations), impacts to the delta could be small, as suggested.

Response 24-17: The location of Greendale, Utah, has been added to Figure 3.10.

Response 24-18: Section 3.3.2.3 has been revised to indicate that completion of the dam resulted in a lowering of the water temperature and that use of the multilevel intake at the dam increased water temperature at the Jensen gauge to values very similar to those for pre-dam conditions for the same time period.

Response 24-19: Section 3.4.1.1 has been modified to clarify the temperature values reported.

Response 24-20: It is true that the decline in carp populations downstream of Glen Canyon Dam may be attributable to loss of main channel reproduction because of cold water temperatures. Section 3.4.1.1.1 of the EIS has been modified to include this information.

Response 24-21: Although the flannelmouth sucker is rarely collected in main channel areas upstream of Nankoweap Creek during most of the year, spawning aggregations of this species occur at the mouth of the Paria River during spring and summer. The text in the EIS has been modified to clarify this point.

Response 24-22: Section 3.4.1.1.2 of the EIS has been modified to describe how low flow conditions could limit access to tributaries. The reference to fluctuating flows has been removed because the minimum flows, not the fluctuations, are responsible for limiting access to tributaries. The Maddux et al. report (1987) is cited in the EIS to support this conclusion and is based on observations made in the Grand Canyon.

Response 24-23: Text has been added to Section 3.4.1.1.3 of the EIS to explain that shifts in dominance between cladophora and oscillatoria are probably related to changes in turbidity, light penetration, and water chemistry that occur as a result of tributary inputs to the main channel of the Colorado River. Text has also been added to state that the effect of this shift in dominance on the aquatic food chain is currently unknown. A multilevel intake structure was not evaluated in this EIS, and speculation on its effect would be inappropriate.

Response 24-24: Activities in marshes and other types of wetlands are regulated by the U.S. Army Corps of Engineers under Section 404 of the Clean Water Act and Section 10 of the River and Harbors Act. Because the control of hydropower releases does not entail construction within wetlands or the discharge of dredge or fill material into wetlands, it is not in violation of these wetland protection laws, and mitigation is not required. Executive Order 11990 instructs all Federal agencies to include protection of wetlands in management plans and projects; this executive order does not establish a "no net loss" policy. To comply with the executive order, the DOE established 10 CFR 1022, which requires that a wetlands assessment be prepared for all actions that may affect wetlands. Appendix D of the EIS serves as the wetlands assessment for the actions being evaluated in this EIS.

Response 24-25: The text of Section 3.4.1.2.2 of the EIS has been modified to indicate that use of the Colorado River below Glen Canyon Dam by waterfowl has increased since construction of the dam.

Response 24-26: The commenter has correctly identified a discrepancy in the stated temperature of the water released from the dam. The temperature of released water averages 46·F, as stated in Section 3.4.1.1.

Response 24-27: The primary sources of information for those sections of the Power Marketing EIS dealing with humpback chub in the Colorado River downstream of Glen Canyon Dam were the Bureau of Reclamation Glen Canyon Dam EIS and the Glen Canyon Environmental Studies (GCES) Phase II data. This EIS includes the GCES Phase II data that were available when the EIS was finalized.

Response 24-28: Section 3.4.1.3.1 of the EIS notes that the razorback sucker may never have been very common in the reach between Glen Canyon Dam and Lake Mead, and competition with and predation by introduced fish species are mentioned as possible causes for declining numbers of razorback suckers. Section 3.4.1.3.1 of the EIS has been revised to state that 14 specimens have been collected below Glen Canyon Dam since 1979.

Response 24-29: It is not clear how the proportions identified in the comment were derived from the EIS. The referenced text provides a summary of what is known regarding native fish reproduction and identifies some of the major categories of factors, including hydropower operations, that have been suggested as causes for the decline of native fish in the Green River. No ranking of importance or recommendations for focusing recovery efforts are presented, nor could such a ranking be established on the basis of currently available information.

Response 24-30: The impacts of each of the alternatives on individual Western customer utility rates and financial viability were presented for all municipals and cooperatives in two reliance categories at the state level for the four states receiving the bulk of Western power. This approach was used under the provisions of a confidentiality agreement between individual customer utilities and ANL. The intent of that agreement was to protect data provided to ANL by individual utilities from disclosure to outside parties in any form that would allow the reconstruction of those data. Providing information in a more disaggregated form (i.e., for individual utilities or smaller groups of utilities than presented in the EIS) would have meant that data received from individual utilities would have been exposed, thus compromising the conditions set under the confidentiality agreement.

Response 24-31: See response 18-4.

Response 24-32: Section 4.1.3 of the EIS has been revised to include discussion of the potential impacts of new hydropower facilities on natural and cultural resources.

Response 24-33: The commenter is correct in the observation that impacts associated with the construction of new power generation plants could reach beyond the local environment. The EIS has been revised to include some of the regional impacts (utility corridors, transportation, and mining) identified by the commenter.

Response 24-34: The up- and down-ramping durations were set to a relatively short period of one hour so that worst-case potential impacts could be evaluated. Flows that are capable of building or maintaining beaches (e.g., discharges in excess of about 8,000 cfs at Flaming Gorge Dam during a wet year) would not affect the annual amount of water released from any given dam during a wet year. However, if flows of this magnitude were implemented during a dry or moderate year, the monthly release patterns would have to be modified to maintain the same total annual release.

Response 24-35: An evaluation of possible releases above power plant capacity at the Aspinall Unit is beyond the scope of the EIS. Such releases would be under Reclamation's jurisdiction.

Response 24-36: The impacts of each alternative on utility rates are fully discussed elsewhere in the EIS (Section 4.1.1.2) and in supporting documentation (Bodmer et al. 1995). Therefore, no need exists to extend the discussion in the Section 4.2.1.1 as suggested in the comment.

Response 24-37: Comment noted.

Response 24-38: The text in question refers to a study that was conducted as part of the Glen Canyon Environmental Studies and that was subsequently used as the basis for the recreation-related impacts below Glen Canyon Dam reported in this EIS. Adjusting the text to respond to the commenter's suggestion would amount to a revision of the assumptions employed in the study referenced in the EIS and is therefore inappropriate. Moreover, the cause of the decrease in angler days is not known at this time and could, in fact, be attributable to a number of different factors.

Response 24-39: The results of the nonuse study undertaken for the Glen Canyon EIS are used in the analysis of nonuse values in this Power Marketing EIS without an independent review of the supporting analyses. This procedure was used because the Glen Canyon study was peer-reviewed and found to be of high quality. The incorporation of nonuse valuation into an economic analysis of this nature is still somewhat controversial, however. Part of the controversy surrounds the methodology used to collect information on nonuse valuation, in particular the sample frame and questionnaire design. We do not agree, however, that the there is sufficient controversy surrounding the technique to change the EIS in the manner being suggested.

Response 24-40: The reference made to the data used to determine the use rates in Section 4.2.1.2.2 has been changed to refer to the original document rather than the support documentation for the EIS. References to analysis undertaken specifically for the EIS have not been changed, since these are stand-alone documents that describe the method that was used to derive the estimates used in the EIS.

Response 24-41: Comment noted.

Response 24-42: Conclusions regarding the short-term effects of Glen Canyon Dam hydropower operations were extracted from the Glen Canyon Dam EIS. In the short term (15 years), when the impacts of commitment-level alternatives would be relevant, fluctuating flows could affect the Lake Mead delta, with larger fluctuations producing greater impacts. Over a longer period of time, differences between scenarios would probably be undetectable, as suggested in the comment.

Response 24-43: The scope of the EIS was limited to a period of 15 years because that is the period in which the effects of commitment-level alternatives would be relevant. Speculation on the long-term impacts of dam operations and flood frequencies is beyond the scope of the EIS.

Response 24-44: A detailed discussion of the importance of sand to the Colorado River system below Glen Canyon Dam is provided in Section 3.3.1.2 of the EIS. Sand is important for building and maintaining beaches, increasing bank stability, maintaining the number and location of backwaters, and preserving channel margin bars. Sand transport also affects the dynamics of the Lake Mead delta. Text describing the importance of sand to the Colorado River system has been added to Section 4.2.3.1.2.

Response 24-45: The text of Section 4.2.3.1.2 of the EIS has been modified to indicate that the greater rate of erosion for the maximum power plant capacity operational scenario is attributed to larger fluctuations and higher ramping rates.

Response 24-46: As mentioned in the text, details on the sediment transport modeling effort for the Browns Park reach of the Green River are discussed in Appendix C and in a supporting technical memorandum by Williams et al. (1995). Briefly, these documents state that the Engelund-Hansen formulation (Engelund and Hansen 1967) was used to predict the sediment load for the affected reach on the basis of an average particle size of 0.4 mm (Andrews 1986), a water velocity obtained from a HEC-2 flow model developed for the river downstream of the dam (Yin et al. 1995), a water depth predicted by the same HEC-2 model used to define the water velocity, a bed slope of 0.0004356 obtained from a USGS 7-1/2 minute map of the Green River, and a channel cross section near Swinging Bridge in Browns Park estimated from the USGS 7-1/2 minute map. As mentioned in Appendix C, the Engelund-Hansen method was used because it requires a minimum amount of site-specific data, it has been demonstrated to give satisfactory results for similar flow systems, and it has been previously used for the Browns Park reach of the Green River (Andrews 1986). Because the dam effectively removes upstream sediment from the system, sediment load for the Browns Park reach is derived from the reach itself (material of the Browns Park alluvium and previously stored sediment from pre-dam flows). This loss of sediment from the reach is considered to be net erosion in the EIS.

Response 24-47: The text has been corrected to read that the 29-hour travel time corresponds with the 4,000-cfs flow rate, and the 51-hour travel time corresponds with the 1,000-cfs flow rate.

Response 24-48: It would not be appropriate to attribute the existing condition of the trout fishery to current hydrological conditions. The fishery has developed over a number of years and is, in part, a result of the hydrological conditions that have occurred during that period. The EIS addresses the decline in the condition of the trout fishery that has been observed since the early 1980s, well before the implementation of interim flows. The EIS further identifies several possible causes that have been suggested to explain the observed decline in the fishery.

Response 24-49: Comment noted.

Response 24-50: The assessment of potential adverse impacts to trout presented in the EIS takes into account the availability of food resources for trout. The importance of cladophora "sloughing" and drift to the diet, growth, and condition of trout is not known. Some researchers suggest that trout actively forage on drifting cladophora, while others feel that the cladophora is incidentally ingested when trout forage on insects inhabiting the cladophora. Some question also exists as to whether the cladophora found in trout is consumed as drift or represents attached algae removed from the substrate while the fish is feeding on the invertebrates inhabiting the algae. Although drift could be reduced with decreased flow fluctuations, the aquatic food base would increase under the steady flow scenarios as a result of increases in the amount of aquatic substrate available for the production of the aquatic food base. No information is available to support or refute a relationship between cladophora drift and the condition factor of trout and other fish.

Response 24-51: Trout populations could remain stable under some operational scenarios because there would be little or no increase in available spawning habitat. In the absence of additional reproductive habitat but increased food supply, the condition of individual trout may improve without appreciable increases in population size. Although management of fisheries populations may not be sufficiently refined to maximize growth rates, periodic estimation of population size, hatching success, juvenile and adult survival, fish condition, and growth rates is commonly used by fisheries managers to adjust stocking practices in order to maintain high condition factors and growth rates for a particular fishery.

For the assessment presented in the EIS, we assumed that the area of permanently submerged substrate represents the stream area capable of supporting production of the aquatic food base. Food production can be estimated as biomass per unit stream area or number of prey organisms per unit stream area. Although the absolute values of these estimates will differ, the relationship between each measure and stream area will be similar ? as available stream area increases, both biomass and number per unit area will increase. Thus, the conclusion that food production will increase with increasing minimum flows because of increasing available stream area is unaffected by the units used for estimating food production.

Section 3.4.1.1.3 of the EIS has been revised to include additional discussion about food production with increasing distances downstream. Additional text discussing the effects of fluctuating flows on food production and availability has also been added.

Response 24-52: The EIS does not offer suggestions for mitigating temperature effects. Mitigation of cold water temperatures is largely outside the scope of the EIS because it is not a hydropower issue per se, but rather is related to other impacts of dam operations that are under the control of the Bureau of Reclamation.

Response 24-53: As suggested in the comment, the response of riparian vegetation to different flow regimes is relatively complex, and steady flow scenarios are expected to result in benefits to one riparian type (upper zone) and adverse impacts to another (lower zone, including marshes). The magnitude of these benefits and adverse impacts along the Colorado River below Glen Canyon Dam was derived from the assessments presented in the Glen Canyon Dam EIS. By incorporating the findings from the latest version of the Glen Canyon Dam EIS, which was subject to public review, the Power Marketing EIS incorporates and addresses comments made on the Glen Canyon Dam EIS, including those alluded to in the comment.

The concern raised in the comment relative to long-term effects of altered flows on relict riparian vegetation is valid. However, over the period relevant to the Power Marketing EIS, it is unlikely that lowered flows would produce adverse effects to the older riparian vegetation that became established under either pre-dam conditions or historical operations. Most of this vegetation is mature and can exploit water far below the soil surface. Over the longer term, this vegetation would be replaced by species adapted to drier conditions, because drier soil conditions would not be favorable for the establishment of the seedlings of riparian species. It is unclear how much riparian habitat would exist at this new equilibrium state.

There is an energy relationship between the terrestrial and aquatic systems of the Colorado River. Although this relationship has not been quantified, it is likely that the amount of energy input from the terrestrial system is dependent on the amount of vegetation present. It is expected that as the upper riparian zone expands in response to steadier flows, the energy contribution to the aquatic system would increase.

Response 24-54: The EIS does not identify any benefits for the razorback sucker from any of the operational scenarios for Glen Canyon Dam, and the comment regarding page 4-70 discussed only the humpback chub. Only slight or moderate benefits for the humpback chub are expected under steady flow scenarios at Glen Canyon Dam. Benefits would be this low because of the cold water temperature in the river. If warmer temperatures could be achieved, the benefits of reduced flow fluctuations would probably be greater.

Response 24-55: Although Section 2.3.4 does state that the operational scenarios included scenarios similar to historical options, it is pointed out in Section 2.3.4.2 that the year-round high fluctuating flow operational scenario at Flaming Gorge Dam features slightly higher maximum flows and fluctuations than historical operations. Section 4.2.4.2.1 also states that the year-round high fluctuating flow operational scenario and the seasonally adjusted high fluctuating flow operational scenario have maximum releases that would be about 500 cfs greater than those under historical operations and that the magnitude of daily flow fluctuations would also be greater. Thus, the conclusion that slight to moderate impacts to the trout fishery could occur is warranted on the basis of these increases in fluctuation.

Response 24-56: Daily flow fluctuations could affect habitat suitability and, thus, fish energetics. The potential adverse effects of fluctuating flows on habitats of endangered fish are discussed in detail in a technical memorandum by Hlohowskyj and Hayse (1995) and in Appendix D of the EIS. Although changes in operations may not directly prevent adults from using the reach, reduced habitat quality resulting from hydropower operations could limit adult (and juvenile) growth, increase overwinter mortality, and reduce overall survival. The text has been revised to indicate that cold water temperature is the principal factor in reducing the suitability of habitat within the Canyon of Lodore, but that daily fluctuating flows resulting from peaking hydropower operations may further limit habitat quality and use by mature fish.

Response 24-57: The impacts and benefits identified in the EIS and presented in the supporting technical memorandum by Hlohowskyj and Hayse (1995) were developed with available scientific information and accepted hydrological modeling methods. Although the commenter is correct in stating that there is little apparent difference in the present and historic hydrographs of average monthly flows (as shown in Figure 3.26 of the Draft EIS), hourly and daily values, which are not shown in the figure, can differ markedly. In addition, historic operations, along with other such factors as cold water temperatures, diking, and loss of flooded bottomlands, are considered to be the factors responsible for the current status of many of the native fish in the system.

Response 24-58: Relevant U.S. Fish and Wildlife Service reports were reviewed for use in the EIS, and results were incorporated when appropriate. All conclusions in those reports were not necessarily accepted as valid. Conditions other than flow, including water temperature, are identified in the EIS as important factors that may have led to the decline of native fish in the Green River. These factors are identified in Chapters 3 and 4 of the EIS. Although the Green River above the Yampa River confluence and particularly above Flaming Gorge Reservoir may have been marginal habitat for the endangered fish even before dam construction, the Green River from the Yampa River confluence to below Jensen, Utah, currently represents the largest population center for endangered fish in the upper Colorado River Basin. The EIS discusses possible increases in the abundance of introduced fish species and potential adverse impacts that might occur with such increases.

Response 24-59: The comment is not applicable to the EIS. The EIS did not identify adverse impacts to larval drift from hydropower operations and cites the reference (Tyus and Haines 1991) as one of several that discusses factors that may affect native and endangered fish in the Green River.

Response 24-60: We agree that the relationship between backwater number or volume and river flow is not well defined. The EIS uses an empirically derived relationship between flow and backwater area as an indicator of habitat availability. The EIS evaluation also considers backwater stability as a function of daily changes in flow and stage. Details regarding the assumptions and methods used to evaluate backwater availability and stability are presented in Appendix D of the EIS. These assumptions and methods were based on the best information available at the time the EIS was prepared.

Response 24-61: Flow releases above hydropower capacity have been proposed by the U.S. Fish and Wildlife Service and by the National Park Service. Such releases have not been proposed by Western and are not one of the operational scenarios developed and evaluated in the EIS. Evaluation of the potential impacts of these proposed water releases is not Western's responsibility and is outside the scope of the EIS.

Response 24-62: While it may be true that some anglers see some benefit from the initial effects of fluctuations, the results of the attributes survey conducted by Bishop et al. (1987) indicate that anglers have a clear preference for constant flows over fluctuating flows. This observation was supported by discussions with the U.S. Forest Service concerning the preferences of anglers below Flaming Gorge Dam. The results of the attributes survey are the best available information on which to base a distinction between constant and fluctuating flows as it relates to angler preferences.

Response 24-63: In general, river flows sufficiently low to strand boats and create obstacles or sufficiently high to limit control and threaten occupant safety will adversely affect use rates. However, although minimum flows on both the Green and Colorado rivers affect the quality of a boating experience, demand for such an experience is such that use rates have not declined at minimum flows. Because use rates appear to be unaffected by change in flow within the range examined in the EIS, the goal of any modification within that range would be to increase the quality of the experience (i.e., present users with flow regimes they most prefer).

Response 24-64: Western has identified possible mitigation that Western can undertake or is in a key position to influence (as a cooperating agency in the Glen Canyon Dam EIS, for example). New hydropower facilities such as pumped storage cannot be constructed by Western.

Response 24-65: While the actions identified as mitigation in the Glen Canyon Dam EIS largely mitigate the environmental impacts of the construction of the Glen Canyon Dam, they still may be considered mitigation for the operation of the dam as well. Implementation of these mitigation actions would result in benefits to downstream natural resources. In so doing, any adverse hydropower impacts would be reduced as well.

Response 24-66: It is sometimes difficult to separate the effects of dam operations from the impacts of power plant operations at the dam. Nevertheless, Western has only proposed monitoring efforts that relate to power plant operations.

Response 24-67: The EIS correctly includes impacts from dam construction and nonhydropower operations in its assessment of cumulative impacts. The definition of cumulative impacts presented in the Council on Environmental Quality regulations (40 CFR 1508.7) includes past actions, such as dam construction, regardless of the sponsoring federal agency.

Response 24-68: Construction of electrical generating plants to replace capacity lost through water release restrictions at the SLCA/IP power plants would have natural resource impacts. While the Glen Canyon Dam EIS does not undertake an analysis of these impacts, the Power Marketing EIS does. The Power Marketing EIS does not attempt to predict the location of replacement power plants, but does analyze possible impacts of generic facilities.

Response 24-69: Section 8 of the EIS has been revised to incorporate reference to the most current version of the Biological Opinion for the operation of Glen Canyon Dam.

Response 24-70: Executive Order 11990 directs Federal agencies to minimize the destruction, loss, or degradation of wetlands and to preserve and enhance the values of wetlands in carrying out their responsibilities for managing Federal lands and facilities and conducting Federal activities and programs affecting land use, including water and related land resources planning, regulating, and licensing activities. The order also directs agencies to issue or amend existing procedures to comply with the order and to incorporate wetland reviews into other NEPA documents (EISs and EAs) when possible. The U.S. Department of Energy issued regulation 10 CFR 1022 to comply with the executive order. Under this regulation, a wetlands assessment must be prepared for actions potentially affecting wetlands. Such an assessment was prepared and is included in Appendix D of the EIS.

Response 24-71: See responses 18-4 and 18-5.

Response 24-72: See responses 18-4 and 18-5.

Response 24-73: See responses 18-4 and 18-5.

Response 24-74: We agree that the incorporation of nonuse valuation into economic analysis is still somewhat controversial and realize that the Glen Canyon nonuse studies are not accepted by all parties. However, the study was peer-reviewed and found to be of high quality; therefore, the findings of the study were used in this EIS.

Response 24-75: This comment is not directly applicable to the EIS, but has been considered in preparing the final version of the technical memo.

Response 24-76: This comment is not directly applicable to the EIS, but has been considered in preparing the final version of the technical memo.

Response 24-77: It is difficult to determine the effect of hydropower operations on riparian vegetation below the Yampa River confluence. Most riparian vegetation becomes established above the typical maximum flow. Between Flaming Gorge Dam and the Yampa River, there is minimal inflow from nonregulated water sources, and typical maximum flow approximates maximum power plant capacity. Below the confluence with the Yampa River, the "typical" maximum flow to which riparian vegetation would respond is less predictable and would be more closely related to Yampa River flood flows rather than maximum power plant capacity. For this reason, an evaluation of the effects of hydropower operations on riparian vegetation below the confluence was deemed inappropriate. Aquatic resources respond differently to flows than does riparian vegetation, and assumptions relevant for an evaluation of impacts to riparian vegetation would not be appropriate for aquatic resources.

Response 24-78: The upper boundary of the upper riparian zone is determined by pre-dam river flows and post-dam operations, which provided the soil moisture levels required for the establishment of the species present in that zone. Over the time period considered in the EIS, however, it is unlikely that plants in this zone would suffer adverse effects from reduced water levels because of their deep root systems and ability to use groundwater well below the soil surface.

Response 24-79: See response 24-77.

Response 24-80: See response 24-78.

Response 24-81: The stage height of the upper limit of the riparian zone is well above the elevation of 7,000-cfs flows. Many plants in the upper riparian zone are relics of the pre-dam riparian zone; because of their deep root systems, these plants can use deep groundwater sources. They would not be expected to suffer adverse effects from a reduction in maximum stage over the time period considered in the EIS. As stated in the EIS, the plant community constituting the lower riparian zone would indeed be affected by a change from daily inundation (as under the year-round high fluctuating flow scenario) to temporary inundation in spring (as under the seasonally adjusted steady flow scenario). The boundary between the upper and lower riparian zones is expected to move down to approximately the 3,400-cfs elevation.

Response 24-82: As stated in response 24-81, plants near the upper boundary of the riparian zone would likely persist under any of the operational scenarios over the 15-year period covered by the EIS. Upper-zone species colonizing the area between the elevations of 4,200 and 3,400 cfs flows would likely consist of a mix of woody and herbaceous species that could tolerate short-term inundation. Many of the woody species now found in the upper riparian zone can tolerate such inundation. These species include box elder, Fremont cottonwood, tamarisk, and rabbitbrush. However, a prediction of the mix of species in this newly colonized area was not made for the EIS.

Response 24-83: The EIS and technical memorandum explain that marsh and other wetland vegetation occur in the lower riparian zone. Under the seasonally adjusted steady flow scenario at Flaming Gorge Dam, this zone would be expected to be reduced from present elevations (between 800 and 4,200 cfs) to between the 2,400- and 3,400-cfs stages. This change in the elevation of the lower zone represents a 69% decrease in area, which is described in the EIS as a large adverse impact to this resource.

Response 24-84: It is difficult to predict the final species composition in the area between the 3,400- and 4,200-cfs flows, but species from the upper riparian zone are expected to invade the area and eventually dominate the plant community. Although the lower riparian zone contains marsh vegetation, this zone is occupied by other species as well and also contains unvegetated areas. The area of this zone is expected to decrease by 69% (approximately 4.0 acres per mile), but it cannot be concluded that 4.0 acres per mile of marsh habitat would be lost.

A net degradation of riparian vegetation is not expected under the steady flow scenario. Upper zone vegetation would be expected to increase over the 15-year period influenced by the power marketing program under consideration in the EIS. Because this vegetation has relatively high value to the riparian and aquatic ecosystems, this increase would be considered a benefit. Although some marsh vegetation would be replaced by more drought-tolerant species, any such change would be small relative to the vast acreage of marshland managed by the U.S. Fish and Wildlife Service and the State of Utah within Browns Park. The increase in unvegetated area near the shoreline would benefit a variety of shorebirds, including the western snowy plover, which is a Federal candidate for listing (Category 2). Such unvegetated shorelines are considered typical of an undisturbed river system.

Response 24-85: Many plants in the upper riparian zone became established under the flow regime that existed before the construction of Flaming Gorge Dam. They have persisted despite the post-dam reduction in peak flows. While many plants in this zone may eventually be replaced by more drought-tolerant species, the riparian species currently composing that community would be expected to survive under the reduced flows of the seasonally adjusted steady flow scenario over the period considered in the EIS. Plant species currently occupying the upper riparian zone are expected to colonize the zone between the 3,400- and 4,200-cfs flows under the seasonally adjusted steady flow operational scenario. Many of these species, woody and nonwoody, can withstand short-term inundation, and establishment should not be affected by the month-long spring peak. It is expected that this area would eventually be dominated by a mix of upper-zone species.

Response 24-86: The comment appears to contain a number of misinterpretations of the information presented in the technical memorandum. The riparian area described in the table in question extends from the 800-cfs level to the beginning of the upland plant community. The elevation change from the 800-cfs level to the riparian/upland boundary is variable, but on the basis of the information presented, the average is about 10.4 ft. This boundary is approximately at the elevation of an 11,000-cfs flow and is well above the maximum operating capacity of 4,200 cfs. Much of the riparian vegetation near this boundary was established before the dam was constructed, and its persistence for the 30 years of reduced post-dam flows is an indication of the relative insensitivity of this vegetation to small changes in hydropower operations. Plants in this upper zone are expected to persist over the 15-year period considered for the EIS.

Response 24-87: The EIS and the supporting technical memorandum by Hlohowskyj and Hayse (1995) have been revised to reflect the U.S. Fish and Wildlife Service's designation of critical habitat for the endangered fish of the Upper Colorado River Basin.

Response 24-88: This comment is not directly applicable to the EIS, but it has been taken into consideration in preparation of the final draft of the technical memorandum.

Response 24-89: We believe that the time periods used to compare pre- and post-dam flows are adequate. While it is true that the differences between pre- and post-dam monthly average flows at the Jensen gage are not that great, the hourly and daily fluctuations in post-dam flows are considerably higher than those occurring under pre-dam conditions. Daily fluctuations in flows and the associated changes in river stage can alternately inundate and dewater backwater habitats, which serve as nursery habitat, and may also affect overwinter survival of native and endangered fish species. While flow fluctuations may have contributed to the decline of these fish, other factors, including altered water temperatures and a variety of nonhydropower activities, have probably had even greater effects. These other factors are acknowledged in the EIS.

Response 24-90: We agree that flooding of bottomland areas that may have historically served as nursery areas for some endangered fish species has been severely altered by such activities as diking and bank stabilization. These factors, as well as a number of other possible reasons for declining populations of endangered fish in the Green River, are presented in Section 3 of the EIS. We do not attribute the loss of bottomland flooding to hourly fluctuations produced by hydropower operations.

Response 24-91: The EIS evaluates the effect of the hydropower operational scenarios on fish in the Green River. All the seasonally adjusted operational scenarios meet the requirements of the Biological Opinion for operations of Flaming Gorge Dam, but they differ in the impacts to fish and other aquatic resources in the river. Although hydropower operations may not be the sole factor affecting the decline or continued survival of endangered fish populations in the Green River, there are potential impacts from hydropower operations on these species.

Response 24-92: Since construction of Flaming Gorge Dam, areas upstream and downstream of the confluence of the Green River with the Yampa River have been subjected to daily fluctuations in stage and discharge that did not occur under pre-dam conditions. Although under pre-dam conditions the river was subjected to occasional fluctuations in discharge and stage because of storms in the upper Green River and Yampa River basins, these events did not occur on the repeated, daily basis that result from peaking hydropower operations. The greater stability in day-to-day flows in the Green River downstream of the confluence with the Yampa River may have benefits to native and endangered fish using downstream reaches. Benefits of reduced daily fluctuations may include increased suitability of backwaters as nursery habitats for larvae and juveniles and improved overwinter survival of juveniles and adults.

Response 24-93: This comment is not directly applicable to the EIS, but it has been taken into consideration in preparation of the final draft of the technical memorandum. The relative abundances of cladophora and oscillatoria in the Green River were not evaluated for the EIS and remain unknown. No significant changes in temperature regimes are anticipated under any of the operational scenarios evaluated for Flaming Gorge Dam, and no temperature modification plans were evaluated.

Response 24-94: The impact assessments regarding operational scenarios developed for Flaming Gorge Dam were based upon a number of assumptions, which are presented in Appendix D of the EIS and in greater detail in the technical memorandum by Hlohowskyj and Hayse (1995). These assumptions were based upon the currently available scientific literature.

Response 24-95: Although flow can change the river bed over time, the degree of change would be extremely difficult to predict for the Green River given our current understanding. The estimated relationship between water surface area and flow for the Green River between Flaming Gorge Dam and Browns Park is expected to persist for some time because extensive armoring of the bed has already occurred and because sediment input into the system is limited above Red Creek.

Response 24-96: The fluctuation zone is defined in the text. Since the fluctuation zone is sometimes submerged and in direct hydraulic connection with the main channel, we chose to consider the fluctuation zone as a portion of the aquatic habitat. Fluctuation zones become increasingly similar to more permanently wetted areas as the period of inundation increases. Under appropriate conditions, the fluctuation zone may support production of algae and aquatic invertebrates and may provide spawning habitats for fish. This function can, in turn, affect resources in the main channel. The EIS identifies the amounts and characteristics of the fluctuation zone under each operational scenario in evaluating impacts to the aquatic resources below Flaming Gorge Dam.

Response 24-97: The possibility for food production within the fluctuation zone, even if the amount of production is small compared with production in the other zones considered, provides an additional measure of the differences between the various operational scenarios for Flaming Gorge Dam. Consequently, the analysis of impacts to the fluctuation zone has been retained.

Response 24-98: The suitability of a seasonally wetted zone for trout reproduction was considered in the evaluation presented in the EIS. This seasonally wetted zone was not part of the evaluation for native fish.

Response 24-99: Loss of trout fry and failure of trout recruitment is an important concern for several reasons and is, therefore, evaluated in this EIS. Brown trout are not stocked, and the population depends completely upon natural recruitment for maintenance. If natural recruitment of other trout species could be increased, stocking efforts could be relaxed. Some recreational anglers prefer naturally spawned trout over hatchery-reared fish.

Response 24-100: We agree that the response of introduced fish to stabilization of backwaters and resulting changes in competition with and predation on native species is an important concern. The impact assessments presented in the EIS were qualified with a statement regarding the possible effect of introduced fish species on native and endangered fish.

Although no changes have been made to the EIS, the comment has been considered in preparation of the final version of the technical memorandum.

Response 24-101: We agree that the suitability of a particular backwater area as nursery habitat for native fish is a function of both physical and biological factors. It is also true that any advantages to native fish could be offset by concomitant advantages to introduced species, as stated in the EIS. However, currently there is no substantive evidence to indicate that introduced species and native species differ in their tolerance to changes in backwater conditions.

Response 24-102: The section identifies the potential role of stage fluctuations on overwinter survival as a hypothesis and attributes the hypothesis to Valdez and Masslich (1989). The assumptions made in the technical memorandum are appropriate given the current level of information regarding overwinter survival of endangered fish in the Green River. The potential importance of fluctuating flows on cladophora sloughing is not applicable to the discussion presented in Section 4.3.2. In contrast to its abundance in the Colorado River below Glen Canyon Dam, cladophora is very limited or nonexistent in the Green River below the Yampa River confluence, and cladophora sloughing is not important in food transport in areas of the Green River that support endangered fish.

The Valdez presentation at the 10th Annual Upper Colorado River Researchers in Moab included data on the humpback chub population below Glen Canyon Dam, which is in many ways unique and different from the upper basin populations. Dr. Valdez discussed preliminary results of a humpback chub tagging study and reported that fish movement appeared to be strongly correlated with ramping rates (not daily fluctuations). He postulated that ramping may increase food availability by dislodging cladophora and its associated invertebrates into the water column. Although he did report a decline in fish condition, he also reported that the cause of the decline was not known. BIO/WEST is currently studying ice dynamics in the Green River system because of the potential for adverse impacts to endangered fishes from winter ice breakup. Insufficient information currently exists to definitively determine whether ice breakup caused by fluctuating flows poses an unacceptable risk to the endangered fish. In the absence of such information, we made the conservative assumption that it does. This conservative assumption represents the most protective approach for the impact evaluation presented in the technical memorandum.

Response 24-103: Because the availability of spawning habitat can affect the level of spawning success, availability of such habitat is an important consideration in evaluating the effects to the trout fishery. See response 24-99 for additional discussion.

Response 24-104: See response 24-96.

Response 24-105: The comment is directed toward the technical memorandum, not the EIS. The backwater area-flow relationship used in the technical memorandum represents the best currently available information on the relationship between the areal extent of backwater habitats and flow. Appendix D (Section D.2.1.2.2) of the EIS discusses the use of the backwater area-flow relationship and identifies factors other than surface area that may affect backwater quality.

Response 24-106: The comment is directed toward the technical memorandum, not the EIS. The potential for increasing populations of introduced fish and thereby increasing competition and predation on native and endangered fish is discussed in Section 4.2.4 and Appendix D of the EIS, as well as in Section 6.2.4 of the technical memorandum.

Response 24-107: The importance of trout spawning to the Flaming Gorge trout fishery is discussed in response 24-99. We agree that an exceptional fishery has developed under historic operations and that it might be difficult to produce observable increases in the already high growth rates. However, reductions in growth rates could be produced by changes in hydropower operations. Growth rate was one of several evaluation criteria considered in assessing potential impacts to the trout fishery. The year-round and seasonally adjusted high fluctuating flow operational scenarios would feature discharges approximately 500 cfs greater than historic levels and greater daily fluctuations in discharge. These increases could adversely affect growth rate and other characteristics of the trout fishery.

Response 24-108: Although we know of no references to directly attribute increased trout growth to a reduction in flow fluctuations, we believe that steady flows (i.e., no daily fluctuations) would result in better trout growth for a number of reasons. Trout commonly maintain a position in the stream with a particular mix of microhabitat conditions, including current velocity, depth, and structure. Changes in discharge can force individual trout to alternate locations at some cost to the trout's energy budget. Energetic costs may also be associated with competition for the most suitable locations in the stream. Any of these changes could result in a reduction in feeding or energy input. Although flow fluctuations temporarily increase drift, productivity of the food base probably does not increase.

It is unlikely that senescent growth of cladophora would present any significant impediment to cladophora growth under the seasonally adjusted steady flows operational scenario because cladophora fragments relatively easily with changes in flows. Changes in flow would occur over the course of the year, and a high spring release would occur under all of the seasonally adjusted operational scenarios. Such changes in flows would likely serve to remove any senescent growth. In addition, the production of cladophora has been shown to be considerably lower in fluctuation zones than in permanently wetted areas, and the recolonization of bare areas is slower under fluctuating flows than under steady flows.

Response 24-109: The comment is directed toward the technical memorandum rather than the EIS. Section 4.2.4.2 of the EIS states that reproduction will continue to be limited in the Green River above the Yampa River confluence because of cold water temperatures, regardless of the operational scenario implemented. Section 4.2.4.2 of the EIS also states that use of the Canyon of Lodore, and not reproduction, by adults and juveniles could slightly increase because of increased habitat stability.

Response 24-110: Appendix D (Section D.2.1.2.2) of the EIS and the technical memorandum by Hlohowskyj and Hayse (1995) identify the potential role of flow fluctuations on overwinter survival as a hypothesis and provide a supporting reference. We acknowledge that insufficient information exists to precisely quantify the magnitude of these effects. In the absence of more definitive information, a conservative approach (i.e., most protective of endangered fish) was used.

Response 24-111: The comment is not directly applicable to the EIS but has been considered in preparation of the final version of the technical memorandum.

Response 24-112: The comment is not directly applicable to the EIS but has been considered in preparation of the final version of the technical memorandum.

Response 24-113: We agree that the flooding of bottomland areas that served historically as nursery areas has been reduced by activities such as diking and bank stabilization along the Green River. The seasonally adjusted flow scenarios include a sustained spring peak in dam releases that, together with naturally occurring spring peak flows from the Yampa River, could flood bottomland habitats for extended periods of time. Such sustained flooding would increase the period during which razorback sucker larvae could enter bottomland nursery areas. Because most of the historically flooded bottomlands in the Green River occur downstream of Jensen, overbank flooding was not a major consideration in the EIS for evaluation of impacts to native fish in the Green River.

Response 24-114: The comment is directed toward the technical memorandum, not the EIS, and has been considered in preparation of the final version of the technical memorandum. The effects of increased backwater habitat stability (as well as the potential effects of competition and predation from introduced species) on growth, condition, and survival of native and endangered fish are discussed in Section 4.2.4 and Appendix D of the EIS.

Response 24-115: The comment is directed toward the technical memorandum, not the EIS, and has been considered in preparation of the final version of the technical memorandum. Section 4.2.4 of the EIS discusses the potential for increased competition and predation from non-native fish species to offset any benefits that native species could receive.

Response 24-116: The comment is directed toward the technical memorandum, not the EIS, and has been considered in preparation of the final version of the technical memorandum. The effects of increased nursery habitat stability on razorback sucker recruitment is unknown and is complicated by the possibility of increased competition and predation by introduced fish species. Section 4.2.4 of the EIS discusses this uncertainty.

Response 24-117: See response 24-110 for a discussion of assumptions used to evaluate overwinter survival of native and endangered fish under different operational scenarios. The assessment of impacts to native and endangered fish presented in the EIS and in the technical memorandum did not focus solely on the effects of flow changes on stability of backwater conditions, but also considered potential effects of daily stage changes on overwinter survival, spawning, migration, food availability, and competition and predation from introduced species.

Response 24-118: The comment is directed toward the technical memorandum, not the EIS, and has been considered in preparation of the final version of the technical memorandum. Sections 3.4.2.1.1, 4.2.4.2.1, and 4.2.4.2.3 of the EIS address the potential detrimental effects posed to native fish species by competition and predation from introduced fish species, especially if changes in hydropower operations provide improved conditions for introduced species.

Response 24-119: See response 24-118.

Response 24-120: The main purpose of the EIS is to examine issues related to Western's power marketing programs. Discussion in the EIS of the impacts of each marketing alternative on lost capacity is limited to the determination of the impacts on Western power customer capacity expansion plans. Power customers may respond to the loss of hydropower capacity either by building additional capacity or by purchasing alternate long-term firm power through Western from nonhydropower sources. The technical memorandum (Veselka et al. 1995) discusses the need for Western to augment SLCA/IP resources under certain conditions, and simulations of hourly hydropower operations are fully discussed and illustrated. The effects of power marketing on short-term firm power sales and Western spot-market activities are also discussed. Least-cost integrated resource plans for 12 large system long-term firm power customers are also examined. Issues relating to the replacement of capacity at Glen Canyon are specifically discussed in the Glen Canyon Dam EIS. The socioeconomic and environmental impacts of power marketing programs are fully discussed in the Power Marketing EIS.

Response 24-121: The long-term impact of three different hydropower operational scenarios on generation capacity are assessed under each alternative in the EIS. It was assumed that hydropower capacity lost as a result of each scenario would either be replaced by Western customers through lower power deliveries from Western or through the purchase of replacement power by Western to fulfill contract obligations with power customers. When customers have lower power deliveries they may build additional capacity. The long-term impacts of each scenario on capacity are fully discussed in the technical memorandum (Veselka et al. 1995). The precise locations and types of generating technologies that might be added as a result of the conditions existing under these scenarios were not known at the time the analysis was undertaken for the EIS, and, consequently, neither the environmental impacts of new generation nor the impacts on fossil fuel supplies could be fully considered.

Response 24-122: All legal constraints on hydropower operations, including those of the Endangered Species Act, are reflected in the range of commitment-level alternatives and supply options evaluated in the EIS. Thus, the impacts presented in the EIS bound those that would occur given the set of existing constraints. Additional text on the role of legal constraints has been added to the appropriate section of the technical memorandum describing the analysis of power systems (Veselka et al. 1995).

Response 24-123: Capacity lost at SLCA/IP facilities as a result of any of the alternatives could lead to the construction of additional capacity elsewhere in the system. Not all of this capacity would be replaced when restrictions were placed on hydropower operations, and the timing of construction would depend on the distribution of excess capacity across the system over the remainder of the long-term firm power contract. The technical memorandum (Veselka et al. 1995) describes the exact nature of the impact of each alternative on capacity additions and shows that capacity lost due to lower power deliveries would either be replaced by lower power deliveries or by firm capacity purchases by Western. Although a generic long-term firm purchase contract was assumed in the EIS as mandated by the Glen Canyon Protection Act, a more thorough investigation of how Western will purchase this power is presently being conducted by Western.

Response 24-124: See response 24-123.

Response 24-125: Comment noted.

Response 24-126: As explained in Section 3.5.2.2 of the EIS, hydropower operations have negligible effects on the levels of the large Flaming Gorge Reservoir. For this reason, the margins of the reservoir were excluded from the areas covered in the Class I overview and from the affected areas analyzed in the EIS.

Response 24-127: Because the Class I Overview is available to the general public as a supporting document for an EIS, specific locations were not given in order to protect archaeological sites from vandalism. Maps of Reach 2 of the Green River study area, which extends from the Yampa River confluence to the mouth of Cub Creek, are presented in Figures 10, 11, 12, 13, and 14 of the Class I Overview. Sampling methods employed in each survey are described in Table 2 of the Overview, except in cases where this information was not available (as noted in the table).

Response 24-128: The prehistory sections of the Class I Overview are intended to provide a general context for the prehistoric sites encountered in the study area (references to more detailed discussions of each period are included in the text). The distribution of sites is discussed only in broad geographic terms (e.g., uplands versus lowlands). A discussion of regional site distribution patterns in terms of topographic setting is not necessary because the pattern of site distribution specific to the study areas is well illustrated by the existing database for those areas. The age and character of individual sites are presented in tables, and topographic settings are described in the text.

Response 24-129: The purpose of the Class I Overview was to summarize existing information (including results of all previous field surveys and recorded sites) on cultural resources of the study areas. The distribution of sites in these areas is discussed in the text of the report. The Class I Overview was not intended to predict the distribution of sites in unsurveyed areas or impacts to known and predicted sites, but to provide a basis for evaluation of such cultural resources management information in more appropriate contexts (e.g., the EIS). However, the text of Section 4.2.5.2 of the EIS has been modified to include a predictive statement concerning projected impacts to sites in unsurveyed areas downstream of Flaming Gorge Dam (such a statement is not necessary for Glen Canyon Dam or the Aspinall Unit, where all affected areas have been surveyed).

Response 24-130: See response 24-129.

Response 24-131: The air pollutant emission inventory for the western United States compiled by the Grand Canyon Visibility Transport Commission is not yet available. Even if some discrepancies between the two inventories exist, estimates of the region's total emissions should be within the same order of magnitude, and the relative ranking of impacts should not change.

Response 24-132: Because the locations of projected future generating units are not known, it was not possible to perform site-specific air quality impact modeling for those units. Therefore, local air quality impacts for these units were modeled with the Industrial Source Complex model assuming flat terrain to obtain an order-of-magnitude estimate of impacts. Meteorological data for the areas where units are likely to be located were used with the model. Most of the modeling demonstrates that the maximum concentration increments are small fractions of the maximum allowed Prevention of Significant Deterioration increments or of the significant air quality impact levels defined by the U.S. Environmental Protection Agency. Furthermore, these increments occur close to the source (generally within 1 mi or less for short-term concentrations and up to a few miles for long-term concentrations). These impact estimates would be valid for those sources located from one to a few miles from complex terrain. More accurate air quality impact modeling could be performed for locations closer to complex terrain once an actual plant site was determined.

Response 24-133: Airborne carbonaceous material (e.g., soot) is one of many categories of particles making up the fine particles in ambient air. A statement regarding the importance of such carbonaceous particles in visibility impairment has been added to Section 3.2.2 of the EIS. Although an emission inventory was not prepared specifically for carbonaceous particles for the EIS, the significance to regional visibility of variations in carbonaceous particle emissions from the electric utility industry can be inferred from the magnitude of variation in total suspended particulate (TSP) emissions and the relative contribution of carbonaceous particle emissions by the electric utility industry. The maximum variations in TSP emissions among all commitment-level alternative-supply option combinations are estimated to be less than or equal to about 2% of emissions from the region's electric utility industry (Table B.8 of Appendix B of the EIS). It is estimated that the variation in carbonaceous particle emissions would be on the same order of magnitude. Given that the relative contribution by the electric utility is very minor (on the order of 1% of the total man-made carbonaceous material emissions), it is concluded that these changes would have little impact on regional visibility.

The assessment of potential impacts on regional visibility was based on the estimated percent changes in regional emissions of air pollutants contributing to visibility impairment. The maximum percent variation in estimated emissions of such pollutants among all commitment-level alternative-supply option combinations is less than or equal to about 2% of the emissions from the region's electric utility industry or about half of that value (about 1% or less) with respect to the region's total man-made emissions. These values of percent change in emissions are even smaller when emissions from natural sources are included in the region's total emissions. A more detailed modeling for regional visibility was not conducted because models that can reliably predict the effects of emission changes of this magnitude (i.e., about 1% or less) are currently not available.

Response 24-134: The emission reductions and resulting air quality and visibility improvements that would occur as the requirements of the 1990 Clean Air Act Amendments are implemented were not considered in the air quality and visibility impact assessments made for the years 1998 and 2008. However, such emission reductions and resulting improvements in air quality and visibility are not expected to alter the relative ranking of the impacts associated with the various commitment-level alternatives or operating scenarios evaluated in the EIS.

Response 24-135: See response 24-131.

Response 24-136: The megawatt values in Table B.5 in the EIS (Table 2.3 in Chun et al. 1995) are the name-plate gross generating capacity and therefore do not exhibit seasonal variation. These values were obtained from the *Directory of Electric Utilities* (1992 edition) published by Electrical World (New York, N.Y.). They have been checked against the values given in the 1994 edition of the directory and have been updated as necessary.

Response 24-137: See response 24-134.

Response 24-138: See response 24-132.

Response 24-139: This comment is not directly applicable to the EIS but has been considered in preparation of the final version of the technical memo.

Response 24-140: Specific comments on analyses presented in the technical memoranda are addressed in individual responses in other parts of this document. The environmental effects of replacement capacity are discussed in Sections 4.1.2 and 4.1.3 of the EIS.

Response 24-141: Section S.4 of the EIS has been modified to include a statement that purchases and sales are made for economic reasons, as well as for meeting contractual requirements.

Response 24-142: Comment noted.

Response 24-143: See response 18-4.

Response 24-144: The alternatives in Western's EIS are intended to cover the range of possible alternatives that comply with Western's legal requirement and its mission. In the Record of Decision, Western will select a commitment level that best balances competing needs. This commitment level may not be exactly like any of the alternatives in the EIS.

Response 24-145: Section 2.2.1 of the EIS has been modified as suggested.

Response 24-146: Section 2.2.3 of the EIS has been revised to provide a clearer description of the magnitude of rate impacts from each of the alternatives.

Response 24-147: As stated in Section 2.3.1 of the EIS, hydropower operations appear to be only weakly linked to long-term firm commitments for capacity and energy. However, it is ultimately through the hydropower operations employed that downstream natural resources are affected. For this reason, the full range of possible operations at the hydroelectric facilities was analyzed.

Response 24-148: The text in Section 3.1.3 has been revised to include the fact that Utah cooperatives are also predicted to experience 53% increases in rates over the forecast period.

Response 24-149: Information on coverage ratios was not provided separately in the EIS for generation and transmission cooperatives in order to prevent the disclosure of confidential data on individual companies. Results in the EIS are presented for all entities in the four states receiving the majority of Western power. Because only a small number of cooperatives exist within these states, presenting information in the EIS on coverage ratios at any level other than for each state would reveal information on individual utilities and violate confidentiality agreements with these companies.

Response 24-150: The impacts of each alternative on utility rates over the contract term are presented in the tables in Section 4.1.1.2 in terms of constant 1994$/MWh. Additional information presented in the supporting documentation (Bodmer et al. 1995) allows the calculation of the absolute bill impact if desired. The EIS presents percentage changes in rates to indicate the relative impacts of the changes that occur with each alternative. This procedure provides a more accurate assessment of the impact of each alternative on rates than would presentation of the absolute bill impact.

Response 24-151: A statement has been added to Section 4.1.1.2 and Section A.2 of the EIS to clarify the link between the short-term-firm and spot-market analysis results and the remainder of the analysis in the EIS.

Response 24-152: The EIS and supporting documents clearly describe the magnitude of the impact of each alternative on both retail rates and utility financial viability. Section 4.1.2 provides a qualitative description of the relationship between changes in wholesale electricity rates with each alternative and the corresponding changes in retail rates and utility coverage ratios that would occur, and then quantitatively describes precisely how each alternative would affect utility rates (by utility type and reliance level) and utility coverage ratios (by reliance level). No further discussion is required in the EIS to address these impacts.

Response 24-153: See response 24-150. Table 4.1 in the EIS has been revised to aid in the interpretation of the material presented.

Response 24-154: See response 18-4.

Response 24-155: The secondary impacts to socioeconomics and natural resources from construction and operation of additional generating capacity are not evaluated in the EIS because the precise locations, specifications, and the timing of the construction of any new capacity needed to offset shortfalls in supplies from Western is not known at this time. Any such construction would require a separate environmental review.

Response 24-156: See response 18-4.

Response 24-157: See the response to comment 24-155. Secondary impacts that would occur from the construction and operation of additional generating capacity would partially offset the impacts resulting from changes in retail electricity rates. Estimates of overall regional impacts included in the EIS are consequently conservative. Section 4.1.1.4.1 of the EIS has been revised to emphasize this point.

Response 24-158: See response 18-4.

Response 24-159: See response 18-4.

Response 24-160: This comment is not directly applicable to the EIS, but has been considered in preparing the final version of the technical memo.

Response 24-161: See response 18-4.

Response 24-162: This comment is not directly applicable to the EIS, but has been considered in preparing the final version of the technical memo.

Response 24-163: We agree that the use of higher avoided capacity costs would make conservation programs appear to be more cost effective and that variations in avoided energy costs make peak load management programs appear more cost effective. However, the marginal energy costs used to assess the impact of conservation and demand-side management programs produced by the analysis of utility power systems were low and did not show wide variations during the day. There was also little difference in marginal energy costs between the prototypical system and other major systems served by Western. It should be emphasized, therefore, that the use of low avoided capacity costs and relatively invariant energy costs in the EIS has the effect of increasing the impact of each alternative on utility capacity expansion plans by reducing the significance of utility conservation and demand-side management programs. The results of the analysis are, therefore, conservative estimates of the impacts of each alternative.

Response 24-164: This comment is not directly applicable to the EIS, but has been considered in preparing the final version of the technical memo.

Response 24-165: As suggested by the commenter, the results of the financial viability and rate impact analysis are described in the Summary of the EIS (Section S.7). Because this description includes a summary of impacts of each alternative and supply option on financial viability for all utilities and on end-user rates for high- and low-reliance utilities for each of the four states and for both utility types (cooperatives and municipalities), additional description in the Summary of the EIS is not warranted. More information on financial viability and rate impacts is in Section 4 and Appendix A of the EIS.

Response 24-166: This comment is not directly applicable to the EIS but has been considered in preparing the final version of the technical memorandum.

Response 24-167: See response 24-166.

Response 24-168: See response 24-166.

Response 24-169: During the development of the methodology used in the estimation of capacity expansion impacts, ANL considered whether to use the load forecasts and DSM estimates provided by the individual utilities or to develop a series of forecasts for all the utilities being modeled by ANL. A number of factors were considered in this decision. Although ANL attempted to collect forecasts from each of the utilities included in the power systems analysis, a number of problems were encountered, including (1) the utility forecasts were not based on a common set of assumptions about the future growth in energy prices and economic activity, (2) all of the utility forecasts did not extend to the end of the forecast horizon, (3) some of the utility forecasts included very optimistic assumptions about DSM programs while others assumed no DSM, and (4) some of the utility forecasts displayed long-term growth rates that were far greater than the growth rates usually used in load forecasts. Despite these problems, the first few years of all of the utility forecasts appeared to be quite defensible.

Because of these considerations, it was decided to combine the better view of the immediate future contained in the utility forecast along with the consistent assumptions about the long-term growth in energy prices and economic activity that came from a single forecast. Thus, the short-term forecast for each utility was based on the utility-provided forecast. The short term was defined as the 1993-1995 period. The forecasts for the years beyond 1995 were based on the econometric models developed by ANL. The two forecasts were combined by using the annual growth rates implied by the forecasts of the econometric models to extend the utilities' forecasts beyond 1995. As a result of the methodology chosen to forecast utility load used in the modeling analysis, some differences exist between the baseline forecasts produced by the utilities modeled in the analysis and those produced by ANL. To evaluate the significance of these differences on the impact of the alternatives, a sensitivity analysis was performed on the difference between the impact of the power marketing alternative with the most significant hydropower restrictions, using both the ANL forecasts and the forecasts for one utility for selected years. Although the ANL load forecasts for this particular utility for these years were higher than those produced by the utility, the results of the sensitivity analysis showed that the difference between the impact of the alternative on capacity expansion costs using both forecasts was only of minor significance. Even in this extreme case, therefore, the ANL estimates of expansion costs tend to produce impacts that are only slightly higher than those using utility load data, and, as a result, produce estimates of impacts that are only likely to be slightly more conservative than those based entirely on utility data.

Response 24-170: See response 24-166.

Response 24-171: See response 24-166.

Response 24-172: Identical DSM options were used for all the alternatives. This procedure was used because the results of the DSM analysis showed that each alternative and operational scenario had very little or no impact on DSM programs and, therefore, on hourly loads.

Response 24-173: See response 24-166.

Response 24-174: Section S.7 of the EIS has been revised to include a statement that construction of additional generating capacity may be required under each alternative even though Western has more hydropower capacity than would be marketed on a long-term firm basis under each of the alternatives.

Response 24-175: Comment noted.

Responses to David L. Highers, Executive Vice President/General Manager, Plains Electric Generation and Transmission Cooperative, Inc., Albuquerque, New Mexico (Comment Document 25)

Response 25-1: Comment noted.

Response 25-2: See response 24-2.

Response 25-3: See response 4-4.

Responses to F. Danny Eyre, Finance Manager, Bridger Valley Electric Association, Inc., Mountain View, Wyoming (Comment Document 26)

Response 26-1: Comment noted.

Response 26-2: See response 4-4.

Response 26-3: Comment noted.

Response 26-4: Comment noted.

Response 26-5: Comment noted.

Response 26-6: Comment noted.

Responses to Wm. Kent Romney, General Manager, Page Electric Utility, Page, Arizona (Comment Document 27)

Response 27-1: See response 4-4.

Response 27-2 See response 23-2.

Response 27-3: Comment noted.

Response 27-4: See response 23-4.

Responses to Gary A. Aitken, Clerk, Strawberry Electric Service District, Payson, Utah (Comment Document 28)

Response 28-1: Comment noted.

Response 28-2: See response 4-2.

Response 28-3: See response 4-4.

Responses to William L. Gibbs, Mayor, Lehi City Corporation, Lehi, Utah (Comment Document 29)

Response 29-1: Comment noted.

Response 29-2: See response 4-2.

Response 29-3: See response 4-4.

Responses to Leslie James, Manager, Contracts Department, Salt River Project, Phoenix, Arizona (Comment Document 30)

Response 30-1: See response 4-4.

Response 30-2: Paragraph one of the comment is noted. The Glen Canyon Dam EIS was revised on the basis of comments received from the public. The Power Marketing EIS, through citation of the revised Glen Canyon Dam EIS, incorporates this and other public comments on that EIS. The Power Marketing EIS acknowledges and addresses the potential of steady flows and reduced fluctuations for increasing the abundance of introduced fish species and thereby addresses the potential for adverse impacts to native species below Glen Canyon Dam and Flaming Gorge Dam from increased competition and predation. The potential for increasing numbers of introduced fish, as well as the possible consequences of such increases, below Flaming Gorge Dam is also addressed in the supporting technical memorandum by Hlohowskyj and Hayse (1995).

Response 30-3: At the time the draft EIS was issued to the public, Native American consultations had begun but were not complete. The results of these consultations have been included in the final EIS to the extent possible. The Record of Decision and any associated mitigation plan will incorporate the final results of these consultations.

Response 30-4: See responses 23-2 and 24-13.

Response 30-5: Although data recovery is an appropriate mitigation for adverse effects to archaeological sites that cannot be mitigated by any other measures, mitigation by avoidance, preservation, or protection is usually preferred because these measures entail minimal damage to the resource. Data recovery typically involves collection and/or excavation and consequent damage or destruction of the site.

Response 30-6: We disagree with the statement that the logic of the analysis was flawed. Regardless of the degree of flow fluctuation, the daily amount of hydroelectric generation would be approximately the same, because the same amount of water would pass through the turbines to generate hydroelectric energy. With reduced fluctuations at hydroelectric facilities, the amount of hydroelectric energy generated would be smaller during the peak demand period but larger during the offpeak period than has occurred historically. The hydroelectric energy that was no longer produced during the peak demand period would have to be supplied by other peaking units. During the offpeak period, however, the generation of electricity from baseload plants would be reduced to make use of the additional hydroelectric energy made available during that period. The net result is that a given amount of electric energy generated by peaking units other than hydroelectric units would replace the same amount of electric energy generated by baseload units. Because the nonhydroelectric peaking generating units generally have lower emission factors than the baseload units, a net decrease in air pollutant emissions would be expected. Section 4.2.2 of the EIS has been revised to more clearly state how reduced fluctuation would result in lowered emissions.

Response 30-7: See response 24-131.

Response 30-8: See response 24-132.

Response 30-9: See response 24-133.

Response 30-10: See response 24-134.

Response 30-11: See response 24-131.

Response 30-12: See responses 24-136 and 24-139.

Response 30-13: See response 24-137.

Response 30-14: See response 24-138.

Responses to Denis P. Galvin, Associate Director, Planning and Development, U.S. Department of the Interior, National Park Service, Washington, D.C. (Comment Document 31)

Response 31-1: It is not correct to state that the economic impacts of commitment-level alternatives are not statistically different from zero. This is only true for regional economic impacts. Impacts to financial viability and retail rates were detected for alternatives. As discussed in Section 4.1.3 of the EIS, commitment-level alternatives do not differ in their effects on natural resources. This results from the fact that hydropower operations, which do affect natural resources, are only weakly linked to commitment-level alternatives.

Response 31-2: The impact assessments presented in the EIS are based on an evaluation of the most current available information for various natural resources. This information was used to describe the existing environment downstream of the hydropower facilities (including the changes that have occurred since the dams were constructed) and to predict the changes that could occur under different hydropower operational scenarios. These scenarios were formulated to represent the range of operational variation within Western's control and excluded the effects of the presence of the dams (e.g., monthly release volumes, sediment-trapping, and water temperature effects). The effects of hydropower operations on reservoir levels were evaluated initially but excluded from further analysis at Flaming Gorge and Glen Canyon because the hourly variations in releases resulting from hydropower operations had little effect on reservoir levels. Changes in reservoir levels at these facilities were found to be most affected by the monthly changes in volume that are under Reclamation's control.

Response 31-3: The analysis of the impact of power marketing options on utility conservation programs found little difference between the impacts of each alternative and supply option. This finding of minimal difference resulted from the use in the analysis of low avoided capacity costs and relatively invariant energy costs. In effect, this methodology predicts the maximum impacts of alternatives without the mitigating effect of energy conservation measures. Western is preparing additional analysis to assess how long-term firm customers will be required to act regarding conservation and renewable energy. The results will be reported in the Energy Planning and Management Program EIS. In selecting operational scenarios for implementation at Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit, Western will take into consideration the environmental effects of those scenarios.

Response 31-4: Although a visitor to Morrow Point or Crystal reservoirs could camp along the shoreline, use of developed campgrounds for that purpose is encouraged. The text of the EIS has been changed to indicate this fact. The number of persons who actually camp on the water's edge represents a small portion of total users. The incidence of "dry-docked" boats on either reservoir is rare. Both reservoirs are surrounded, for the most part, by steep canyon walls that preclude activities that would likely lead to a boat's being left unattended for prolonged periods. The Curecanti Creek campground is located above the full-pool elevation and does not flood as a result of dam operations.

Response 31-5: Little or no information is available regarding the trophic dynamics of Morrow Point and Crystal reservoirs, and no information is available regarding the relationships between rapid ramping and high fluctuating flows and the conditions of trout fishery of the reservoirs. Modeling results presented in the EIS show that relatively minor daily changes in reservoir elevation would occur under the seasonally adjusted high fluctuating flow scenario at Morrow Point Reservoir. In addition, the monthly water volumes released from each of the Aspinall Unit reservoirs would be identical for the high fluctuating and steady flow scenarios, and nutrient inputs to the reservoirs associated with the release volumes would not differ between the two scenarios. Thus, hydropower operations would have little effect on productivity and fisheries relative to those impacts that would result from Bureau of Reclamation operations of the Aspinall Unit. The EIS has been revised to more strongly indicate the general absence of information for the lower reservoirs and to more clearly identify that any impacts to the productivity (and thus fishery) of the reservoirs would be similar between the fluctuating and steady flow operational scenarios.

Response 31-6: The operational scenarios for the Aspinall Unit evaluated in the EIS are based on the monthly release volumes of U.S. Fish and Wildlife Service research flows. Hourly fluctuations in releases from Crystal Dam would not occur for these scenarios. As stated in Sections 1.6.5 and 1.6.6 of the EIS, operations of the Aspinall Unit are being evaluated and may change in the future. U.S. Fish and Wildlife Service research flows were chosen as the basis for the operational scenarios because they are relevant to the interim period between issuance of the Record of Decision for this EIS and any NEPA documentation planned for future operation to provide contract water for the Black Canyon of the Gunnison.

Response 31-7: Because no hourly fluctuation in Crystal Dam releases would be allowed even under the seasonally adjusted high fluctuating flow scenario, releases from Crystal Dam would be the same under both operational scenarios, as stated in Sections 4.2.3.3 and C.2.1. The surface fluctuations for Crystal Reservoir shown in Table C.22 are due to fluctuation in Morrow Point Reservoir releases, not Crystal Reservoir releases. The EIS does not assess and compare the impacts of hydropower operation on the Gunnison River below Crystal Dam because releases from Crystal Dam would not be patterned to produce power.

Response 31-8: The commenter makes a recommendation that Western choose a particular hydropower operation at Flaming Gorge Dam. This recommendation appears to be based on a misreading of the conclusions of the EIS. The commenter also states that there were no economic impacts identified in the EIS. This statement is not correct. The EIS states only that *regional* economic impacts would not be significant. The regions used in the analysis consisted of large geographic areas or large population centers. Financial viability and rate impacts were detected, however, as discussed in Section 4.1.1 and summarized in Table 4.35 of the EIS.

Western understands and acknowledges the National Park Service's responsibility to protect park resources and resource values. In the Record of Decision, Western will select a commitment level to achieve a balanced mix of purposes, including the fewest associated environmental impacts practicable. In addition, Western will choose hydropower operational scenarios at Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit that are protective of downstream resources. Hydropower operations are only weakly linked to commitment levels. This weak relationship allows a decoupling of the selection of a commitment level and establishment of hydropower operations. Any capacity or energy lost through reduction in hydropower production could be regained through purchases from utilities, although this reduction in hydropower generation could have economic effects.

Response 31-9: The paragraph in question is introductory and only explains why socioeconomic topics are presented before topics related to natural resources. It would be inappropriate at that point in the EIS to present the actual magnitude of impact. The text has been modified to more clearly convey the intended message.

Response 31-10: Comment noted.

Response 31-11: As stated in the comment, few or no empirical data are available to determine the absolute level of benefit that would occur to natural resources under a seasonally adjusted steady flow regime. The impact assessments presented in the EIS are thus a matter of professional judgment based on the best information available at the time the EIS was prepared.

Response 31-12: The operational scenarios assessed in the EIS were identified early in the NEPA process and were selected to represent a range of possible operational scenarios at hydropower facilities. These operational scenarios were chosen on the basis of input from the public and cooperating agencies, including the National Park Service. In the Record of Decision, Western will choose a hydropower operational scenario for Flaming Gorge Dam that is protective of natural resources.

Response 31-13: Because of their firsthand experience, state and Federal agency personnel or other authorities are often the best sources of information on affected environmental resources. These individuals often transmit valuable, but unpublished, information to EIS authors. Citation of the transmittal letters and their attachments is often the only way such information can be utilized in the EIS. These letters and their attachments were made available to the interested public for review at reading rooms at the time the EIS was transmitted.

Response 31-14: Text has been added to the EIS to explain that historic flows refer to flows at hydroelectric facilities that have occurred during the approximately 30 years since these facilities were built and before endangered species concerns prompted changes in operations.

Response 31-15: The statement that weather-induced reservoir surface fluctuations at Blue Mesa and Morrow Point can be greater than those attributable to the two hydropower operations considered (up to 1.5 ft) is based on professional judgment. To avoid confusion, the reference to Table 4.16 has been deleted.

Response 31-16: The text of the EIS has been changed to read "operational scenarios for the Aspinall Unit" rather than "at Flaming Gorge Dam."

Response 31-17: Section 3.4.3.1.2 of the EIS includes a discussion of the spring 1993 entrainment incidents that were observed at Morrow Point Reservoir. The EIS identifies Mr. Hebein as the source of the entrainment information and points out that although the role of hydropower operations in the observed entrainment is unknown, the observed fish losses may have resulted from high water releases from Blue Mesa Reservoir that were necessary because of very high water levels in that reservoir. Because the total number of smelt present in the reservoirs is unknown, but probably is very high (50,000 to 100,000 or more), a loss of 254 smelt and adults may not be considered significant.

Response 31-18: We agree that releases from Morrow Point Reservoir carry nutrients to Crystal Reservoir. However, the Aspinall Unit reservoirs are relatively nutrient poor, and total monthly release volumes from Blue Mesa and Morrow Point reservoirs would be identical under the seasonally adjusted steady and high fluctuating flow scenarios. Thus, water releases probably would not carry a different nutrient load under the seasonally adjusted high fluctuating flow operational scenario than under steady flow releases. In addition, side inflows (such as from the Cimarron River) may serve as a greater nutrient source to Crystal Reservoir than does inflow from Morrow Point Reservoir. The rapid turnover rate of water in Crystal Reservoir would further act to limit utilization of nutrients entering the reservoir from Morrow Point Reservoir. The EIS has been revised to indicate that total monthly water volume inputs (and thus nutrient inputs) between reservoirs would not differ between the operational scenarios and that potential impacts on productivity from hydropower operations would be similar to those that would result from Bureau of Reclamation operations of the Aspinall Unit.

Response 31-19: The 1993 stranding incident involved one of Curecanti's two tour boats. Both tour boats were sold after the 1993 season and will be replaced by one or two pontoon boats that have a shallower draft than the boat that was stranded. Because the period that the tour boat's floating dock would become unusable was limited to a few hours a day during the month of August only, the impact was considered slight. The text in Section 4.2.7.3 of the EIS has been changed to indicate that stranding incidents, although rare, generate adverse impacts.

Response 31-20: See response 31-4.

Response 31-21: Jensen was selected as the downstream limit of the affected area because that is the location of target flow restrictions required for compliance with the U.S. Fish and Wildlife Service Biological Opinion for operations of Flaming Gorge Dam. According to the Biological Opinion, compliance with the target flows at Jensen is considered protective of endangered fish and their habitats downstream of Jensen.

Response 31-22: Both native and non-native species have contributed to the increase in riparian vegetation below Glen Canyon and Flaming Gorge dams. The portion of the increase resulting from non-native colonization is not known at this time. It is anticipated that both native and non-native species would increase under the steady flow scenario.

Response 31-23: Section 4.1.1.4.1 of the EIS and supporting documents present the impact of each alternative on personal income in each subregion. Estimated changes in income were not statistically significant at the subregional level. Impacts are expressed in terms of percentage deviations from the baseline for each year shown. The impacts of each alternative are, therefore, compared in each year with projections of personal income from 1993 to 2008 in each subregion without any change in existing power marketing programs.

No attempt was made to compare the various economic impacts to produce a single number representing the net cost or benefit of each alternative-supply option combination. Because the scope of the EIS is limited to identification of the various impacts attributable to each of the commitment-level alternatives, such a comparison would be beyond the scope of the EIS.

Response 31-24: Section S.7 of the EIS notes that much of the affected region has excess capacity, while later noting that there may be a need for additional capacity. In context, these statements are not contradictory. The need for additional capacity may arise for a number of utilities in later years in the power contract period, even though other utilities in the system have capacity surpluses. Given projected capacity shortages, some utilities may prefer to construct additional capacity rather than rely on continued supplies from elsewhere in the system, if, indeed, use of these sources is possible given the configuration of the existing transmission system.

Response 31-25: Overwinter survival of trout under the seasonally adjusted steady flows operational scenario could be slightly higher than under the seasonally adjusted moderate fluctuating flows scenario because of the absence of daily fluctuations throughout the winter. Although both operational scenarios would provide similar amounts of spawning habitat throughout the spawning periods, the absence of daily fluctuations under the seasonally adjusted steady flows scenario could result in slightly higher hatching success.

Differences in growth rates between the two scenarios might be virtually undetectable, because trout already exhibit exceptional growth rates. Table S.7 has been changed to assign a slight benefit to trout under seasonally adjusted moderate fluctuating flows and a slight to moderate benefit to trout under the seasonally adjusted steady flows operational scenario.

No evidence suggests that cottonwood regeneration would increase under the seasonally adjusted steady flow operational scenario. It is thought that successful cottonwood regeneration would require periodic high spring flows (well above power plant capacity). None of the operational scenarios include such high spring releases, because releases outside power plant capacity are beyond Western's control and thus beyond the scope of the EIS.

It is unclear how Ute ladies-tresses would respond to the different operational scenarios. Spring flows that are thought to be beneficial to the orchid would be equally high for all operational scenarios. Ute ladies-tresses typically occur 1 to 2 ft above the summer water level. Given the elevation of the Browns Park population relative to the minimum flow of 800 cfs (6 or more feet above), it appears that this population may be dependent on the higher flows associated with maximum power plant capacity. Eliminating periodic high flows during the critical summer months could place existing populations in jeopardy, and, thus, monitoring is recommended.

Sediment dynamics are not very different among the operational scenarios. As stated previously, periodic high flows (beyond those associated with hydropower operations) are not a part of any of the operational scenarios that are being evaluated in the EIS and are therefore beyond the scope of the EIS.

Response 31-26: Although steady flows are most beneficial for trout communities, from the perspective of a shore or boat angler, the benefits derived from steady flows would be negated by the high minimum flows that would occur during May and June under the seasonally adjusted steady flow operational scenario. As the EIS indicates, flows between 800 and 1,500 cfs are preferred by anglers. The high minimum flows of May and June would greatly exceed the highest preferred flow (for anglers). Consequently, the impact is considered adverse. The EIS does recognize a moderate benefit after July 10 for this scenario.

The EIS recognizes a moderate benefit to white-water boating under the seasonally adjusted steady flow scenario. A large benefit would have been assessed if the scenario offered the highest flows or consistently higher flows than would be available under the other operational scenarios. It does not. As the EIS indicates, higher flows would be available during May and part of June under the seasonally adjusted high fluctuating flow scenario. Also, while the seasonally adjusted steady flow scenario offers the highest minimum flows after June, these flows would be only slightly higher than those that would occur under other scenarios and are not of a magnitude to justify being characterized as a "large" benefit.

Response 31-27: See responses 31-25 and 31-26.

Response 31-28: See response 31-11.

Response 31-29: This comment suggests a procedure to select operational scenarios and a commitment level. The suggested approach appears to be based on a misreading of the economic impacts presented in the EIS and the relationship between commitment-level alternatives and operational scenarios. The comment states that there were no economic impacts identified in the EIS. That statement is not correct. The EIS states only that *regional* economic impacts would not be significant. The regions used in the analysis consisted of large geographic areas or large population centers. Financial viability and rate impacts were detected, however, as presented in Section 4.1.1 and summarized in Table 4.35 of the EIS.

Hydropower operations are only weakly linked to commitment levels. This weak relationship allows a decoupling of the selection of a commitment level and establishment of hydropower operations at Glen Canyon Dam, Flaming Gorge Dam, and the Aspinall Unit. Any capacity or energy lost through reduction in hydropower production could be regained through purchases from utilities, although this reduction in hydropower generation could have economic effects.

Response 31-30: Changes to the constraints of the Biological Opinion are outside the scope of this EIS. We agree that habitat quantity does not necessarily equate to habitat quality, and the absence of a demonstrated link between quantity and quality is discussed in Appendix D, Section D.2.1.2.2, of the EIS. Appendix D and the supporting technical memorandum by Hlohowskyj and Hayse (1995) discuss the importance of other factors (e.g., temperature, substrate, and depth) in determining overall quality of backwaters as nursery habitats for native and endangered fishes. Dr. Schmidt's research from the 1993 spring flows, which applied a geomorphic analysis of Colorado squawfish habitats, evaluated the relationship between sediment bar elevation and backwater availability, but did not address or evaluate backwater quality.

Response 31-31: This comment is not directly applicable to the EIS. Any modifications to the Biological Opinion would be made by the U.S. Fish and Wildlife Service, and it would be inappropriate to speculate on such actions within this EIS. Western must comply with the operational constraints and requirements of the Biological Opinion in its current form, which identifies the target area as Jensen. Should the U.S. Fish and Wildlife Service change the target location, Western hydropower operations would change accordingly. The EIS contains a complete discussion of potential impacts to ecological resources from the dam to Jensen and, thus, includes consideration of areas upstream of this target location.

Response 31-32: Western developed hydropower operational scenarios that were in compliance with the Fish and Wildlife Service's Biological Opinion for the Operation of Flaming Gorge Dam. This Biological Opinion identified seasonal release patterns that were designed to be protective of endangered fish in the Green River. Release patterns that comply with the Biological Opinion differ in a number of ways from those described in the comment. Unless a new Biological Opinion were issued, there would be no purpose for Western to evaluate other operational scenarios.

Response 31-33: We agree that use values for angling and white-water rafting would be considerably higher for the seasonally adjusted steady flows scenario. The values reported in Section 3.1.2 of the EIS are estimated for historical operations. As Table 4.12 shows, use values for angling and white-water boating are higher for the seasonally adjusted steady flows alternative under most hydrologic conditions.

Response 31-34: High-reliance utilities are the focus of the discussion of impacts because any changes in the cost of Western power are likely to have a more significant impact on retail rates charged by these utilities than on rates charged by low-reliance utilities. As the commenter notes, the high-reliance utilities consume less than a quarter of all power received from Western. As suggested, additional text has been added to Section 4.1.1.2 to emphasize this point.

Response 31-35: Section 3.3.2.1 of the EIS has been revised to indicate more clearly that the presence of the dam has greatly reduced the peak flows in the river. Section 3.4.2 of the EIS includes a detailed discussion of the effects that the dam has had on the downstream ecological resources.

Response 31-36: As mentioned in Section 3.3.2.1 of the EIS, water years 1983 and 1989 represented the wettest and driest years (respectively) for which data were available. Those years were used in the calculations to represent extreme conditions. To further emphasize this point, the text has been revised to indicate that those years were chosen to represent extreme, worst-case conditions, and a reference back to Section 3.3.2.1 has been added to Section 4.2.3.2.

Response 31-37: In Section 3.3.2.2, the Browns Park reach of the Green River is described as having extensive alluvial banks and beds. It would not be surprising if the sediment was sufficient to sustain a number of high-flow events. The text in Section 3.3.2.2 has been modified to state clearly the extensive nature of the sediment deposits in Browns Park.

Response 31-38: The gages in the Green River are owned and operated by the U.S. Geological Survey.

Response 31-39: The EIS identifies the effects of Flaming Gorge Dam on the native fish community of the Green River above and below the confluence of the Yampa River. Results of human activities, including creation of fluctuating flows from hydropower operations, are identified in Section 3.4.2.1.1 of the EIS as possible causes for the loss of native fish larvae. Impacts associated with Flaming Gorge Dam and Reservoir on the native fish fauna of Lodore Canyon are addressed in Section 3.4.2.1.1 of the EIS and in the supporting technical memorandum by Hlohowskyj and Hayse (1995). The EIS provides a reference for limited spawning of native fish in Lodore Canyon. The text of the EIS has been revised to more clearly indicate that the reproduction that occurs in the canyon is limited solely to nonlisted native species. Section 3.4.2.3.1 has also been revised to state that no successful reproduction by listed species is known to occur in the Green River above the Yampa River confluence, and that reproduction in this reach of the Green River is limited by cold water temperatures.

Response 31-40: We acknowledge that fluctuating flows can affect spawning success and survival of emergent trout by stranding spawning adults, exposing eggs or fry, and reducing the quality of individual spawning sites. Section 3.4.2.1.1 has been modified to include information about the effects that daily and hourly fluctuations can have on trout.

Response 31-41: Absence of suitable habitats and decreased food resources as possible causes for the loss of native fish larvae has been added to the discussion in Section 3.4.2.1.1 of the EIS. Section 3.4.2.1.3 has also been revised to state that flooded bottomland habitats represent areas of high invertebrate production and may serve as important feeding habitat for fish.

Response 31-42: The historical aspects of the macroinvertebrate community in the Green River are captured in the Annear (1980) reference in the EIS, which discusses the Pearson study. Although the referenced study showed a loss of invertebrates, this loss was due to the closure of the dam, not to hydropower operations. Addition of the Pearson reference would not affect the conclusions of the EIS.

Response 31-43: The text of Section 3.4.2.2.2 of the EIS has been revised to mention the otters reintroduced to Dinosaur National Monument in 1991.

Response 31-44: Section 3.4.2.2.2 of the EIS has been modified to include Whirlpool Canyon in the range of bighorn sheep within Dinosaur National Monument. It is unlikely that any of the scenarios would affect inbreeding within this population. All scenarios feature a daily period of low flows during which the sheep could cross the river. In addition, dispersal of animals generally does not occur during the breeding season, but rather before the young are born in the spring. This dispersal would have the greatest effect on inbreeding in the population.

Response 31-45: The text of Section 3.4.2.3.1 has been changed to indicate that six listed fish species occur in the area.

Response 31-46: Section 3.4.2.3.2 of the EIS has been changed to indicate that whooping cranes have been observed in the vicinity of Jensen, Utah.

Response 31-47: The statement in Section 3.4.2.3.2 of the EIS that use of the Green River by bald eagles is relatively recent has been removed.

Response 31-48: Although archaeologists have inspected the Canyon of Lodore and archaeological sites are reported from the high bedrock surfaces above the canyon, a 100% survey has not been conducted in the canyon. The text of Section 3.5.2.2 of the EIS had been modified to avoid the implication that all of the study area has been subject to 100% survey and to more clearly state that the assessment is based on the assumption that no archaeological sites could occur in the canyon because of the absence of available geomorphic settings (i.e., lack of floodplain).

Response 31-49: A study conducted by Pratt et al. (1991) for the U.S. Forest Service indicated that it was the elimination of restrictive regulations in 1985 that led to the increase in the popularity of trout fishing below Flaming Gorge Dam. The U.S. Forest Service manages the segment of the river containing most of the trout angling available in the affected area. Penstock modifications may have resulted in larger trout, but we believe that the elimination of restrictive regulations was most important in boosting the popularity of angling in the late 1980s and early 1990s.

Response 31-50: Section 3.7.2.1 of the EIS has been revised to indicate that nonangler boating is less popular than angler boating. Although the popularity of nonangler boating has probably increased since the 1991 study by Pratt et al., boating anglers still account for at least three times as many user days as nonanglers.

Response 31-51: Empirical evidence that supports the statement in the EIS can be found in the study by Shelby et al. (1992), which examined the relationship between flow and perceived quality on the Colorado River. When data are not available for an EIS, the professional opinions of knowledgeable individuals are often used to make determinations of impact. The statement regarding the safety of flows above 6,000 cfs was based on conversations with an official with the U.S. Forest Service, which administers the stretch of the Green River described in the text. The individual is responsible for managing departures on the river below the dam.

Response 31-52: The commenter is correct in pointing out that angling takes place on and near the river throughout the year. Section 3.7.2.1 of the EIS has been revised to indicate year-round use.

Response 31-53: A statement indicating the potential for canoeing and other types of flatwater boating in the Browns Park National Wildlife Refuge has been added to Section 3.7.2 of the EIS.

Response 31-54: The additional data on total number of visitors to Dinosaur National Monument and rafting permit applications are consistent with the trend established by the data for earlier years. These data do not change our conclusions regarding supply versus demand for rafting permits. Regarding the effects of 800-cfs flows on rafting, the statements of the commenter do not differ appreciably from the discussion in the text.

Response 31-55: This description of the "typical" flow on the Green River above the Yampa confluence is applicable to historical operations and flows associated with the Biological Opinion. The Biological Opinion served to formalize this typical flow.

Response 31-56: Section 3.7.2.2 of the EIS has been revised to indicate the specific number of primitive campsites and group sites. The description of the Split Mountain drive-in campground has been changed to reflect that it has been closed "in recent years" instead of "seasonally."

Response 31-57: The EIS has been changed to identify the particular reaches of the Green River that contain visual intrusions. Although visual resources on the Green River in Dinosaur National Monument have not been inventoried, the segment of the river running through Dinosaur National Monument meets all criteria for designation as a wild river under the Wild and Scenic Rivers Act. Implicit in such a designation is a lack of obvious man-made intrusions.

Response 31-58: It is true that supply options A and B would not comply with Endangered Species Act requirements, specifically the biological opinions for operation of Glen Canyon and Flaming Gorge dams. At the time the socioeconomic analyses were conducted, these biological opinions had not been issued. Use of these supply options enabled the establishment of a range of economic impacts. The economic impacts of supply options that are in compliance would be within this range. Also, see the response to comment 31-29.

Response 31-59: The impacts of each alternative on expenditures on electricity by individuals in different household income groups were evaluated for the EIS. The EIS has been revised to make this clear. The results of this analysis are described in sufficient detail in the supporting documentation (Allison and Griffes 1995) to permit calculation of income impacts in any given year, subregion, or income class, as desired.

Response 31-60: Tables 4.26 and 4.27 present the maximum adverse impacts of each alternative for each crop and state to show that the effects of the worst-case scenario would be of minimal significance. Additional information is provided in the supporting technical memorandum by Edwards et al. (1995) that permits a comparison of the impacts of the various alternatives on irrigated agriculture for a range of crops in each of the four states used in the analysis.

Response 31-61: We do not believe that it would be appropriate to exclude Rio Blanco County in Colorado and Uinta County in Wyoming from the analysis. We disagree with the recommendation for a number of reasons. It is not clear that recreation has little to do with the economies in these counties. In fact, some of the major roads to the Flaming Gorge Dam area pass through these counties. Thus, it is reasonable to expect that recreation-related expenditures on such items as food, gas, and lodging occur in these counties. Second, on the basis of employment data, the four remaining counties account for approximately 75% of the total economic activity in the six-county region. Thus, exclusion of the two counties in question is likely to materially affect the results reported in the EIS. No regional economic impacts are reported because the assumption was made that use rates would be unaffected by the operational scenarios included in the EIS. As such, the issue is largely moot.

Response 31-62: We do not disagree with the commenter's contention that steady flows are preferred to fluctuating flows by boaters and anglers. However, there is a reasonable question as to what constitutes fluctuating flows in the minds of many recreationists, as is suggested by the results of the attributes surveys conducted by Bishop et al. (1987). Thus, a decision had to be made whether to classify flows entailing some amount of change over a 24-hour period as "fluctuating" or "steady." This issue was considered especially relevant in those cases in which changes in flow occur during the middle of the night, as opposed to daylight hours (which is when most water-related recreation activities occur). On the basis of the hydrological data developed for the EIS, most fluctuations in flows within Dinosaur National Monument occur during non-daylight hours. According to the decision rule that was developed for the analysis of recreation use values, flow levels were treated as constant so long as the levels were not predicted to fluctuate more than 20% between 7 a.m. and 3 p.m. at the Gates of Lodore. Data on flows were then combined with use value functions and use rates to determine the use value of each recreational activity for each operational scenario. A detailed description of the method used is provided in the supporting documentation by Carlson (1995).

Response 31-63: See response 31-62.

Response 31-64: As noted in response 24-46, in the EIS, net erosion is considered to be the removal of sediment from a given river reach. While the banks and bed of the Green River in this area are extensive, net erosion is occurring. This erosion is evident from the numerous cut banks that line the reach, the high water turbidity, and the lack of a sediment source above the confluence of Red Creek. While it appears likely that the quantity of sediment can support high flows for a number of years, no revision to the EIS is required because of the similarities in predicted results.

Response 31-65: We feel that seasonally adjusted steady flows would provide only slight improvements over seasonally adjusted moderate fluctuations for the following reasons. Overwinter survival could be higher under seasonally adjusted steady flows than under seasonally adjusted moderate fluctuating flows because no daily fluctuations would occur throughout the winter under steady flows. (The seasonally adjusted moderate fluctuation scenario would feature steady flows in February and March.) However, this situation would primarily affect fish spawned in the river because the size of trout stocked in the Green River tailwater under current management practices allows a high survival rate for stocked fish. Although both operational scenarios provide similar amounts of seasonally wetted habitat during spawning, the absence of daily fluctuations under the seasonally adjusted steady flows scenario could result in slightly higher hatching success. Differences in growth rates between the two scenarios could be virtually undetectable because Green River trout already exhibit exceptional growth rates. Tables 4.23 and S.7 have been revised to assign a slight to moderate benefit to trout under the seasonally adjusted steady flows operational scenario.

Response 31-66: The discussion of native fish in Section 4.2.4.2.1 of the EIS acknowledges that use of the Canyon of Lodore by native fishes could increase only slightly under the seasonally adjusted moderate fluctuating flow and steady flow scenarios and that reproduction in the canyon would continue to be limited by releases of cold water from the dam.

Response 31-67: The analyses in the EIS are based on the assumption that the greater the daily fluctuation in flow and stage, the greater the potential for adverse impacts to native and endangered fishes. However, the mathematical relationships between fluctuating flows and impacts to native and endangered fishes are not known at this time. Although daily fluctuations would be greatly reduced or eliminated under the seasonally adjusted moderate fluctuation and steady flow scenarios, water temperature would be largely unaffected and would continue to limit reproduction and habitat use through the Canyon of Lodore. Below Echo Park, water temperature is no longer the limiting factor for native and endangered fish reproduction, and there is little difference in daily flow and stage fluctuations in nursery areas between the moderate fluctuation and steady flow operational scenarios. For these reasons, there is no scientifically based reason to assign greater benefit to the seasonally adjusted steady flow scenario.

Response 31-68: The EIS states that competition and predation by introduced warmwater species could be reduced in Dinosaur National Monument, but only in certain canyon-bound areas of the river. The EIS further states that little or no decrease in the diversity or abundance in introduced fishes is expected in broad floodplain reaches such as Island Park in Dinosaur National Monument or at Jensen. An increase in competition and predation by introduced species in broad floodplain areas is a realistic concern and is a reasonable and possible outcome of increased habitat stability in the Green River. A similar concern has been raised for the Colorado River below Glen Canyon Dam, and research is being conducted to evaluate the response of introduced fish populations to the interim flow operations currently in place for Glen Canyon Dam. Similarly, competition and predation between introduced and native fish and the response of introduced fish to different flow regimes and increased backwater habitat stability are specific research areas identified in the Biological Opinion for Flaming Gorge Dam operations. Given the current state of knowledge, it would be inappropriate to eliminate discussion of these potential adverse effects of steady flows.

Response 31-69: The assessment of impacts of the operational scenarios on woody riparian vegetation does not address differences in impacts to native and non-native species. The assignment of a slight benefit to the seasonally adjusted steady flow scenario results from the estimated 13% increase in area available to all species of woody riparian vegetation, regardless of origin.

Throughout the EIS, the assessment of impacts to marsh vegetation refers to the impact on that vegetation community as a gain or loss of area available. It does not address the issue of whether this impact would simulate natural conditions and therefore be desirable to the National Park Service.

Response 31-70: Comment noted.

Response 31-71: Maximum releases from Flaming Gorge Dam define a high-water line along the Green River, and Canada geese typically nest above this high-water line. An increase in the maximum release from 4,200 to 4,700 cfs would produce a 6-in. increase in the elevation of the high-water line. This slight increase would be expected to have minimal effect on existing nesting areas.

Response 31-72: A reference to Appendix D has been added to the EIS. Section D.2.1.2.2 of Appendix D addresses the possible benefits of steady flows on introduced fish and cites a variety of references, both general and specific to the Green River, on the life history requirements (including spawning habitat, diet, and growth) of the introduced fish species found in the Green River. Also see the response to comment 31-68 regarding (1) flows in canyon-bound river reaches such as the Yampa River and broad floodplain reaches such as Island Park and Jensen and (2) the potential effects of flood flows on (and responses of) introduced fish in these areas.

Response 31-73: There is no scientific basis for assigning an increased benefit level for the steady flow operational scenario. The benefit levels assigned to operational scenarios in the EIS are based on evaluation of currently available scientific information developed by a variety of federal, state, and academic researchers, in addition to research and analyses performed specifically for the EIS.

Response 31-74: The comment correctly identifies the potential for humpback chub to spawn in Whirlpool Canyon. The EIS has been revised to state that none of the operational scenarios would affect known spawning areas. Text has been added to discuss possible spawning in Whirlpool Canyon and assess possible impacts from each of the operational scenarios to spawning in this canyon. No change has been made in the benefit assigned to the seasonally adjusted steady flow scenario. This scenario has been assigned a moderate to high potential benefit to humpback chub, and in the absence of documented spawning in Whirlpool Canyon, this benefit level is appropriate.

Response 31-75: There is very little difference in stage stability and backwater area and stability between the seasonally adjusted moderate fluctuating and steady flow scenarios in areas downstream of the Yampa River where endangered fish typically occur. For this reason, the impacts of these two scenarios on endangered fish are expected to be very similar.

Response 31-76: See response 31-25.

Response 31-77: As is the case with the Ute ladies-tresses orchid, these species occupy riparian habitats and require relatively high soil moisture. It is unclear whether existing populations of these species are dependent on the maximum daily flows produced by hydropower; this would depend on the elevation of the plants above the river. If populations are located above the maximum flow level, as suspected, but are dependent on soil moisture levels maintained by these flows, they may not be able to tolerate the low summer flows of the seasonally adjusted steady flow scenario. Because of this uncertainty, potential adverse effects are assigned to this scenario, and monitoring of these populations is suggested.

Response 31-78: None of the operational scenarios evaluated in the EIS would favor regeneration of cottonwoods along the Green River because the required flows are above power plant operational capacity and, thus, are outside of Western's control and beyond the scope of the EIS. Reducing fluctuation during the winter months, as would occur under all seasonally adjusted scenarios, would result in a reduction in or elimination of open water, especially below the Gates of Lodore, and thus could adversely affect wintering bald eagles, which are attracted to open water. For this reason, a moderate adverse impact to the eagles is expected with all scenarios featuring seasonally adjusted flows. It is unclear how regeneration of roost trees would benefit the eagles, as suggested in the comment, if suitable foraging conditions no longer existed along the river.

Response 31-79: While steady flows generally are preferred to fluctuating flows, the absolute flow level also matters. Thus, both factors must be considered in assessing the relative impacts of alternative flow scenarios on recreation. We considered both factors in assessing the impacts of the different operational scenarios considered in this EIS. The result of considering both factors is that in some cases, operational scenarios involving fluctuating flows were predicted to have more beneficial impacts than steady flows.

Response 31-80: See response 31-26 for that part of the comment related to the effects of fluctuations on trout growth and recruitment. Regarding safety, the commenter is correct in identifying safety issues related to fluctuating flows. However, consultation with the U.S. Forest Service (which administers the river segment where most of the trout angling occurs) indicates that higher flows, especially those that would occur in May and June under the seasonally adjusted steady flow scenario, would pose a safety threat to all anglers (particularly all shore anglers), not just those who cross the river and become stranded during periods of low flow. Consequently, the steady flow scenario does not appear to offer clear safety advantages over the fluctuating flow scenarios considered in the EIS.

Response 31-81: As was discussed in response 31-79, flow levels are also an important determinant of the quality of white-water boating. It is reasonable to expect that there is trade-off between the frequency and timing of fluctuations and flow levels. In the EIS, this trade-off is taken into account and results in a determination that operational scenarios with higher fluctuations have greater benefits than the steady flow scenarios at certain times of day and year. These conclusions are based on the results of surveys conducted for the Glen Canyon EIS.

Response 31-82: The estimates of nonuse values presented in Section 4.2.1.2.2 of the EIS capture the effects of flow variation on the recreational experience. The higher values associated with the seasonally adjusted steady flows scenario reflect the effect of a more natural flow regime.

Response 31-83: The EIS states that the seasonally adjusted steady flow scenario has the highest minimum flows, thus resulting in fewer adverse low-flow impacts (stranded debris, historic "bathtub" ring, etc.). However, we do not believe that the variety of scenes presented by this operational scenario offers a visual value necessarily higher than those associated with other operational scenarios. A viewer's assessment of a particular visual resource is multidimensional; a "satisfying" view is comprised of many elements. Fluctuating flows that result in the exposure of sand bars or other natural features for part of a day should not be considered adverse because such features could be considered attractive to certain viewers. Consequently, the operating scenarios that feature daily fluctuations also offer a variety of scenes.

Response 31-84: Section 4.4.1 of the EIS has been revised to indicate that exceeding normal operating parameters could have adverse ecological and recreational impacts. Such impacts would be fully considered before any exceedance.

Response 31-85: Section 4.4.2 of the EIS has been revised to include releases above power plant capacity as possible mitigation for hydropower operations at Flaming Gorge Dam.

Response 31-86: Although it is true that establishment of a new population of humpback chub is a recovery activity that should be accomplished regardless of the operational scenarios selected, establishment of such a population would mitigate the adverse effects of hydropower operations on this species.

Response 31-87: See response 31-29.

Response 31-88: See responses 31-25 and 31-78.

Response 31-89: Section 7 of the EIS has been revised to indicate that occasional flows above power plant capacity may be required at Flaming Gorge Dam to restore high- elevation sediment deposits, maintain high-elevation riparian communities, and maintain productivity of backwater habitats.

Response 31-90: The text in Sections S.6.2 and 3.2.2 of the EIS describing nonattainment areas states that the major population centers are designated as nonattainment areas with respect to one or more of the National Ambient Air Quality Standards. The text has been modified to emphasize that (1) the region as a whole enjoys good ambient air quality, with a large number of Class I areas where air quality degradation is stringently limited under the Prevention of Significant Deterioration regulations; and (2) nonattainment areas are limited to major population centers and some of their suburbs, while all remaining areas of the region are designated as either in attainment or unclassified.

Response 31-91: Reference to Grand Canyon National Park has been removed from Section S.6.3 to make the description of the affected environment for Glen Canyon Dam comparable to those for Flaming Gorge Dam and the Aspinall Unit.

Response 31-92: The text of the EIS has been modified to replace the reference to the Southern Paiute with a reference to the three tribes mentioned in the comment.

Response 31-93: The text in Section S.7 has been changed to include energy conservation as an additional means of providing more generating capacity.

Response 31-94: Section S.8.1 of the EIS has been modified as suggested to clarify that adverse impacts have occurred to many resources.

Response 31-95: Section S.8.1 and the other relevant portions of the EIS were modified to maintain consistency with the latest version of the Glen Canyon EIS.

Response 31-96: Although the terminology used in the Power Marketing EIS for describing impacts to humpback chub in the Colorado River below Glen Canyon Dam is different from that used in the Glen Canyon Dam EIS (GCDEIS), the information presented in the GCDEIS was used in determining the appropriate impact designation in the Power Marketing EIS. We feel that a designation of "slight adverse impact" for the restricted high fluctuating flows operational scenario is warranted given the status of the humpback chub. The analysis for Glen Canyon Dam concluded that the restricted high fluctuating flow operational scenario would continue to constrain growth rates and reduce survival of humpback chub because of a lack of warm nursery areas and continued cold main channel temperatures; potentially restrict access to some tributaries during low flow periods; produce large (7- to 8-ft) daily stage changes during July and August in river reaches of primary importance to larval and juvenile humpback chub; and would be less conducive than other restricted fluctuating flow scenarios for development of backwater habitats. However, it appears that the humpback chub population has been relatively stable under fluctuating flows, probably because of continued reproduction and recruitment in the Little Colorado River. Because survival of larvae and recruitment within the main channel are presently less important than within the Little Colorado River, the potential negative impacts of fluctuating flows are considered slight.

Response 31-97: The Glen Canyon Dam EIS used a variety of impact descriptors, as indicated in the comment. However, impact levels of slight, moderate, and large were used in the Power Marketing EIS to maintain consistency among the facilities evaluated. The impact assessments presented in the Glen Canyon Dam EIS were used as the basis for making the determination of slight, moderate, or large impact for the Glen Canyon Dam operational scenarios.

Response 31-98: As discussed in the response to comment 31-97, the findings presented in the Glen Canyon Dam EIS were used in making the determination of the level of adverse impacts or benefits presented in the Power Marketing EIS. The terminology used in this EIS is different from that presented in the Glen Canyon EIS to provide for consistency among facilities and to facilitate a comparison of operational scenarios. Current conditions, even if degraded relative to pre-dam conditions, were used as the baseline for all facilities. A reduction in degradation was considered a benefit in the Power Marketing EIS relative to current conditions.

Response 31-99: The text of the EIS has been modified as recommended in the comment to reflect the status of the isolated finds as specified in the Programmatic Agreement on the Operations of Glen Canyon Dam.

Response 31-100: The text of the EIS has been modified to refer to the Ross Wheeler as a "boat," not a wreck, reflecting its intact condition.

Response 31-101: See response 30-3.

Response 31-102: The text has been revised to indicate that the affected area below Glen Canyon Dam extends along the Colorado River from the dam to the headwaters of Lake Mead, a length of river approximately 290 mi long.

Response 31-103: The text has been changed as suggested. According to local government officials, Page is located on a mesa above both the Colorado River and Lake Powell.

Response 31-104: The incorrect statement indicating that the Navajo Nation controls 2% of the park has been removed from the EIS.

Response 31-105: The reference to Bright Angel has been removed from Section 3.7.1 of the EIS.

Response 31-106: The recommended editorial changes have been made, and the statement indicating that the NPS does not have a landscape classification program has been deleted from the EIS.

Response 31-107: The text of the EIS has been modified to state that a 100% Class I inventory of the river corridor between Glen Canyon Dam and Separation Canyon has been conducted.

Response 31-108: Hydropower operations would have adverse effects on archaeological sites, but as the EIS states, "no adverse effects to *specific* sites (italics added) have been explicitly linked to hydropower operations" (Section 4.2.5.1.1). However, comparisons of general impacts to archaeological sites among the hydropower operational scenarios addressed in the EIS are presented in the same section.

Response 31-109: The Glen Canyon Dam EIS and supporting documents do not tie adverse effects to specific archaeological sites and to Native American cultural resources to the hydropower operational scenarios considered in the EIS. Although it has been established that dam operations have affected sites, these impacts have yet to be tied to hourly fluctuations caused by hydroelectric generation, and it is difficult to isolate these effects from those of other processes (such as the long-term downcutting action of the Colorado River in Glen Canyon). For this reason, the Glen

Canyon Dam EIS is referenced in Section 4.2.5.1 only with respect to general impacts to archaeological sites and Native American cultural resources.

Response 31-110: Information on the percentage of Western's customers that are high and low reliance is presented in Section S.6.1.

Response 31-111: See response 31-25.

Response 31-112: A description of the hydropower operational scenarios evaluated in the EIS for these facilities is provided in Section 2.3 of the EIS. Western's Record of Decision will include identification of a commitment level, as well as operational limits, at these hydropower facilities.

Response 31-113: The EIS has been revised to provide a more detailed description of how Western identifies capacity and energy commitment levels.

Response 31-114: Hourly fluctuations in water releases due to hydropower generation would produce virtually undiscernible daily fluctuations in reservoir elevation because of the large reservoir capacity. Surface water elevations would change on a monthly basis, but these changes would be due to reservoir management activities and water delivery and storage requirements that are the responsibility of the Bureau of Reclamation and largely unrelated to hydropower operations.

Response 31-115: The summary of recreational impacts in Table 2.6 of the EIS has been revised to indicate no change from current conditions, rather than no impact, under the continuation of historical flows operational scenario.

Response 31-116: According to the Glen Canyon Dam EIS, the two counties referred to in the text are the only two counties that were included in the regional economic analysis of recreation impacts.

Response 31-117: See response 31-41.

Response 31-118: Section 3.4.2.2.1 of the EIS has been modified to state that although the contribution of the unregulated Yampa River results in a more natural flow regime in the Green River, spring floods are still much reduced from pre-dam conditions.

Response 31-119: Whirlpool Canyon is located below the Yampa River confluence and therefore is not included within the affected area for Flaming Gorge Dam as defined in Section 3.5.2.2.

Response 31-120: The only canyon in Dinosaur National Monument that is within the affected area for Flaming Gorge Dam is Lodore Canyon. Few, if any, archaeological remains are likely to occur (especially remains in an undisturbed context) in Lodore Canyon because of the absence of available geomorphic settings for such remains. Portions of Echo Park have been surveyed, and three sites are located upstream of the Yampa River confluence; one of these sites is included in the affected area and is mentioned in Section 3.5.2.2 of the EIS.

Response 31-121: Section 3.6.2 of the EIS already states that most of the Green River corridor in Dinosaur National Monument is being considered for designation as wilderness.

Response 31-122: Air pollutant emissions from all projected new units, including peaking, intermediate, and baseload units, have been estimated for the annual capacity factors projected for the no-action alternative and the projected percent changes in the annual capacity factors for three other commitment-level alternatives. These projections were obtained from the results of power systems modeling performed for this EIS.

Response 31-123: No estimate of nonuse value was actually assigned to the resources in question. Rather, the description of the affected environment included a possible estimate of the *lower-bound* on nonuse values associated with the environments below Glen Canyon Dam and Flaming Gorge Dam. It is incorrect to assume that consideration of nonuse values associated with hydropower generation falls outside the criteria used in the EIS to identify nonuse values. As is discussed in Appendix A, Section A.6, the potential exists for nonuse values to be associated with a number of different resources. Hydropower generation of electricity is one such resource. In order to eliminate any confusion regarding the definition of nonuse values and the variety of situations in which nonuse values might arise, discussion of nonuse values in this section of the EIS has been expanded and clarified.

Response 31-124: The difference between emission projections made for the end of the modeling period with the EGEAS/ELFIN modeling system and those made by ANL with its PACE modeling system is caused by the difference in the procedures and assumptions used in estimating the total regional emissions. One of the primary reasons for the difference is that the EGEAS/ELFIN model runs accounted for the emissions associated with power generation but did not account for the emissions associated with power purchases by utilities. The model used by ANL accounted for both. Possible differences in capacity expansion plans used in the two modeling studies may also have contributed to the difference in emission projections at the end of the modeling period.

Response 31-125: Although the mesa country surrounding the Aspinall Unit is highly erosive, and spring runoff flows in the Gunnison River can discharge large quantities of sediment, most of the sediment would be deposited in Blue Mesa Reservoir. Little sediment would remain to enter Morrow Point Reservoir or the Aspinall Unit except for that locally generated. Because none of the operational scenarios would significantly affect water levels in Blue Mesa Reservoir, impacts to sediment for the Aspinall Unit would be slight. For clarity, the text stating that releases from Blue Mesa and Morrow Point do not traverse any sediment-bearing intermediate reaches has been removed.

Response 31-126: Although the federal responsibilities of the National Park Service (as well as the responsibilities of other federal agencies that manage potentially affected lands and other resources) are not limited to a fixed time period, the EIS addresses the environmental consequences of a power marketing program that extends for a period of 15 years. The effects of hydropower operations related to the power marketing program after this 15-year period are beyond the scope of this EIS.

Response 31-127: A change of 0.1 ft (1.2 in.) would not have a measurable impact on archaeological sites located along the shoreline of Blue Mesa. Adverse effects to these sites cannot be linked to the hydropower operation scenarios under consideration in this EIS.

Response 31-128: Various land use control documents that govern the affected area, such as general management plans, statements of management, and resource management plans, were reviewed for possible conflicts resulting from operational scenarios. In addition, officials with the BLM, USFS, and State of Utah were consulted regarding potential impacts to land use. None were found, and the EIS reflects this finding.

Response 31-129: The EIS states that the cumulative impacts associated with construction and operation of the dam were considered in the analysis of the impacts of the different operational scenarios on recreation as presented in Section 4.2.7. Moreover, as is stated in the EIS, the impacts of going from one flow regime to another were also considered in the analysis.

Response 31-130: While we agree that there may be some substitution among recreation sites as a result of a change in dam operations at a particular location, we do not believe that it can be asserted, without qualification, that "there is interaction and dependency of recreation among the three facilities." Given the distance between each of the facilities and the other two, we believe it is unlikely that there would be substitution among these three facilities. Rather, it is much more reasonable to expect that other sites with similar characteristics would be substituted for the site in question. However, given the uncertainties surrounding this issue, the text in Section 5.7 has been modified to suggest that a limited amount of interaction may in fact occur, but that the cumulative effects would likely be minimal.

Response 31-131: The portion of the Black Canyon of the Gunnison identified by the commenter as designated wilderness was not included because it does not lie within the designated affected area of the Aspinall Unit.

Responses to Carl R. Albrecht, General Manager, Garkane Power Association, Inc., Richfield, Utah (Comment Document 32)

Response 32-1: Comment noted.

Response 32-2: See response 4-2.

Response 32-3: See response 4-4.

Responses to R.D. Justice, Vice-Chairman, Manager, Electric District Number Seven, Waddell, Arizona (Comment Document 33)

Response 33-1: Comment noted.

Response 33-2: See response 4-4.

Responses to Q.L. "Van" Tenney, General Manager, Electrical District No. 3, Stanfield, Arizona (Comment Document 34)

Response 34-1: Comment noted.

Response 34-2: See response 4-4.

Responses to Thomas C. Jensen, Executive Director, Grand Canyon Trust, Flagstaff, Arizona (Comment Document 35)

Response 35-1: One of the benefits of Western's broad marketing considerations in this EIS is that it provides a forum for public consideration of appropriate levels of commitment under circumstances in which SLCA/IP power plant operations are restricted. Moreover, the Grand Canyon Protection Act certainly concedes to Western the legal authority to study possible commitment levels that exceed its resources.

Response 35-2: The focus of Western's SLCA/IP Electric Power Marketing EIS and Reclamation's Glen Canyon Dam EIS are different. The power marketing EIS alternatives are commitment-level alternatives and are related to Western's need to establish commitment-levels in their power marketing program. The Glen Canyon Dam EIS, however, establishes operational alternatives related to ways to operate Glen Canyon Dam. Western markets power from not only Glen Canyon Dam but also 11 other dams. In addition, Western purchases power from regional utilities. There is consistency, however, between the Glen Canyon hydropower operational scenarios evaluated in the Power Marketing EIS and the Glen Canyon Dam EIS alternatives. It is at this level that consistency is required.

Response 35-3: Preparation of the EIS was undertaken as part of a public process. The general public was informed of Power Marketing EIS activities through Federal Register notices, public meetings, draft documentation, and information circulars distributed by Western. In addition, ANL and Western met with representatives of the Colorado River Energy Distributors Association (CREDA) to discuss ANL data requirements and preliminary modeling methodologies to be used in the EIS process. After these meetings, CREDA agreed to provide proprietary data to ANL on the condition that ANL allow individual utility systems to review preliminary model runs of the no-action alternative. Throughout the modeling process, ANL power system analysts contacted CREDA utility systems as questions regarding data, operations, and transmission constraints arose. A methodology document and modeling results for the no-action alternative were sent to individual CREDA member utility systems for review and comment. Near the end of the EIS review process, two CREDA members and a CREDA consultant visited ANL to review final model results for all power marketing alternatives. One ANL staff is also a member of the Glen Canyon Dam Power Resource Committee (PRC). Other members of the PRC include Bureau Of Reclamation staff, CREDA representatives, Environmental Defense Fund (EDF) staff, and private consultants. At PRC meetings, members would periodically hold discussions that compared the PRC methodology to that used for the EIS.

Several quality assurance measures were used to verify the results produced by the models used for the analysis of power systems and financial and rate impacts. While almost all of the data that were used for the power systems modeling were provided by individual utility systems, information in the public domain was used to cross check the data supplied by utility contacts. Where discrepancies were encountered, ANL staff contacted the utility to uncover the source of the discrepancies. Some discrepancies were found in historical peak loads reported in public sources compared with the highest hourly load that was supplied by a particular utility system because of load diversity among member systems. In some cases, there were minor data discrepancies for heat rates for jointly owned units. In these cases, data from the operating utility system were used. It was not possible to cross check all of the data with publicly available information because of its proprietary nature. For example, information on specific contract terms are not available in public documents. In these cases, ANL researchers only judged if the data were reasonable. Data inputs and initial model results for all large Western customers were sent to individual utility system contacts for their review and comment. Almost all of the suggestions made by utility system contacts were incorporated into the final results. Other suggestions would have made only very minor changes in the final results and did not effect final study conclusions. In all cases, except for projected load growth (see response 24-151), ANL used data that were supplied by the utility system. Model results were also evaluated for consistency by outside reviewers experienced in the analysis of utility power systems models and data.

For the analysis of utility financial viability and rate impacts, the models were calibrated with historic data published by the Rural Electrification Association, the Energy Information Association, and the Federal Energy Regulatory Commission. Quality checks used for the model results were comparisons of model output with existing individual utility balance sheets and the percentage of power purchased from Western. Model results were also evaluated for consistency by outside reviewers experienced in the analysis of utility financial models and data.

Response 35-4: Data provided to the Power Resources Committee (PRC) of the Glen Canyon Environmental Studies by Dave Onstad were used for the analysis of the cost of replacement power in the modeling of small utility systems in the EIS. After review of the data by ANL, Western, and the PRC, it was concluded that the information was a more accurate reflection of replacement power costs for small utility systems than were the auxiliary supplier cost data produced by the PACE and ICARUS modeling of the large utility systems by ANL.

Response 35-5: See response 35-4.

Response 35-6: The rates reported in Table 4.1 demonstrate that hydroelectric release patterns have a clear impact on rates, with the more restricted releases having a higher impact. However, the impact of each commitment-level alternative is not entirely related to the energy and capacity characteristics of each alternative. Specific characteristics of individual utility systems also influence the magnitude of changes in rates. These characteristics are load growth, incremental cost of capacity and energy, reliance on Western, and the rates Western charges its customers. The impacts of each of these factors, in addition to the impacts of changes in energy and capacity with each alternative and supply option, are discussed in detail in the technical memorandum by Bodmer et al. (1995).

Response 35-7: Tables B.7 and B.8 in Appendix B of the EIS have been revised to present projected annual emissions for each commitment-level alternative/supply-option combination and the changes from the baseline (i.e., the no-action alternative/supply option A [high fluctuating flow] case). To facilitate comparisons among different alternatives or supply options, the average values of (1) projected emissions, (2) changes in emissions from the baseline, and (3) percent changes in emissions from the baseline, have also been added to these tables.

Section 4.1.2.1.2 of the EIS has been revised to point out that the regional total emissions of SO2 and TSP projected for alternative 5 (low capacity-high energy) show slightly higher values than the emissions for the no-action alternative, and those for alternatives 2 (high capacity-low energy) and 4 (low capacity-low energy) show slightly lower values than the no-action alternative. Although some of the projected annual emission changes from the baseline are large in terms of their absolute values, impacts on regional air quality are not expected to be significant because these emissions would be released over a very large area. Section S.7 and Table S.5 of the EIS have been revised to indicate that slight changes in regional air quality are projected for the various alternatives analyzed.

Response 35-8: See response 35-7. Section 4.2.2.1.2 of the EIS has been revised to point out that there are slight, but consistent, decreases in regional emissions in SO2 and TSP as the flow fluctuation at hydroelectric facilities is reduced from high fluctuation to low fluctuation, and from low fluctuation to steady flows.

Response 35-9: In general, we agree with the commenter's summary of rate impacts based on the sales-weighted average rate information presented in Table 4.1 of the EIS. Changes in capacity commitment cause the largest impacts on retail utility rates, followed by changes in operational scenarios, with changes in energy commitment having the smallest rate impact.

Response 35-10: See response 35-6.

Response 35-11: We agree that the use of low avoided capacity costs would make conservation programs appear less cost-effective and that no variation in avoided energy costs would make peak load management programs appear less cost-effective. Low marginal energy costs are used, however, in the analysis of utility conservation and demand-side management programs because the marginal energy costs calculated by the analysis of utility power systems were low and did not show wide variations during the day. There was also little difference in marginal energy costs between the typical system and other major systems served by Western.

The use of low avoided capacity costs and relatively invariant energy costs in the EIS, therefore, has the effect of increasing the impact of each alternative on utility capacity expansion plans by reducing the significance of utility conservation and demand-side management programs. The results of the analysis are, therefore, conservative estimates of the impacts of each alternative.

Response 35-12: The analysis of conservation and renewable energy programs undertaken for the EIS did not examine non-price-induced conservation programs, such as reducing dependence of the United States on foreign oil or improvements in the global environment. Because the nature of non-price-induced programs and the likelihood of their being adopted by Western customer utilities are not known, an evaluation of the impact of these programs is not included in the EIS.

Response 35-13: Western did no research of its own regarding the effects of alternative operations at Glen Canyon Dam. Research summaries and conclusions presented in Western's EIS regarding these effects have been taken from the Glen Canyon Dam EIS.

Response 35-14: Comment noted.

Response 35-15: Comment noted.

Response to R. Leon Bowler, General Manager, Dixie-Escalante, Rural Electric Association, Inc., Beryl, Utah (Comment Document 36)

Response 36-1: Western has identified commitment-level alternative 1 as the preferred alternative. Moreover, this alternative is incorporated into Western's proposal to implement the replacement capacity requirements of the Grand Canyon Protection Act.

Responses to William D. Woehlecke, Electric District Number Five, Pinal County, Red Rock, Arizona (Comment Document 37)

Response 37-1: Comment noted.

Response 37-2: See response 4-4.

Responses to Thomas Kip Bingham, City Manager, City of Safford, Safford, Arizona (Comment Document 38)

Response 38-1: See response 4-4.

Response 38-2: See response 23-2.

Response 38-3: Comment noted.

Response 38-4: See response 23-4.

Responses to Leonard S. Gold, Power Consultant, Ak-Chin Indian Community, Tempe, Arizona (Comment Document 39)

Response 39-1: Comment noted.

Response 39-2: See response 4-4.

Responses to James R. Sweeney, District Manager, Electric District No. 4, Pinal County, Eloy, Arizona (Comment Document 40)

Response 40-1: Comment noted.

Response 40-2: See response 4-4.

Responses to Stanley H. Ashby, Secretary, Roosevelt Irrigation District, Buckeye, Arizona (Comment Document 41)

Response 41-1: Comment noted.

Response 41-2: See response 4-4.

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