Effects of Flaming Gorge Dam Hydropower Operations on Flow and Stage in the Green River, Utah and Colorado

Environmental Assessment Division

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Effects of Flaming Gorge Dam Hydropower Operations on Flow and Stage in the Green River, Utah and Colorado

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MASTER

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FOREWORD

This report is one of a series of technical memorandums prepared to support an environmental impact statement (EIS) on power marketing prepared by Argonne National Laboratory for the U.S. Department of Energy's Western Area Power Administration (Western). 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 the states of Arizona, Colorado, New Mexico, Utah, and Wyoming.

Western proposes to establish a level of commitment (sales) of long-term firm electrical capacity and energy from the SLCA/IP hydroelectric power plants; the impacts of this proposed action are evaluated in the EIS. Of the SLCA/IP facilities, only the Glen Canyon Dam, Flaming Gorge Dam, and Aspinall Unit (which includes Blue Mesa, Morrow Point, and Crystal dams) are influenced by Western's power scheduling and transmission decisions. For this reason, the impacts of hydropower operations at these three facilities were examined in the EIS.

The technical memorandums present detailed findings of studies conducted by Argonne National Laboratory specifically for the EIS. These studies are summarized in the EIS, and the results were used to assess environmental impacts related to alternative commitment levels. Technical memorandums were prepared on a number of socioeconomic and natural resource topics. Staff members of Argonne National Laboratory's Decision and Information Systems Division and Environmental Assessment Division prepared these technical memorandums and the EIS as part of a joint effort managed by the Environmental Assessment Division.

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EFFECTS OF FLAMING GORGE DAM HYDROPOWER OPERATIONS ON FLOW AND STAGE IN THE GREEN RIVER, UTAH AND COLORADO

by

S.C.L. Yin, J.J. McCoy, S.C. Palmer, and H.E. Cho

ABSTRACT

This report presents the development of Flaming Gorge Reservoir release patterns and resulting downstream flows and stages for four potential hydropower operational scenarios. The release patterns were developed for three representative hydrologic years: moderate, dry, and wet. Computer models were used to estimate flows and stages in the Green River resulting from these release patterns for the moderate water year. The four hydropower operational scenarios for Flaming Gorge Dam were 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. The remaining seasonally adjusted flow scenarios would comply with the 1992 Biological Opinion of the U.S. Fish and Wildlife Service, which requires high flows in the spring and limited hourly fluctuations, especially in summer and autumn releases, to protect endangered fish. Within one year, the maximum daily river stage fluctuations resulting from hydropower operations under the seasonally adjusted high fluctuating flow scenario would be similar to the maximum daily fluctuations under the year-round high fluctuating flow scenario. However, reduced or no fluctuations would occur in some time periods under the former scenario. The maximum daily river stage fluctuations under the seasonally adjusted moderate fluctuating flow scenario would be about half of those under the seasonally adjusted high fluctuating flow scenario.

1 INTRODUCTION

The Western Area Power Administration (Western) markets electricity produced at hydroelectric facilities operated by the Bureau of Reclamation on the Upper Colorado River. The facilities are known collectively as the Salt Lake City Area Integrated Projects. Hydropower operations at three of these facilities are affected by Western power marketing activities: Glen Canyon Dam on the Colorado River, Flaming Gorge Dam on the Green River,

and the Aspinall Unit on the Gunnison River (Figure 1[*]). This report presents the development of release patterns and resulting downstream flows and stages for four hydropower operational scenarios proposed for Flaming Gorge Dam. The results of this study were used for assessing potential impacts of the hydropower operational scenarios on sediment transport, ecology, cultural resources, and recreation below Flaming Gorge Dam. The results of these assessments are presented in the environmental impact statement (EIS) and, in some cases, separate technical memorandums.

1.1 FLAMING GORGE DAM

Flaming Gorge Dam, completed in 1963, is part of the Colorado River Storage Project and is used for hydropower production. The dam is located on the Green River near the Wyoming/Utah border (Figure 1). The study area for this report extends from Flaming Gorge Dam to the U.S. Geological Survey (USGS) gaging station near Jensen, Utah (about 93 mi downstream of the dam). This reach was chosen to be consistent with the Biological Opinion of the U.S. Fish and Wildlife Service (USFWS 1992), which specifies flow fluctuations below the dam and target flows at the Jensen gage.

After the completion of the dam, historical spring flows that averaged about 7,000 cfs between 1951 and 1962 were reduced to about 3,000 cfs (Smith and Green 1991). Water releases from the dam for power generation have ranged from 800 to 4,200 cfs, although an upgrade of the generators allows power releases up to 4,950 cfs. The maximum power release is limited by the capacity of the turbines, whereas the lower limit is set by an agreement with the State of Utah to maintain a high-quality cold-water fishery (Smith and Green 1991). An additional 4,000 cfs 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 electric power.

1.2 GREEN RIVER BELOW FLAMING GORGE DAM

For the first 7 mi below Flaming Gorge Dam, the Green River flows through Red Canyon, a hard-rock canyon with fast currents and moderate rapids (Figure 2). 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 is about 8.5 ft/mi. 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. The river meanders through Browns Park for about 36 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. Many sandbars occur in this reach.

At the Gates of Lodore, 48 mi downstream of the dam, the Green River enters Lodore Canyon 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 about

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[*]For readability, all figures and tables are placed in sequence following Section 3 of this report.

13 ft/mi. Lodore Canyon ends in Echo Park where the Green River is joined by the Yampa River (about 65 mi below the dam), its main tributary in the study reach. At Echo Park, the combined flows of the Green and Yampa rivers enter Whirlpool Canyon. Farther downstream, the river meanders through open country in Island Park and Rainbow Park. Many wooded islands are present in this reach. At Split Mountain Canyon, the current again quickens as the river enters another hard-rock region. Below Split Mountain Canyon, the river enters a cultivated valley and flows slowly for the next 100 mi. Jensen, Utah, is about 18 mi below Split Mountain Canyon.

2 RESERVOIR RELEASE PATTERNS

Four hydropower operational scenarios for Flaming Gorge Dam were considered in this study — 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. The remaining scenarios assume seasonally adjusted flows that would comply with the USFWS Biological Opinion (USFWS 1992) and would include sustained high flows in the spring and limited hourly fluctuations, especially in summer and autumn releases, to protect downstream populations of endangered fish.

The main differences in the operational scenarios are as follows. With 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. 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 except when ice cover is present on the Green River below the dam (assumed to be February and March). When ice cover is present, no hourly fluctuations would be allowed. For the seasonally adjusted moderate fluctuating flow scenario, hourly releases would have fluctuations equal to 50% of those in the seasonally adjusted high fluctuating flow scenario. On-peak durations would be adjusted so that the average daily releases would be the same as the preceding scenario. For the seasonally adjusted steady flow scenario, reservoir releases would be constant throughout the day in each season. Seasons here refer to periods of variable length, ranging from several weeks to one month, as defined by the Biological Opinion (USFWS 1992).

Reservoir release patterns were developed for three representative hydrologic years that were selected on the basis of streamflow records: moderate (1987), dry (1989), and wet (1983). (A water year begins on October 1 of the preceding calendar year and ends on September 31 of the current calendar year, e.g., water year 1987 begins on October 1, 1986, and ends on September 30, 1987.) Each release pattern has a minimum release for a certain duration 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 in one hour to the minimum release. The on-peak period is assumed to center around 4:00 p.m. The derivation of the release patterns is discussed in Sections 2.1 through 2.3.

2.1 YEAR-ROUND HIGH FLUCTUATING FLOW SCENARIO

The year-round high fluctuating flow scenario assumes that the monthly total releases would be approximately the same as historical releases (Table 1) and that maximum fluctuation would occur daily throughout the year. The release patterns for this scenario assume that the maximum release would be 4,700 cfs and the minimum release would be 800 cfs as required by the Utah Division of Wildlife Resources. Ramp up and ramp down

between these flow limits would occur in one hour. On the basis of the assumptions that ramping would occur in one entire hour and on-peak periods would last one or more entire hours, the seasonal averages vary slightly from the historical releases. The calculated daily average releases would range from about 1,290 to 3,720 cfs for the moderate year, 865 to 1,290 cfs for the dry year, and 2,420 to 10,100 cfs for the wet year (Tables 2, 3, and 4). For average releases greater than 4,700 cfs, such as occurred in June to August 1983, a constant flow of 4,700 cfs would pass through the powerhouse and the remaining flow would bypass. This scenario would not comply with the Biological Opinion (USFWS 1992). It is representative of maximum power plant operations and was considered in the EIS to enable an evaluation of the effects of seasonal and daily adjustment of releases required by the Biological Opinion.

2.2 SEASONALLY ADJUSTED FLUCTUATING FLOW SCENARIOS

For the seasonally adjusted high fluctuating and moderate fluctuating flow scenarios, the Biological Opinion specifies allowable fluctuations within one day for Flaming Gorge Reservoir releases in summer and autumn months. For all three seasonally adjusted flow scenarios, the Biological Opinion also requires shifting seasonal releases to provide high flows in the spring and low flows in the summer and autumn (USFWS 1992).

2.2.1 Allowable Release Fluctuations for Summer and Autumn

The reservoir release fluctuations allowed for seasonally adjusted fluctuating flow scenarios are:

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 to October 31
Dry year:	June 20 to October 31
Wet year:	July 20 to October 31

2. Variations of flow at Jensen, Utah, for any 24-hour period would be limited to a total of 25% around the target flow. Variations above or below the target should be as close as possible.

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

Flaming Gorge Reservoir daily releases that comply with the above constraints are presented in Table 5. Each daily release pattern is expressed in terms of a base and a peak 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 base and peak releases and the time on-peak. The minimum allowable base release and maximum allowable peak release for each month, or partial month when required by the Biological Opinion, were determined with the Streamflow Synthesis and Reservoir Regulation (SSARR) computer model being used by the Bureau of Reclamation for the Green River below Flaming Gorge Dam (Section 3.1). 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 target flows shown in Table 5 were selected on the basis of the Biological Opinion constraints.

2.2.2 Seasonal Reservoir Releases

In addition to constraints on fluctuations for summer and autumn releases, the Biological Opinion also requires altering the historical seasonal pattern of release 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 6. These criteria comply with the Biological Opinion whenever possible; other considerations include the minimum release requirement and reservoir safety.

On the basis of the above criteria, reservoir releases were developed for the seasonally adjusted flow scenarios for the three representative hydrologic years. The monthly release volumes for the three representative years are summarized in Table 7. The spread-sheet used to derive the monthly release volumes for the moderate hydrologic year is presented in Table 8 in three parts. Part 1 summarizes the monthly reservoir releases; part 2 shows the reservoir storage routing, which was performed to ensure that releases are feasible and that reservoir storage targets are attained as much as possible at various times; and part 3 shows the estimated releases for April through July based on the Biological Opinion. Similarly, Tables 9 and 10 present the spreadsheets used to derive the monthly release volumes for the dry and wet water years, respectively. The objective of the total annual releases is not always to make the annual total power release or total reservoir release (power and nonpower) equal to the respective actual historical releases. The total reservoir release for the wet year is less than the historical release so as to reduce power plant bypass while maintaining the reservoir level below the normal maximum water surface elevation. The total reservoir release for the dry year is greater than the historical release to comply with the Biological Opinion (USFWS 1992).

2.3 DAILY RESERVOIR RELEASE PATTERNS

On the basis of the criteria described in Section 2.2, reservoir release patterns were derived by trial and error. Table 2 summarizes the release patterns in a moderate hydrologic year for an average day in each month, or partial month where necessary to comply with the Biological Opinion. Tables 3 and 4 summarize the release patterns for the dry and wet hydrologic years, respectively.

3 RIVER FLOWS AND STAGES BELOW THE DAM

Flows in the Green River and the corresponding river stages resulting from reservoir releases under the four operational scenarios were estimated for five locations below Flaming Gorge Dam for the moderate hydrologic year. The five locations are Gates of Lodore, Hells Half Mile, Jones Hole, Rainbow Park, and the Jensen gage (Figure 2). The SSARR model for the Green River was used to calculate the downstream flows, and a water surface profile model for estimating the river stages was developed with the HEC-2 computer program (U.S. Army Corps of Engineers 1982).

3.1 MODELING RIVER FLOW

The SSARR model developed by the Bureau of Reclamation for the Green River was used to estimate river flows between Flaming Gorge Dam and the Jensen gage for different operational scenarios. The model uses the flow routing portion of the SSARR computer program to route river flow hydrographs through river channels (U.S. Army Corps of Engineers 1987). This routing method is a "cascade of reservoirs" technique, which simulates the delay and attenuation of the flood wave as it travels downstream by treating the channel as a series of small reservoirs (channel segments). The model user specifies the number of segments, also known as routing phases, and the routing characteristics of each segment. Routing through each segment is based on the law of continuity as expressed in the storage equation, which relates the change in the storage to the average inflow into and the average outflow from the segment. The outflow from each segment becomes the inflow to the next segment. If S, I, and O represent the storage, inflow to, and outflow from the channel segment, respectively, the storage equation for the segment can be written as:

$$S_2 - S_1 = \frac{1}{2}(I_1 + I_2)\,t - \frac{1}{2}(O_1 + O_2)\,t\ ,$$

where t is the computational time interval and subscripts 1 and 2 denote values at the beginning and end of the time interval, respectively.

The storage of a channel segment can be expressed as a function of the outflow, with T_s representing the proportionality factor between storage and outflow:

$$S = T_s O\ .$$

The factor T_s is known as the time of storage and is approximately equal to the water travel time through the channel segment. By substitution, the following form of the storage equation can be derived and used to compute outflow from one channel segment:

$$O_2 = O_1 + \frac{t}{(T_s + \frac{t}{2})} \left[\frac{1}{2} (I_1 + I_2) - O_1 \right] .$$

Normally, when the river flow is confined to the channel, the time of storage decreases as the discharge increases — which can be expressed as

$$T_s = \frac{K_T}{O^n} ,$$

where

K_T = a constant determined by trial and error or estimated from measurements of flows and corresponding travel times, and

n = a coefficient.

The coefficient n is usually a positive number between 0 and 1, which indicates that the time of storage decreases as the flow increases. In the model calibration process, K_T and n (the number of routing phases) are adjusted to obtain the best match between the model-predicted and the observed flows (U.S. Army Corps of Engineers 1987).

The study reach for the Green River between Flaming Gorge Dam and Jensen gage was divided into five modeling reaches, with boundaries at Gates of Lodore, Hells Half Mile, Jones Hole, Rainbow Park, and the Jensen gage (Figure 2). The SSARR model was verified during this study by comparing the model-predicted flow with the recorded flow at the Jensen gage for the periods from April 1 to June 21, 1987, and from May 1 to June 30, 1992. The Yampa River is the only major tributary of the Green River between the dam and Jensen; its flow is accounted for in the model by the assumption that the tributary flow is equal to that recorded at the Deerlodge Park gage. The time interval used in the Green River SSARR model is one hour. Figure 3 shows the computed and recorded hourly flows at the Jensen gage. The correlation coefficients of the computed and recorded flows for the two verification periods are 0.96 and 0.98, respectively. Both the flow comparisons in Figure 3 and the correlation coefficients indicate that the model is relatively reliable. In particular, the model appears to predict reasonably well the general patterns of flow fluctuation at the Jensen gage. The model parameters for the modeling reach are shown in Table 11 (for flow in cubic feet per second and time in hours).

3.2 CALCULATED RIVER FLOWS

The verified SSARR model for the Green River and the reservoir release patterns presented in Table 2 were used to calculate hourly flows at selected downstream locations for the moderate hydrologic year for the four hydropower operational scenarios. The daily maximum and minimum flows at these locations are discussed in Sections 3.2.1 through 3.2.4.

3.2.1 Year-Round High Fluctuating Flow Scenario

Figure 4 and Table 12 show the daily maximum and minimum flows in the moderate water year 1987 under the year-round high fluctuating flow scenario at Flaming Gorge Dam, Gates of Lodore, and the Jensen gage. (Table 12 also shows the seasonal average inflow of the Yampa River.) Under this operational scenario, the maximum daily reservoir release fluctuation would be 3,900 cfs year-round, with releases fluctuating between 800 and 4,700 cfs. The fluctuations at Gates of Lodore would be reduced to about 30 to 82% of the fluctuations below the dam. The difference in the magnitude 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, or a relatively long one, such as the 17-hour duration in November and December (Table 2), tends to reduce the flow fluctuation rapidly. A medium on-peak duration, 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 fluctuations would be minor. At Hells Half Mile, the fluctuations would be 29 to 80% of those at the dam. At the Jensen gage, the fluctuations would still be 27 to 77%. Flow patterns at the Jensen gage are different from those at Gates of Lodore because of inflow from the Yampa River.

3.2.2 Seasonally Adjusted High Fluctuating Flow Scenario

Figure 5 and Table 13 show the daily maximum and minimum flows in the moderate water year 1987 under the seasonally adjusted high fluctuating flow scenario. Under this operational scenario, the daily release fluctuations would range from 2,010 to 3,900 cfs, except that no fluctuations would be allowed in February and March (the assumed ice cover period), October would have a steady release of 800 cfs (the required minimum release), and June 1 through 21 would have a steady release of up to 4,700 cfs (as required by the Biological Opinion). The fluctuations at Gates of Lodore would be reduced to about 19 to 80% of the fluctuations at the dam. Similar to the year-round high fluctuating flow scenario, further downstream reductions in fluctuations would be minor. At Hells Half Mile, the fluctuations still would be 19 to 80% of those at the dam. At the Jensen gage, the fluctuations would be 17 to 78%.

3.2.3 Seasonally Adjusted Moderate Fluctuating Flow Scenario

Figure 6 and Table 14 show daily maximum and minimum flows in the moderate water year 1987 for the seasonally adjusted moderate fluctuating flow scenario. Under this operational scenario, the daily release fluctuations would range from 1,000 to 1,950 cfs, except that no fluctuations 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 of up to 4,700 cfs (as required by the Biological Opinion). The fluctuations at Gates of Lodore would be reduced to about 0 to 88% of the fluctuations at the dam, depending on

the on-peak duration. Similar to the two preceding operational scenarios, reductions in fluctuations farther downstream would be minor. At Hells Half Mile, the fluctuations still would be 0 to 88% of those at the dam. At the Jensen gage, the fluctuations would be 0 to 83%.

3.2.4 Seasonally Adjusted Steady Flow Scenario

Under the seasonally adjusted steady flow scenario, the reservoir release in each season (which was defined to be several weeks to one month, depending on requirements of the Biological Opinion) would be steady (Tables 2 to 4). Figure 7 shows the flows at the dam, Gates of Lodore, and Jensen gage for the moderate water year. 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 the reservoir releases and the Yampa River inflows.

3.3 MODELING RIVER STAGE

Stages of the Green River were estimated for the maximum and minimum river flows resulting from reservoir releases under the four hydropower operational scenarios for the same locations for which the flows were calculated. The river stage at a particular location depends mainly on the river flow and channel geometry in the area. The stages were estimated with the HEC-2 computer program from a water surface profile model for the Green River (U.S. Army Corps of Engineers 1982).

The HEC-2 model for the Green River was developed with the best data available, including USGS 7.5-minute topographic maps, cross-section data at river gages, and discharge rating tables for the gages; field data were not collected for the EIS. Except at the gages, all river cross sections used in the model were estimated from the USGS maps, which have elevation contour intervals of 20 to 40 ft. Channel roughness coefficients required for the model were estimated to be 0.03 to 0.06 for the main channel and 0.05 to 0.07 for the overbanks; these estimates were based on field observation and values in the literature (Chow 1959; Barnes 1967). The model was calibrated with the discharge ratings for the gages and the water surface elevations shown on the USGS maps, at 5- to 40-ft intervals. Because of the limitations in the data used to develop the Green River HEC-2 model, estimated changes in river stages are believed to be more reliable than the estimated water surface elevations.

3.4 CALCULATED RIVER STAGES

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 to 7 and the stage-flow relationships calculated with the HEC-2 water surface profile model. 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 the moderate year (1987) in Figures 8 to 10

for the year-round high fluctuating flow, seasonally adjusted high fluctuating flow, and seasonally adjusted moderate fluctuating flow scenarios, respectively. River stage increases above the water surface elevation at 800 cfs flow are shown in Figure 11 for the seasonally adjusted steady flow scenario.

Under the year-round high fluctuating flow scenario, the daily stage fluctuations at the dam resulting from hydropower operations 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. Under the seasonally adjusted high fluctuating flow scenario, the daily stage fluctuations would be about 0 to 4.8 ft at the dam, about 0 to 4.9 ft at the Gates of Lodore, and about 0 to 2.2 ft at the Jensen gage. Under the seasonally adjusted moderate fluctuating flow scenario, the daily stage fluctuations would be about 0 to 2.2 ft at the dam, about 0 to 2.1 ft at the Gates of Lodore, and about 0 to 0.9 ft at the Jensen gage. Under the seasonally adjusted steady flow scenario, no daily stage fluctuations would result from hydropower operations.

3.5 CONCLUSIONS

The SSARR model developed by the Bureau of Reclamation for routing flow hydrographs has been shown to be a reliable tool for predicting flow fluctuations in the Green River below Flaming Gorge Dam. The combined use of the SSARR model and the water surface profile model developed during this study has provided useful information for evaluating the potential impacts of hydropower operations on natural resources downstream of the dam.

The maximum daily river stage fluctuations from hydropower operations under the seasonally adjusted high fluctuating flow scenario would be similar to the maximum daily fluctuations under the year-round high fluctuating flow scenario. However, no fluctuations would occur in some time periods under the former scenario. The maximum daily river stage fluctuations under the seasonally adjusted moderate fluctuating flow scenario would be about half of those under the seasonally adjusted high fluctuating flow scenario.
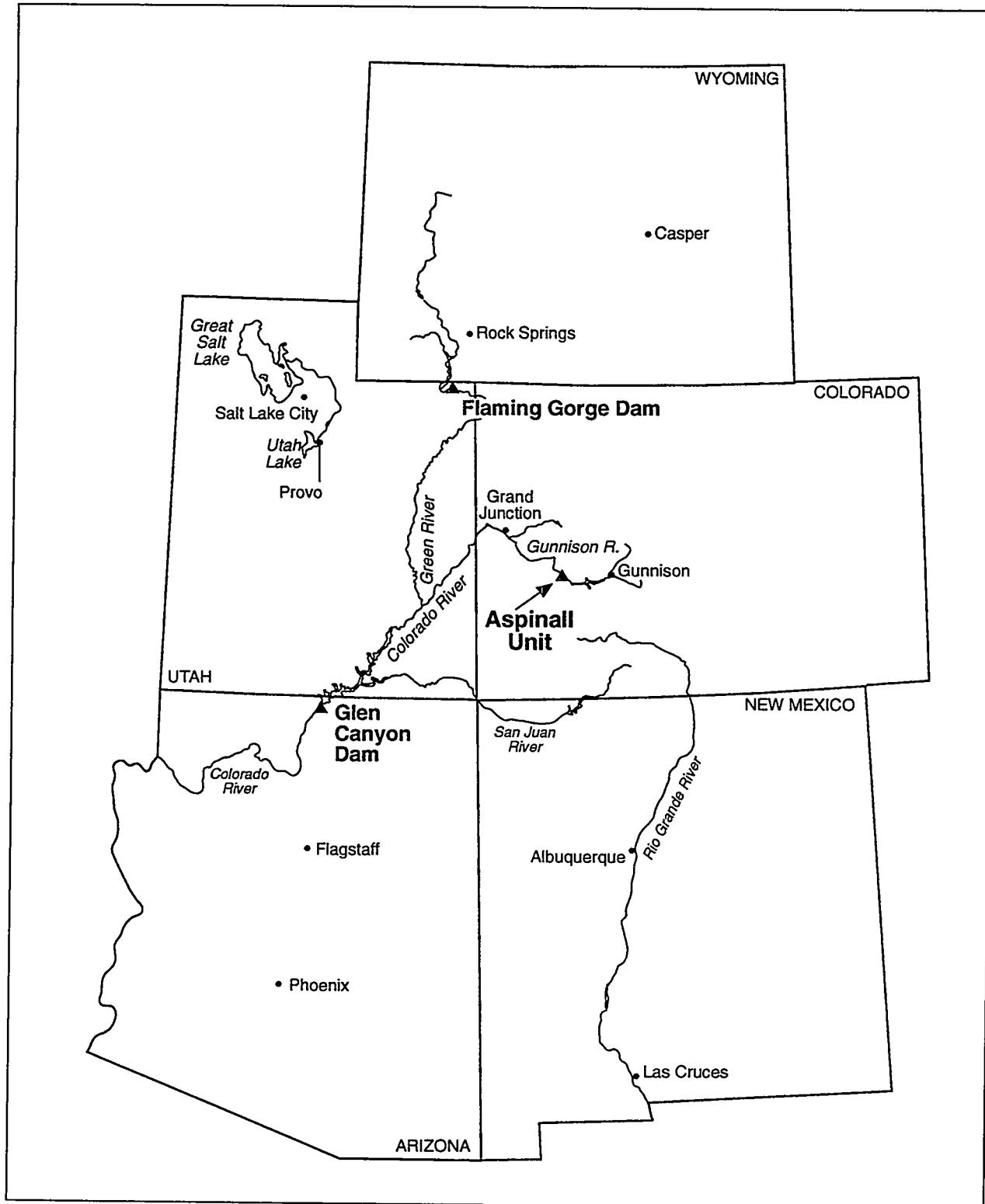
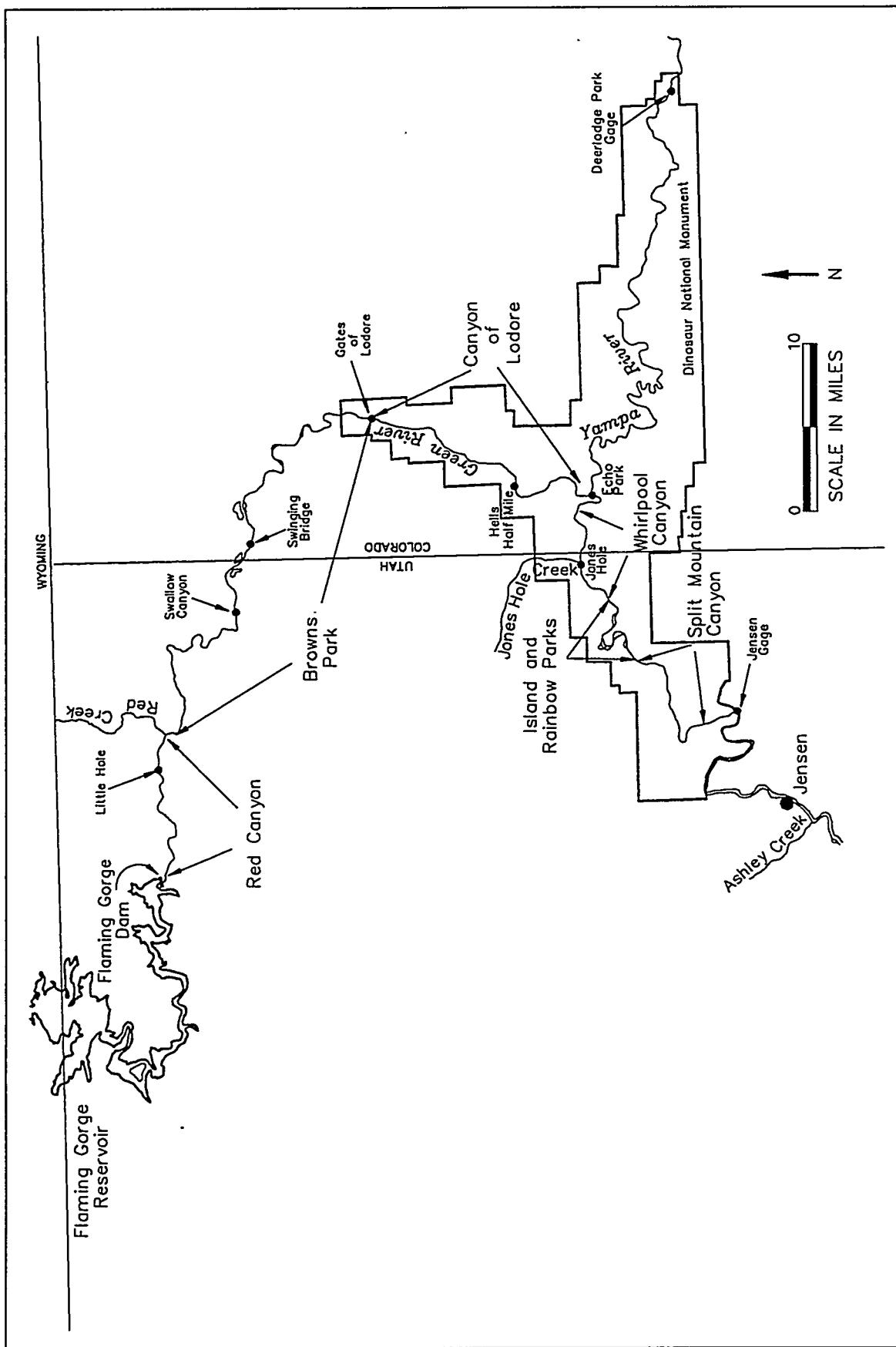**FIGURE 1 Locations of Flaming Gorge Dam, Glen Canyon Dam, and the Aspinall Unit**

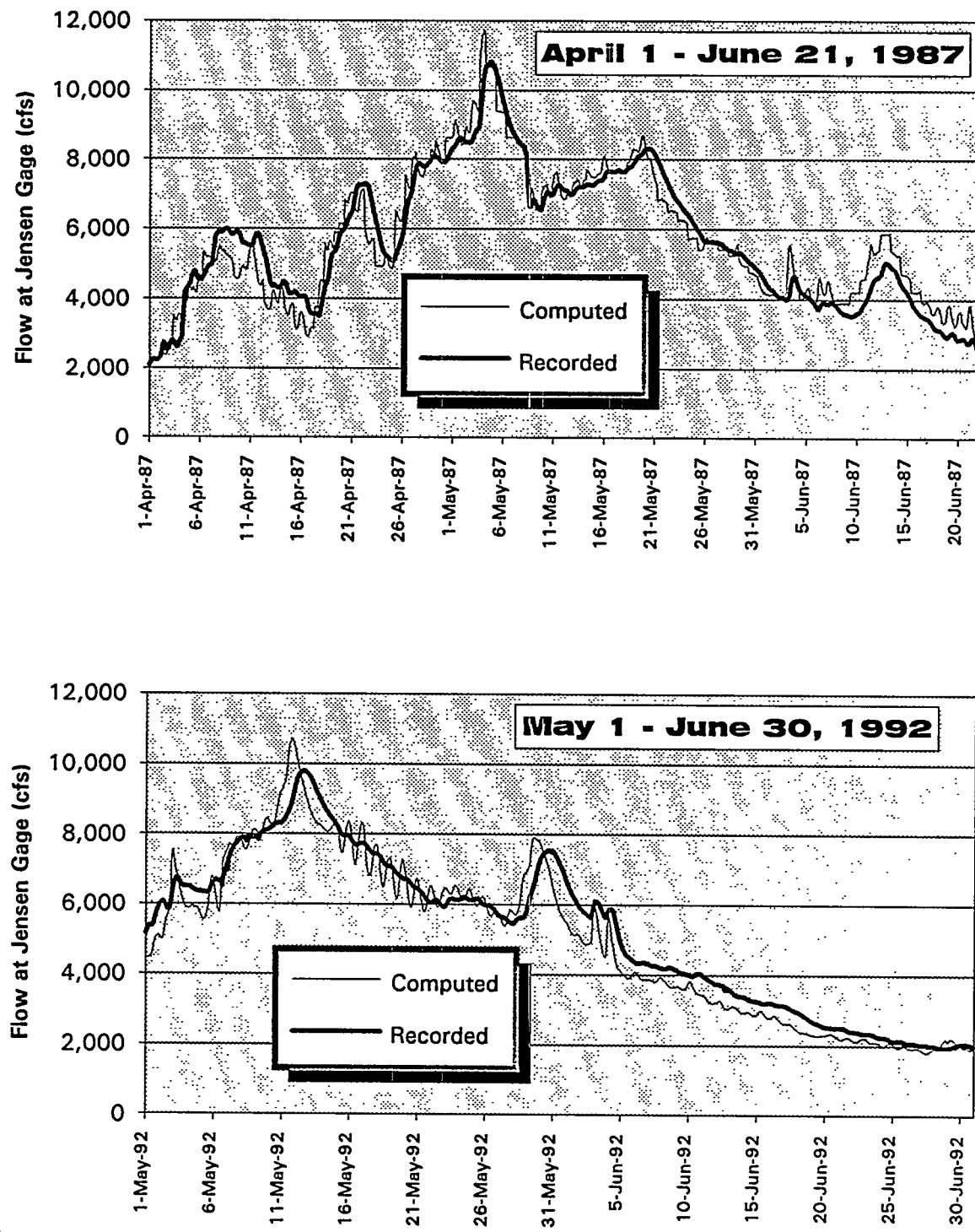FIGURE 2 Green River from Flaming Gorge Dam to Jensen, Utah

FIGURE 3 Comparison of Computed and Recorded Hourly Flows at the Jensen, Utah, Gage
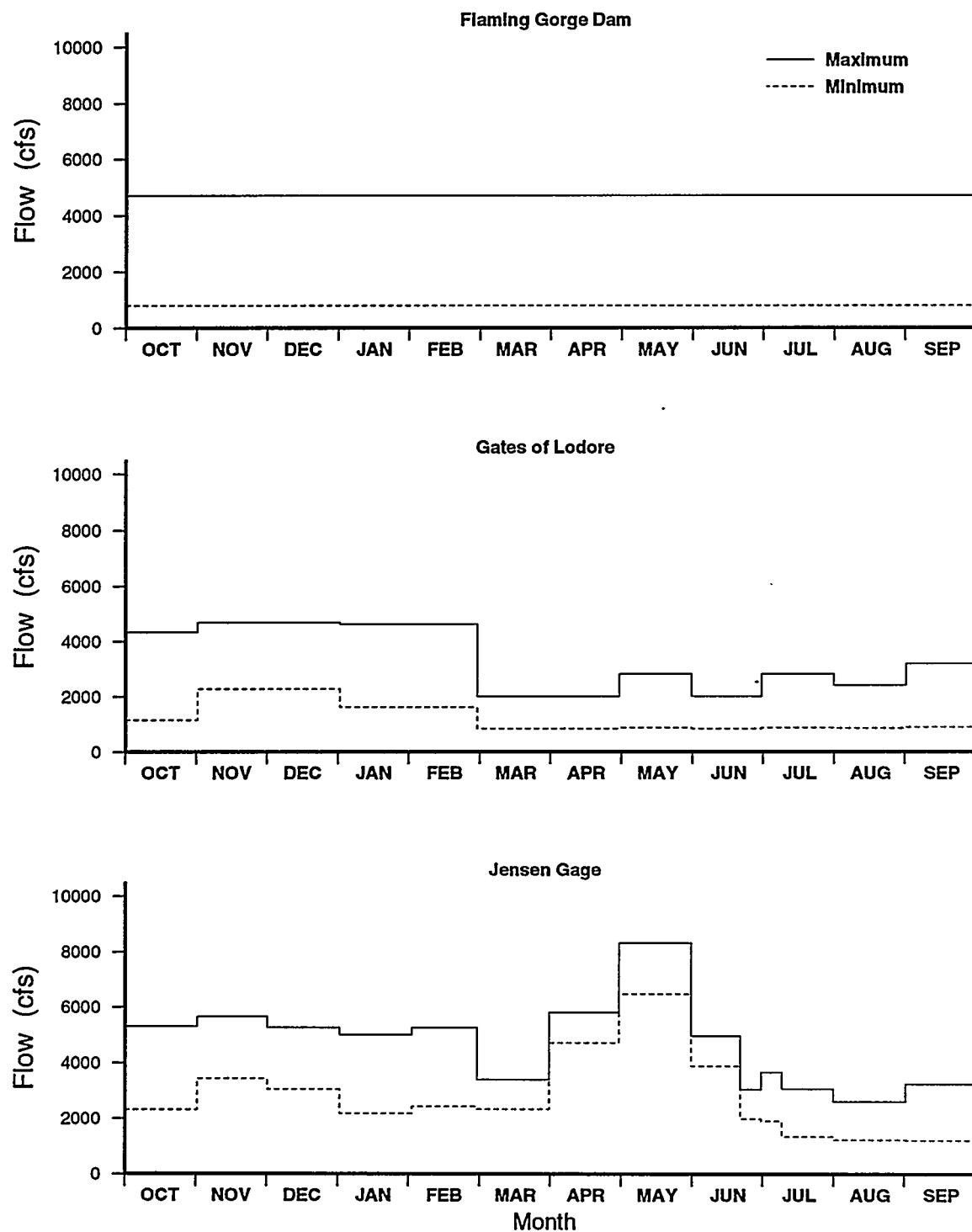
FIGURE 4 Maximum and Minimum River Flows under the Year-Round High Fluctuating Flow Scenario for a Moderate Water Year
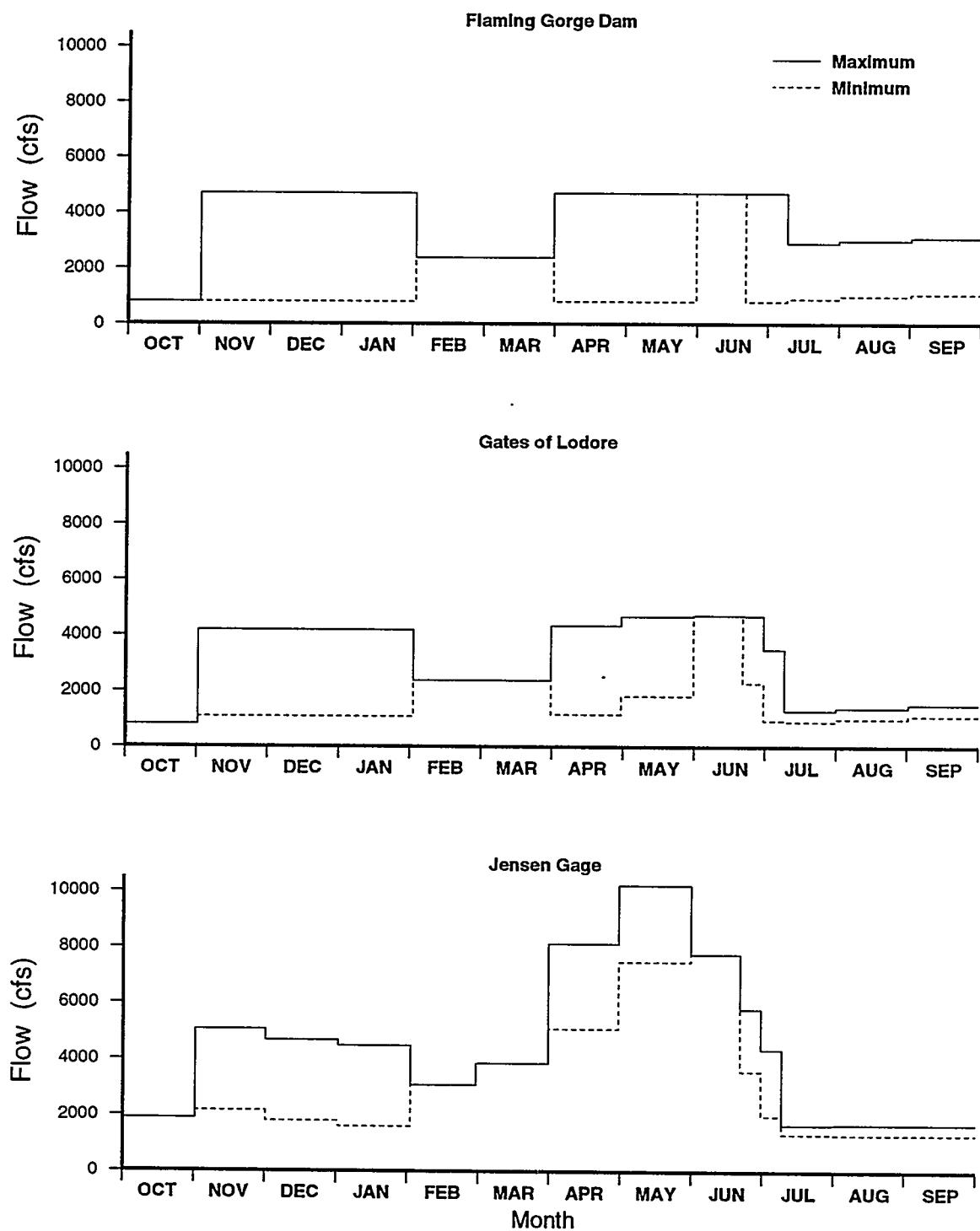
FIGURE 5 Maximum and Minimum River Flows under the Seasonally Adjusted
High Fluctuating Flow Scenario for a Moderate Water Year
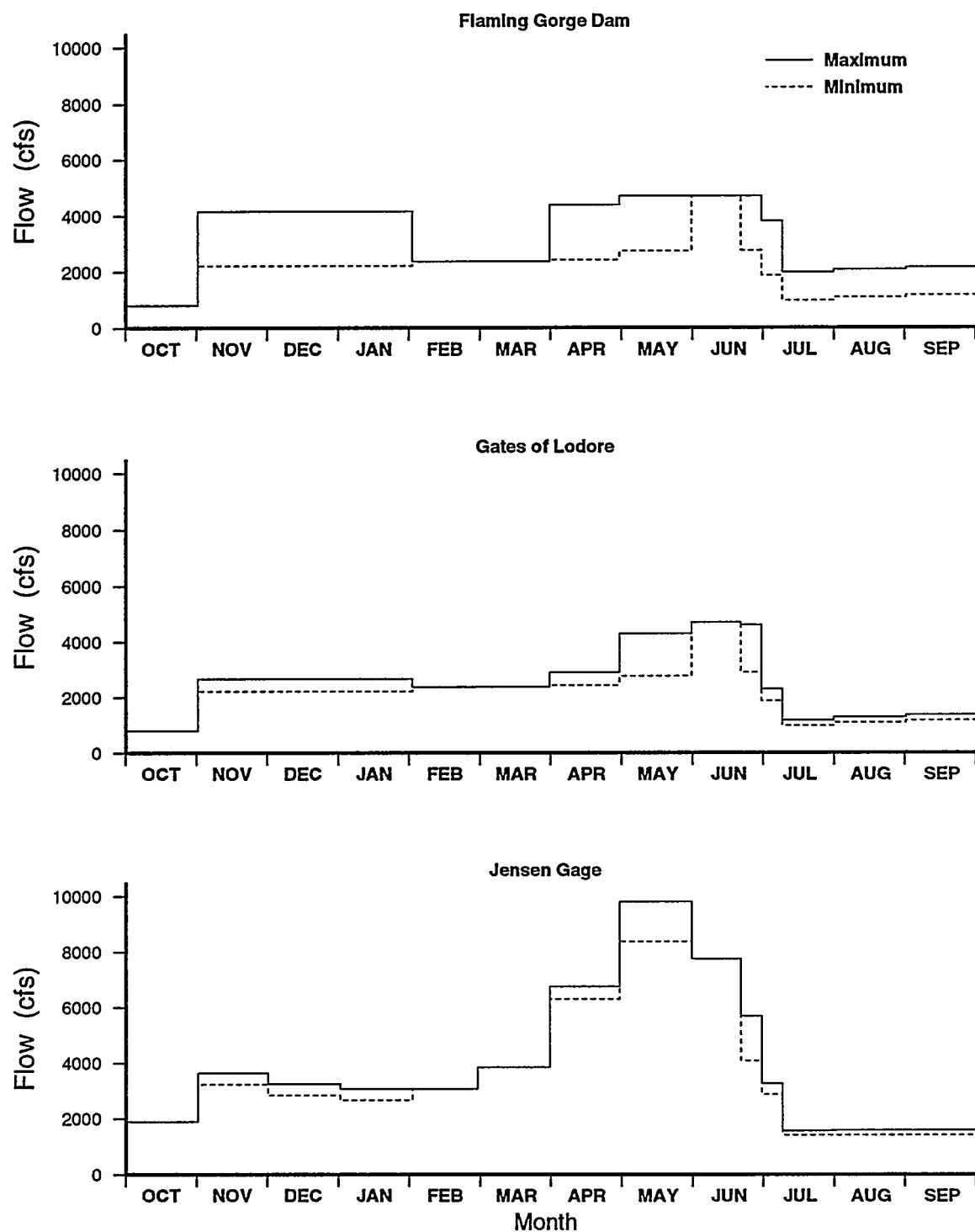
FIGURE 6 Maximum and Minimum River Flows under the Seasonally Adjusted Moderate Fluctuating Flow Scenario for a Moderate Water Year

FIGURE 7 River Flows under the Seasonally Adjusted Steady Flow Scenario
for a Moderate Water Year

FIGURE 8 Maximum and Minimum River Stage Increases under the Year-Round High Fluctuating Flow Scenario for a Moderate Water Year

FIGURE 9 Maximum and Minimum River Stage Increases under the Seasonally Adjusted High Fluctuating Flow Scenario for a Moderate Water Year

FIGURE 10 Maximum and Minimum River Stage Increases under the Seasonally Adjusted Moderate Fluctuating Flow Scenario for a Moderate Water Year
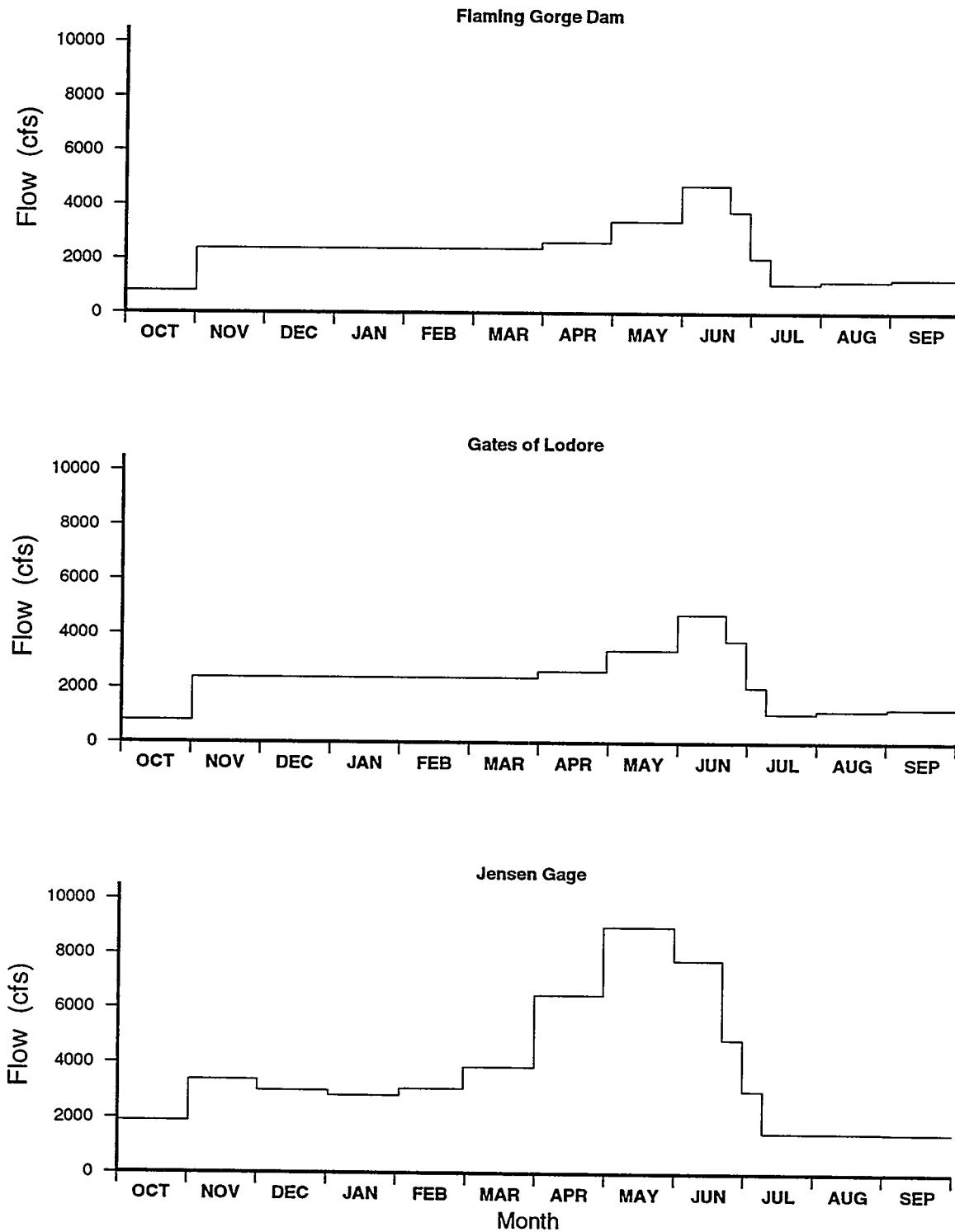
FIGURE 11 River Stage Increases under the Seasonally Adjusted Steady Flow
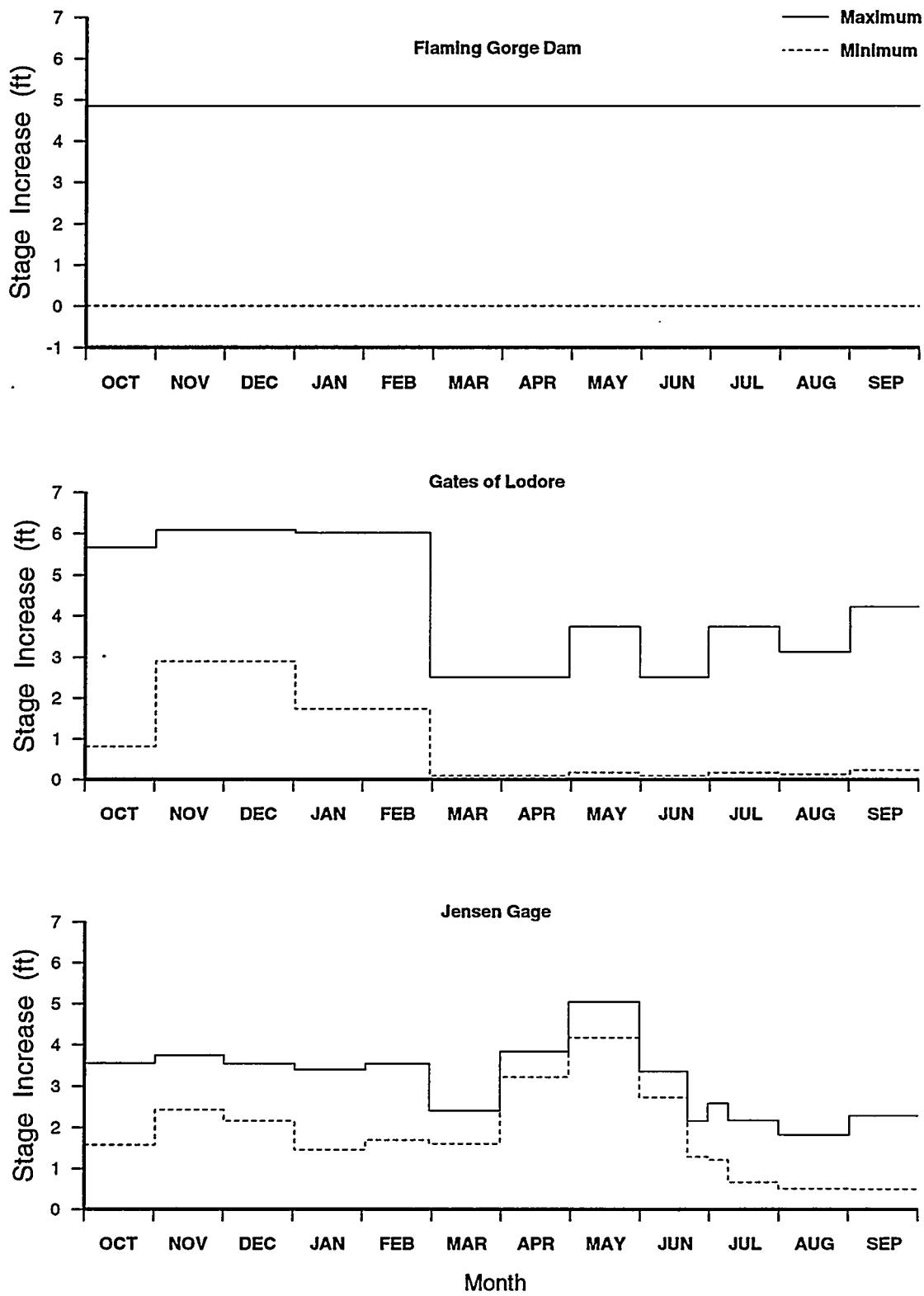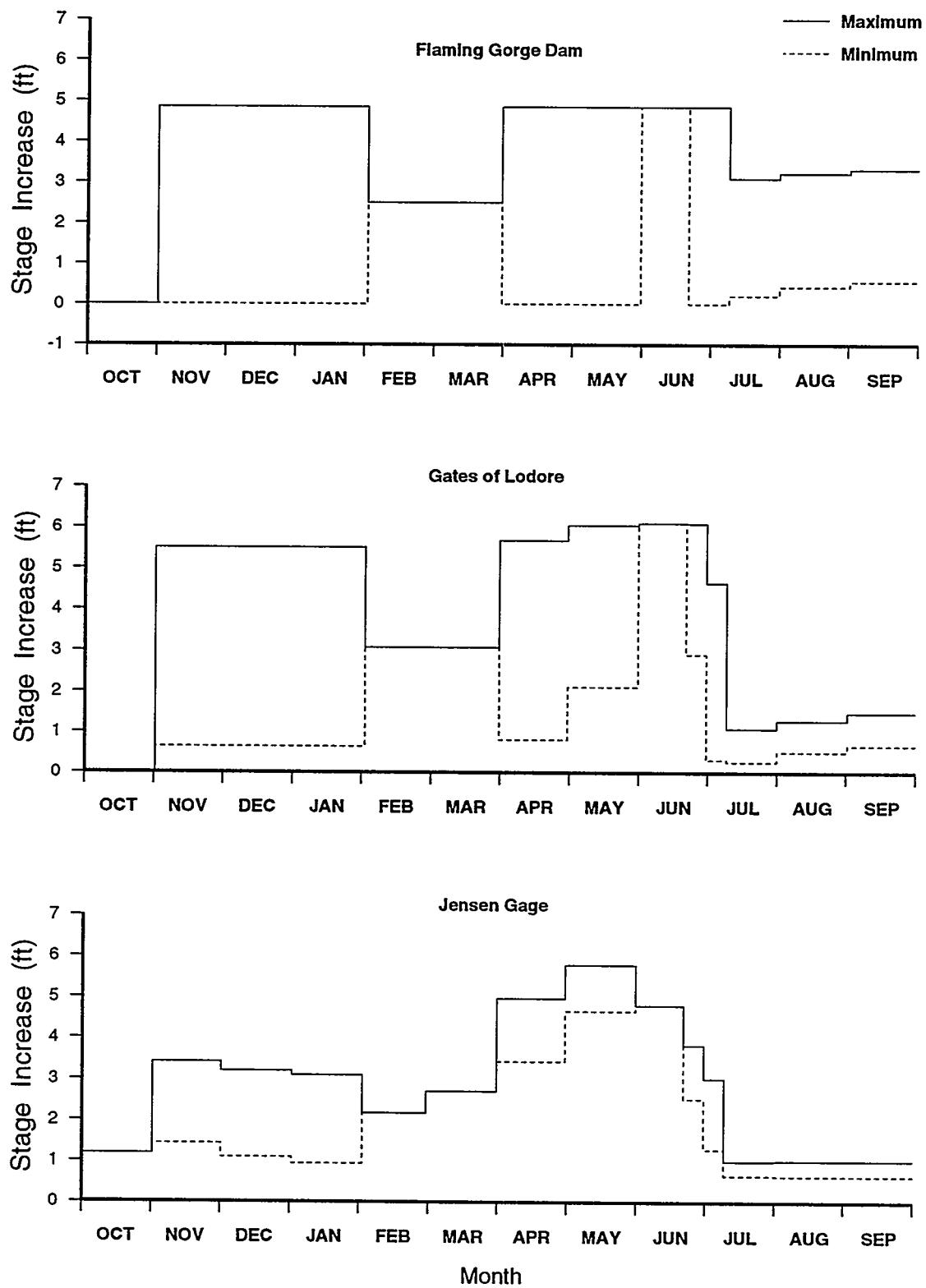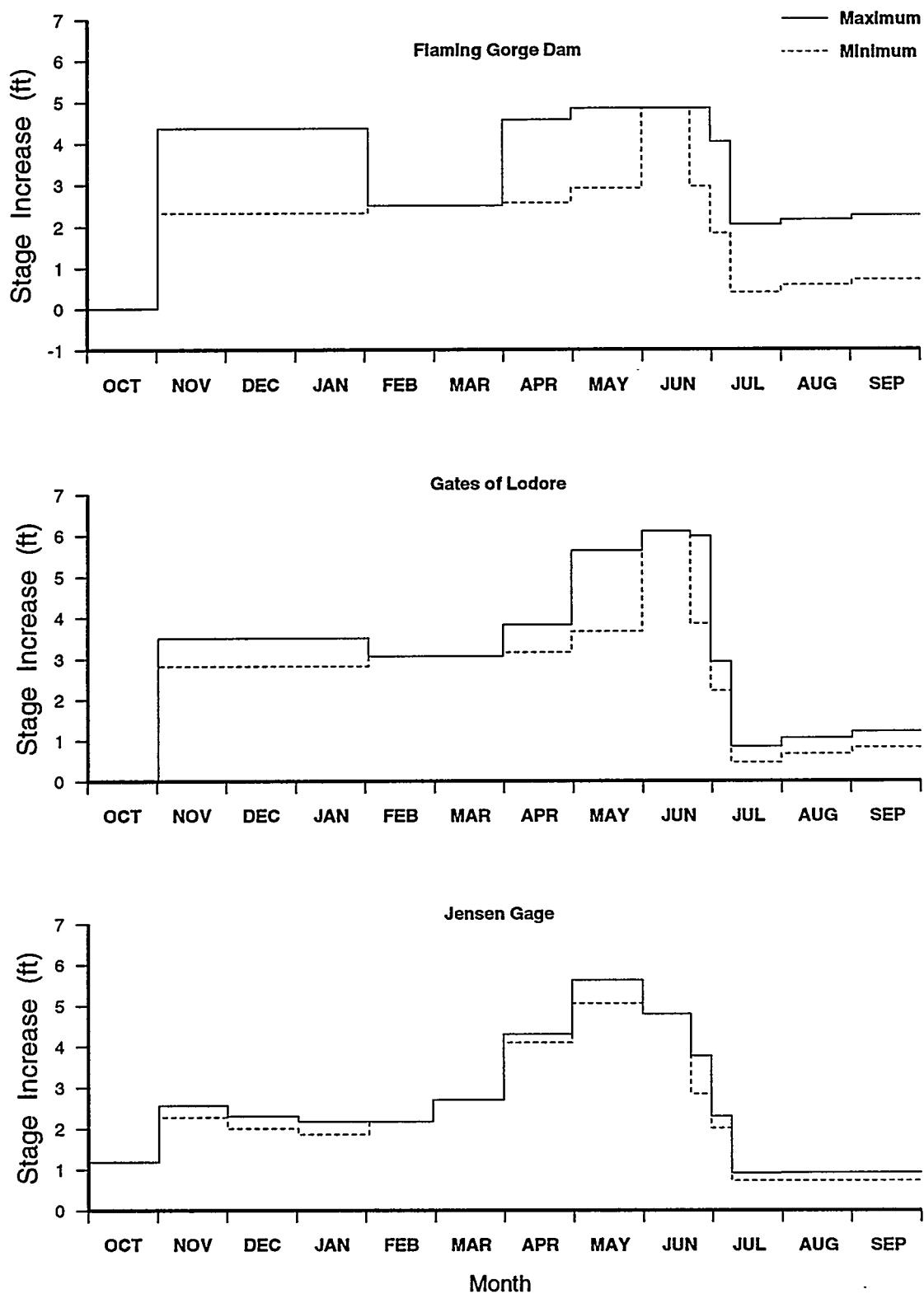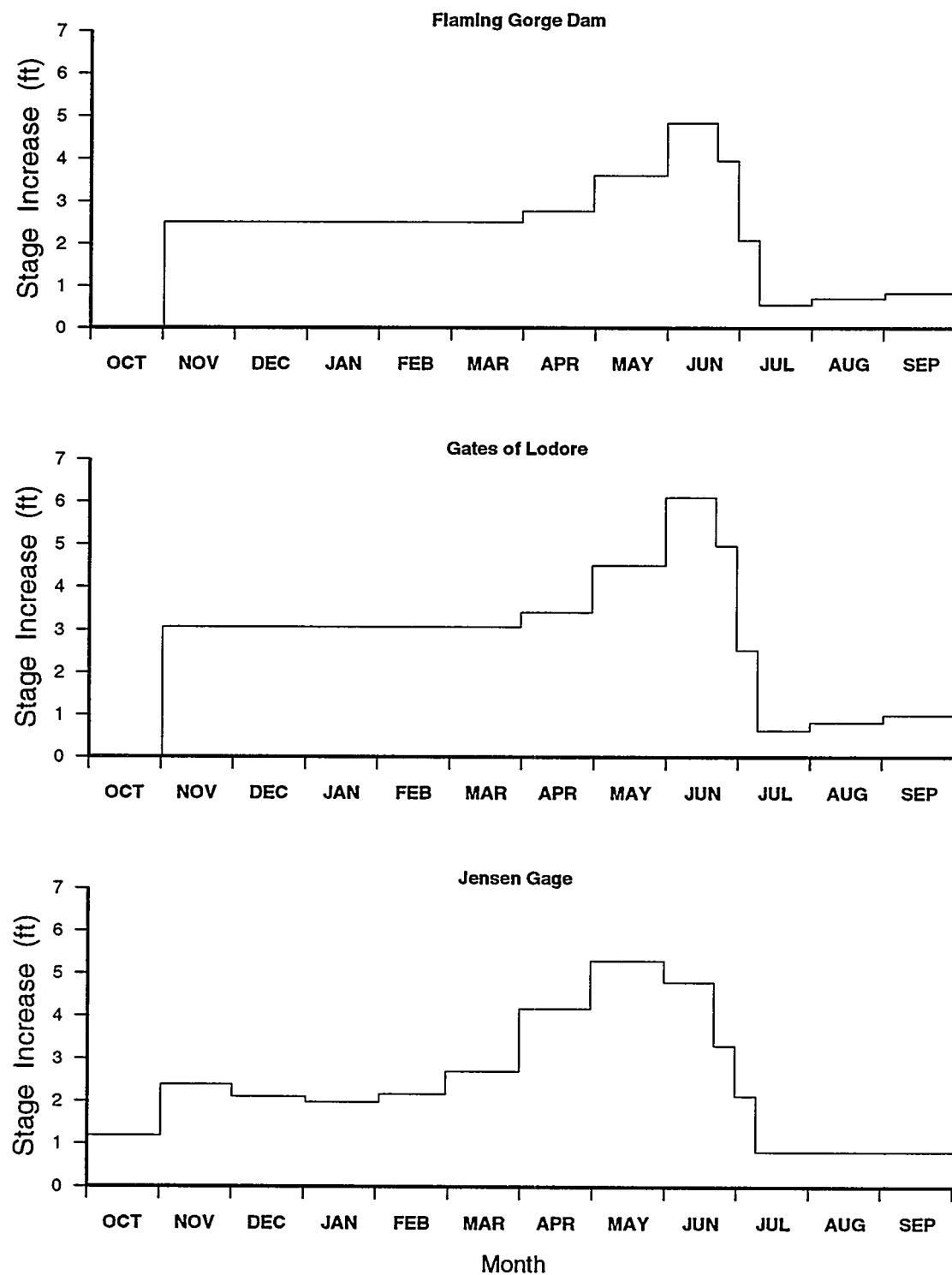Scenario for a Moderate Water Year

TABLE 1 Flaming Gorge Reservoir Historical Releases

Water Year/ Month	Power Release (acre-feet)	Other Release (acre-feet)	Total Release (acre-feet)	Average Release (cfs)
Moderate Water Year, 1987				
October	163,970	0	163,970	2,667
November	226,320	0	226,320	3,804
December	230,760	0	230,760	3,754
January	199,970	0	199,970	3,253
February	179,700	0	179,700	3,236
March	75,330	0	75,330	1,225
April	75,270	0	75,270	1,265
May	96,940	0	96,940	1,577
June	74,850	0	74,850	1,258
July	100,820	0	100,820	1,640
August	92,500	0	92,500	1,505
September	101,160	0	101,160	1,700
TOTAL	1,617,590	0	1,617,590	2,234
Dry Water Year, 1989				
October	57,900	0	57,900	942
November	57,070	0	57,070	959
December	58,670	0	58,670	954
January	56,570	0	56,570	920
February	50,620	0	50,620	912
March	55,080	0	55,080	896
April	58,370	0	58,370	981
May	56,376	0	56,376	917
June	78,644	0	78,644	1,322
July	53,380	0	53,380	868
August	80,493	0	80,493	1,309
September	53,468	0	53,468	899
TOTAL	716,641	0	716,641	990
Wet Water Year, 1983				
October	215,920	33,000	248,920	4,049
November	221,510	0	221,510	3,723
December	180,320	0	180,320	2,933
January	182,960	0	182,960	2,976
February	131,030	0	131,030	2,360
March	150,240	0	150,240	2,444
April	165,780	0	165,780	2,787
May	185,160	0	185,160	3,012
June	246,180	234,000	480,180	8,072
July	254,000	366,000	620,000	10,086
August	241,050	67,000	308,050	5,011
September	219,050	0	219,050	3,682
TOTAL	2,393,200	700,000	3,093,200	4,274

Source: U.S. Bureau of Reclamation, Colorado River Storage Project Database.

TABLE 2 Daily Reservoir Release Patterns for Four Hydropower Operational Scenarios in a Moderate Water Year[a]

Period	Year-Round High Fluctuation				Seasonally Adjusted High Fluctuation			Seasonally Adjusted Moderate Fluctuation			Seasonally Adjusted Steady Flow (cfs)
	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)	
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 3 Daily Reservoir Release Patterns for Four Hydropower Operational Scenarios in a Dry Water Year[a]

Period	Year-Round High Fluctuation				Seasonally Adjusted High Fluctuation			Seasonally Adjusted Moderate Fluctuation			Seasonally Adjusted Steady Flow (cfs)
	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 (cfs)	On-Peak Duration (hours)	
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 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 4 Daily Reservoir Release Patterns for Four Hydropower Operational Scenarios in a Wet Water Year[a]

Period	Year-Round High Fluctuation				Seasonally Adjusted High Fluctuation			Seasonally Adjusted Moderate Fluctuation			Seasonally Adjusted Steady Flow (cfs)
	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)	
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	8,070	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	10	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.

TABLE 5 Allowable Daily Release Fluctuations for Flaming Gorge Reservoir

Year/Month	Average Yampa River Flow[a] (cfs)	Target Flow at Jensen[b] (cfs)	Daily Reservoir Release[c] (cfs)			Daily Flow at Jensen[d] (cfs)			
			Average	Base Flow	Peak Flow	Min.	% Below Target	Max.	% Above Target
1987 (Moderate)									
Jul 10-31	425	1,500	1,060	890	2,900	1,320	12.0	1,680	12.0
Aug	325	1,500	1,160	990	3,000	1,320	12.0	1,690	12.7
Sep	242	1,500	1,240	1,070	3,100	1,320	12.0	1,690	12.7
1989 (Dry)									
Jun 20-30	1,350	1,100	800	800	800	-[e]	-	-[e]	-
Jul	313	1,100	920	800	2,280	1,110	0.0	1,370	24.5
Aug	155	1,100	1,070	950	2,400	1,110	0.0	1,370	24.5
Sep	101	1,100	1,120	1,000	2,450	1,100	0.0	1,370	24.5
1983 (Wet)									
Jul 20-31	3,460	1,800	800	800	800	-[e]	-	-[e]	-
Aug	1,400	1,800	800	800	800	-[e]	-	-[e]	-
Sep 1-15	555	1,800	1,000	800	3,250	1,360	24.4	1,800	0.0
Sep 16-30	333	2,400	1,720	1,470	4,410	1,800	25.0	2,400	0.0

[a] As recorded at Deerlodge Park gage (Figure 2).

[b] Based on the Biological Opinion (USFWS 1992).

[c] Base and peak flows were determined such that the maximum and minimum flows at Jensen would 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 computed with the SSARR model.

[e] Flows at Jensen not computed for cases where the reservoir releases would be constant at 800 cfs.

TABLE 6 Criteria for Developing Flaming Gorge Seasonally Adjusted Releases

Month	Criteria
October	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.
November-March	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.
April-July	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. |
| August-September | 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 would range from 800 to 4,700 cfs (if possible). The minimum release is required by an agreement with the Utah Division of Wildlife Resources, and the maximum release is considered a typical maximum release. |

TABLE 7 Flaming Gorge Reservoir Releases for Seasonally Adjusted Fluctuating Flow Scenarios

Water Year/ Month	Power Release (acre-feet)	Other Release (acre-feet)	Total Release (acre-feet)	Average Release (cfs)
Moderate Water Year, 1987				
October	49,190	0	49,190	800
November	141,800	0	141,800	2,383
December	146,500	0	146,500	2,383
January	146,500	0	146,500	2,383
February	132,300	0	132,300	2,383
March	146,500	0	146,500	2,383
April	154,600	0	154,600	2,598
May	208,600	0	208,600	3,393
June	262,600	0	262,600	4,413
July	82,280	0	82,280	1,338
August	71,300	0	71,300	1,160
September	73,780	0	73,780	1,240
TOTAL	1,616,000	0	1,616,000	2,232
Dry Water Year, 1989				
October	51,590	0	51,590	839
November	47,600	0	47,600	800
December	49,190	0	49,190	800
January	49,190	0	49,190	800
February	44,430	0	44,430	800
March	49,190	0	49,190	800
April	71,130	0	71,130	1,195
May	149,000	0	149,000	2,424
June	130,100	0	130,100	2,187
July	56,570	0	56,570	920
August	65,790	0	65,790	1,070
September	66,640	0	66,640	1,120
TOTAL	830,500	0	830,500	1,147
Wet Water Year, 1983				
October	91,430	0	91,430	1,487
November	279,700	0	279,700	4,700
December	289,000	0	289,000	4,700
January	289,000	0	289,000	4,700
February	261,000	0	261,000	4,700
March	289,000	0	289,000	4,700
April	279,700	0	279,700	4,700
May	289,000	0	289,000	4,700
June	279,700	165,000	444,700	7,473
July	157,500	0	157,500	2,561
August	49,190	0	49,190	800
September	80,930	0	80,930	1,360
TOTAL	2,635,000	165,000	2,800,000	3,868

TABLE 8 Flaming Gorge Reservoir Operations for a Moderate Water Year

Month	Base Release		Adjustments[b] (acre-feet)	Power Release (base plus adjustment, acre-feet)	1987 Power Release[c] (acre-feet)	Difference (acre-feet)		Secondary Release Adjustment (acre-feet)	Projected Total Power Release	
	cfs	acre-feet				Surplus	Deficit		acre-feet	cfs
October	800	49,190		49,190	164,000	0	114,810	0	49,190	800
November	800	47,603	94,196	141,800	226,000	0	84,200	-9	141,791	2,383
December	800	49,190	97,336	146,526	231,000	0	84,474	-9	146,517	2,383
January	800	49,190	97,336	146,526	199,000	0	52,474	-9	146,517	2,383
February	800	44,430	87,917	132,346	180,000	0	47,654	-9	132,338	2,383
March	1,070	65,792	80,734	146,526	75,000	-71,526	0	-9	146,517	2,383
April	2,598	154,575		154,575	75,000	-79,575		0	154,575	2,598
May	3,393	208,598		208,598	97,000	-111,598		0	208,598	3,393
June	4,413	262,570		262,570	75,000	-187,570		0	262,570	4,413
July	1,338	82,276		82,276	101,000	0	18,724	0	82,276	1,338
August	1,160	71,326		71,326	92,000	0	20,674	0	71,326	1,160
September	1,240	73,785		73,785	101,000	0	27,215	0	73,785	1,240
Total	19,211	1,158,525	457,520	1,616,045	1,616,000	-450,269	450,224	-45	1,616,000	

[a] Notes on base release (minimum, 800 cfs):

October: Median allowed at the Jensen gage (1,500 cfs) minus Yampa River flow for October 1987 (1,080 cfs).

November to March: Assumed equal to median monthly pre-dam releases (1951-1962), but not less than 800 cfs, to simulate pre-dam releases for moderate years.

April to July: From calculated spring and summer release patterns (see part 3 of this table).

August to September: Based on data presented in Table 5.

[b] To approximate historical total yearly releases, additional releases were assumed for up to a total release of 2,382 cfs.

[c] Nonpower release in 1987 = 0 acre-feet.

TABLE 8 (Cont.)

		Reservoir Routing[a]						
Month	Inflow[b] (10³ acre-feet)	Releases (10³ acre-feet) Power	Releases (10³ acre-feet) Other	Volume Change (10³ acre-feet)	End-of-Month Storage (10³ acre-feet)	End-of-Month Elevation (ft)	End-of-Month Elevation Difference (ft)	Storage Curve (ft/10³ acre-feet)
October	122	49	0	72.81	3,418.78	6,031.87	1.87	0.0257
November	86	142	0	-55.79	3,362.99	6,030.44	-1.43	0.0256
December	50	147	0	-96.52	3,266.48	6,027.92	-2.52	0.0261
January	42	147	0	-104.52	3,161.96	6,025.13	-2.79	0.0267
February	46	132	0	-86.34	3,075.62	6,022.77	-2.36	0.0273
March	87	147	0	-59.52	3,016.10	6,021.11	-1.66	0.0279
April	231	155	0	76.42	3,092.53	6,023.24	2.13	0.0278
May	341	209	0	132.40	3,224.93	6,026.82	3.58	0.0271
June	221	263	0	-41.57	3,183.36	6,025.75	-1.07	0.0268
July	159	82	0	76.72	3,260.08	6,027.75	2.00	0.0267
August	98	71	0	26.67	3,286.76	6,028.46	0.71	0.0263
September	61	74	0	-12.79	3,273.97	6,028.12	-0.34	0.0263

[a] Assumptions:
  Initial storage = 3,346,000 acre-feet.
  Initial elevation = 6,030 ft, the median end-of-month elevation for 1976 to 1992 and assumed representative of moderate conditions.
  Vacant target (March) = 6,020 ft.
  Fill target (August 1) = 6,035 ft.
  Maximum normal water surface elevation = 6,042.5 ft.
  End-of-September elevation target = 6,038 ft.

[b] Inflows based on historical monthly inflows for 1987.

TABLE 8 (Cont.)

Spring and Summer Average Daily Releases

Day	April Release (cfs)	Day	May Release (cfs)	Day	June Release (cfs)	Day	July Release (cfs)
1	2,400	1	2,809	1	4,700	1	2,784
2	2,414	2	2,823	2	4,700	2	2,593
3	2,427	3	2,836	3	4,700	3	2,401
4	2,441	4	2,850	4	4,700	4	2,209
5	2,455	5	2,864	5	4,700	5	2,018
6	2,468	6	2,877	6	4,700	6	1,826
7	2,482	7	2,891	7	4,700	7	1,635
8	2,495	8	2,905	8	4,700	8	1,443
9	2,509	9	2,918	9	4,700	9	1,252
10	2,523	10	2,932	10	4,700	10	1,060
11	2,536	11	2,945	11	4,700	11	1,060
12	2,550	12	2,959	12	4,700	12	1,060
13	2,564	13	2,973	13	4,700	13	1,060
14	2,577	14	2,986	14	4,700	14	1,060
15	2,591	15	3,000	15	4,700	15	1,060
16	2,605	16	3,100	16	4,700	16	1,060
17	2,618	17	3,200	17	4,700	17	1,060
18	2,632	18	3,300	18	4,700	18	1,060
19	2,645	19	3,400	19	4,700	19	1,060
20	2,659	20	3,500	20	4,700	20	1,060
21	2,673	21	3,600	21	4,700	21	1,060
22	2,686	22	3,700	22	4,508	22	1,060
23	2,700	23	3,800	23	4,317	23	1,060
24	2,714	24	3,900	24	4,125	24	1,060
25	2,727	25	4,000	25	3,934	25	1,060
26	2,741	26	4,100	26	3,742	26	1,060
27	2,755	27	4,200	27	3,551	27	1,060
28	2,768	28	4,300	28	3,359	28	1,060
29	2,782	29	4,400	29	3,167	29	1,060
30	2,795	30	4,500	30	2,976	30	1,060
		31	4,600			31	1,060
Avg.	2,598		3,393		4,413		1,338
				6/22-6/30	3,742	7/1-7/19	2,018

Spring and Summer Release Patterns

Start Date	Release[a] (cfs)	Change (cfs)	Number of Days	Change Rate (cfs/d)
4/1	2,400			
5/15	3,000	600	44	13.6
6/1	4,700	1,700	17	100.0
6/21	4,700	0	21	0.0
7/10	1,060	-3,640	19	-191.6
7/31	1,060	0	22	0.0

[a] April, May, and June based on the USFWS Biological Opinion (USFWS 1992); July based on data presented in Table 5.

TABLE 9 Flaming Gorge Reservoir Operations for a Dry Water Year

Monthly Reservoir Releases[a]

Month	Base Release cfs	Base Release acre-feet	Adjustments[b] (acre-feet)	Power Release (base plus adjustment, acre-feet)	1989 Power Release[c] (acre-feet)	Difference (acre-feet) Surplus	Difference (acre-feet) Deficit	Secondary Release Adjustment (acre-feet)	Projected Total Power Release acre-feet	Projected Total Power Release cfs
October	839	51,588	0	51,588	57,900	0	6,312	0	51,588	839
November	800	47,603	0	47,603	57,070	0	9,467	0	47,603	800
December	800	49,190	0	49,190	58,670	0	9,480	0	49,190	800
January	800	49,190	0	49,190	56,570	0	7,380	0	49,190	800
February	800	44,430	0	44,430	50,620	0	6,190	0	44,430	800
March	800	49,190	0	49,190	55,080	0	5,890	0	49,190	800
April	1,195	71,134		71,134	58,370	-12,764	0	0	71,134	1,195
May	2,424	149,031		149,031	56,376	-92,655	0	0	149,031	2,424
June	2,187	130,116		130,116	78,644	-51,472	0	0	130,116	2,187
July	920	56,569		56,569	53,380	-3,189	0	0	56,569	920
August	1,070	65,792		65,792	80,493	0	14,701	0	65,792	1,070
September	1,120	66,645		66,645	53,468	-13,177	0	0	66,645	1,120
Total	13,755	830,477	0	830,477	716,641	-173,256	59,420 / -113,836	0	830,477	

[a] Notes on base release (minimum, 800 cfs):
   October: Minimum allowed at the Jensen gage (1,100 cfs) minus Yampa River flow for October 1989 (261 cfs).
   November to March: Assumed equal to minimum monthly pre-dam releases (1951-1962), but not less than 800 cfs, to simulate pre-dam releases for dry years.
   April to June: From calculated spring and summer release patterns (see part 3 of this table).
   July to September: Based on data presented in Table 5.

[b] To approximate historical total yearly releases, additional releases were assumed for up to a total release of 800 cfs.

[c] Nonpower release in 1989 = 0 acre-feet.

TABLE 9 (Cont.)

Reservoir Routing[a]

Month	Inflow[b] (10³ acre-feet)	Releases (10³ acre-feet) Power	Other	Volume Change (10³ acre-feet)	End-of-Month Storage (10³ acre-feet)	End-of-Month Elevation (ft)	End-of-Month Elevation Difference (ft)	Storage Curve (ft/10³ acre-feet)
October	70	52	0	18.41	3,364.39	6,030.48	0.48	0.0258
November	55	48	0	7.40	3,371.78	6,030.67	0.19	0.0258
December	57	49	0	7.81	3,379.59	6,030.87	0.20	0.0257
January	18	49	0	-31.19	3,348.40	6,030.06	-0.80	0.0258
February	24	44	0	-20.43	3,327.97	6,029.53	-0.53	0.0259
March	66	49	0	16.81	3,344.78	6,029.97	0.44	0.0260
April	73	71	0	1.87	3,346.65	6,030.02	0.05	0.0259
May	82	149	0	-67.03	3,279.62	6,028.27	-1.75	0.0261
June	74	130	0	-56.12	3,223.50	6,026.78	-1.49	0.0265
July	57	57	0	0.43	3,223.93	6,026.79	0.01	0.0266
August	70	66	0	4.21	3,228.14	6,026.91	0.11	0.0266
September	73	67	0	6.36	3,234.50	6,027.08	0.17	0.0266

[a] Assumptions:
  Initial storage = 3,346,000 acre-feet.
  Initial elevation = 6,030 ft, the median end-of-month elevation for 1976 to 1992 and assumed representative of moderate conditions.
  Vacant target (March) = 6,020 ft.
  Fill target (August 1) = 6,035 ft.
  Maximum normal water surface elevation = 6,042.5 ft.
  End-of-September elevation target = 6,038 ft.

[b] Inflows based on historical monthly inflows for 1989.

TABLE 9 (Cont.)

Spring and Summer Average Daily Releases

April		May		June	
Day	Release (cfs)	Day	Release (cfs)	Day	Release (cfs)
1	800	1	1,618	1	4,000
2	827	2	1,645	2	4,000
3	855	3	1,673	3	4,000
4	882	4	1,700	4	4,000
5	909	5	1,727	5	4,000
6	936	6	1,755	6	4,000
7	964	7	1,782	7	4,000
8	991	8	1,809	8	3,754
9	1,018	9	1,836	9	3,508
10	1,045	10	1,864	10	3,262
11	1,073	11	1,891	11	3,015
12	1,100	12	1,918	12	2,769
13	1,127	13	1,945	13	2,523
14	1,155	14	1,973	14	2,277
15	1,182	15	2,000	15	2,031
16	1,209	16	2,118	16	1,785
17	1,236	17	2,235	17	1,538
18	1,264	18	2,353	18	1,292
19	1,291	19	2,471	19	1,046
20	1,318	20	2,588	20	800
21	1,345	21	2,706	21	800
22	1,373	22	2,824	22	800
23	1,400	23	2,941	23	800
24	1,427	24	3,059	24	800
25	1,455	25	3,176	25	800
26	1,482	26	3,294	26	800
27	1,509	27	3,412	27	800
28	1,536	28	3,529	28	800
29	1,564	29	3,647	29	800
30	1,591	30	3,765	30	800
		31	3,882		
Avg.	1,195		2,424		2,187
				6/1-6/7	4,000
				6/8-6/19	2,400
				6/20-6/30	800

Spring and Summer Release Patterns

Start Date	Release[a] (cfs)	Change (cfs)	Number of Days	Change Rate (cfs/d)
4/1	800			
5/15	2,000	1,200	44	27.3
6/1	4,000	2,000	17	117.6
6/7	4,000	0	7	0.0
6/20	800	-3,200	13	-246.2
6/30	800	0	11	0.0

[a] April, May, and June 1 and 7 based on the USFWS Biological Opinion (USFWS 1992); June 20 and 30 based on data presented in Table 5.

TABLE 10 Flaming Gorge Reservoir Operations for a Wet Water Year

| | Monthly Reservoir Releases[a] | | | | | | | | |
| Month | Base Release | | Adjustments[b] (acre-feet) | Power Release (base plus adjustment, acre-feet) | 1983 Power Release[c] (acre-feet) | Difference (acre-feet) | | Secondary Release Adjustment (acre-feet) | Projected Total Power Release | |
	cfs	acre-feet				Surplus	Deficit		acre-feet	cfs
October	1,487	91,432		91,432	216,000	0	124,568	0	91,432	1,487
November	1,340	79,735	199,937	279,672	222,000	-57,672	0	0	279,672	4,700
December	988	60,750	228,245	288,995	180,000	-108,995	0	0	288,995	4,700
January	814	50,051	238,944	288,995	183,000	-105,995	0	0	288,995	4,700
February	1,503	83,472	177,555	261,027	132,000	-129,027	0	0	261,027	4,700
March	2,434	149,661	139,333	288,994	150,000	-138,994	0	0	288,994	4,700
April	4,700	279,669		279,669	166,000	-113,669	0	0	279,669	4,700
May	4,700	288,992		288,992	185,000	-103,992	0	0	288,992	4,700
June	4,700	279,669		279,669	246,000	-33,669	0	0	279,669	4,700
July	2,561	157,488		157,488	254,000	0	96,512	0	157,488	2,561
August	800	49,190		49,190	241,000	0	191,810	0	49,190	800
September	1,360	80,926		80,926	219,000	0	138,074	0	80,926	1,360
Total	27,387	1,651,034	984,014	2,635,049	2,394,000	-792,014	550,965	0	2,635,049	
							-241,049			

[a] Notes on base release (minimum, 800 cfs):

October: Maximum allowed at the Jensen gage (2,400 cfs) minus Yampa River flow for October 1983 (913 cfs).

November to March: Assumed equal to maximum monthly pre-dam releases (1951-1962) to simulate pre-dam releases for wet years.

April to July: From calculated spring and summer release patterns (see part 3 of this table).

August to September: Based on data presented in Table 5.

[b] To reduce power plant bypass in later months, additional releases were assumed for up to a total release of 4,700 cfs.

[c] Nonpower release in 1983 = 700,000 acre-feet.

TABLE 10 (Cont.)

Reservoir Routing[a]

Month	Inflow[b] (10³ acre-feet)	Releases (10³ acre-feet) Power	Other[c]	Total	Total Release (cfs)	Volume Change (10³ acre-feet)	End-of-Month Storage (10³ acre-feet)	End-of-Month Elevation (ft)	End-of-Month Elevation Difference (ft)	Storage Curve (ft/10³ acre-feet)
October	249	91	0	91	1,487	157.57	3,503.54	6,034.01	4.01	0.0255
November	85	280	0	280	4,700	-194.67	3,308.87	6,029.03	-4.98	0.0256
December	77	289	0	289	4,700	-212.00	3,096.87	6,023.36	-5.68	0.0268
January	93	289	0	289	4,700	-196.00	2,900.88	6,017.83	-5.53	0.0282
February	86	261	0	261	4,700	-175.03	2,725.85	6,012.67	-5.16	0.0295
March	159	289	0	289	4,700	-129.99	2,595.86	6,008.67	-4.00	0.0308
April	244	280	0	280	4,700	-35.67	2,560.19	6,007.55	-1.12	0.0313
May	362	289	0	289	4,700	73.01	2,633.20	6,009.83	2.27	0.0312
June	938	280	165	445	7,473	493.33	3,126.53	6,024.17	14.34	0.0291
July	606	157	0	157	2,561	448.51	3,575.04	6,035.79	11.62	0.0259
August	246	49	0	49	800	196.81	3,771.85	6,040.53	4.74	0.0241
September	163	81	0	81	1,360	82.07	3,853.93	6,042.46	1.93	0.0236

[a] Assumptions:
  Initial storage = 3,346,000 acre-feet.
  Initial elevation = 6,030 ft, the median end-of-month elevation for 1976 to 1992 and assumed representative of moderate conditions.
  Vacant target (March) = 6,020 ft.
  Fill target (August 1) = 6,035 ft.
  Maximum normal water surface elevation = 6,042.5 ft.
  End-of-September elevation target = 6,038 ft.

[b] Inflows based on historical monthly inflows for 1983.

[c] Biological Opinion (USFWS 1992) dictates that other releases occur during or prior to Yampa River peak flows (mid-April through June); releases selected so that reservoir maximum normal surface elevation not exceeded.

TABLE 10 (Cont.)

Spring and Summer Average Daily Releases

	April		May		June		July	
Day	Release (cfs)	Day	Release (cfs)	Day	Release (cfs)	Day	Release (cfs)	
1	4,700	1	4,700	1	4,700	1	4,700	
2	4,700	2	4,700	2	4,700	2	4,700	
3	4,700	3	4,700	3	4,700	3	4,700	
4	4,700	4	4,700	4	4,700	4	4,700	
5	4,700	5	4,700	5	4,700	5	4,700	
6	4,700	6	4,700	6	4,700	6	4,700	
7	4,700	7	4,700	7	4,700	7	4,700	
8	4,700	8	4,700	8	4,700	8	4,700	
9	4,700	9	4,700	9	4,700	9	4,700	
10	4,700	10	4,700	10	4,700	10	4,345	
11	4,700	11	4,700	11	4,700	11	3,991	
12	4,700	12	4,700	12	4,700	12	3,636	
13	4,700	13	4,700	13	4,700	13	3,282	
14	4,700	14	4,700	14	4,700	14	2,927	
15	4,700	15	4,700	15	4,700	15	2,573	
16	4,700	16	4,700	16	4,700	16	2,218	
17	4,700	17	4,700	17	4,700	17	1,864	
18	4,700	18	4,700	18	4,700	18	1,509	
19	4,700	19	4,700	19	4,700	19	1,155	
20	4,700	20	4,700	20	4,700	20	800	
21	4,700	21	4,700	21	4,700	21	800	
22	4,700	22	4,700	22	4,700	22	800	
23	4,700	23	4,700	23	4,700	23	800	
24	4,700	24	4,700	24	4,700	24	800	
25	4,700	25	4,700	25	4,700	25	800	
26	4,700	26	4,700	26	4,700	26	800	
27	4,700	27	4,700	27	4,700	27	800	
28	4,700	28	4,700	28	4,700	28	800	
29	4,700	29	4,700	29	4,700	29	800	
30	4,700	30	4,700	30	4,700	30	800	
		31	4,700			31	800	
Avg.	4,700		4,700		4,700	7/1-7/19	2,561	3,674

Spring and Summer Release Patterns

Start Date	Release[a] (cfs)	Change (cfs)	Number of Days	Change Rate (cfs/d)
4/1	4,700			
5/15	4,700	0	30	0.0
6/1	4,700	0	31	0.0
7/9	4,700	0	39	0.0
7/20	800	-3,900	11	-354.5
8/1	800	0	11	0.0

[a] April, May, and June based on the USFWS Biological Opinion (USFWS 1992); July and August based on data presented in Table 5.

TABLE 11 Parameters for the Green River SSARR Model

River Reach	Number of Routing Phases	n	K_T
Flaming Gorge Dam to Gates of Lodore	30	0.20	3.0
Gates of Lodore to Hells Half Mile	40	0.50	3.0
Hells Half Mile to Jones Holes	45	0.50	4.0
Jones Hole to Rainbow Park	30	0.40	3.0
Rainbow Park to Jensen Gage	28	0.37	2.9

TABLE 12 Daily Green River Flows under the Year-Round High Fluctuating Flow Scenario during a Moderate Water Year

| Month | Daily Reservoir Release (cfs) | | Daily Flows at 48 and 58 Miles[a] (cfs) | | | | Yampa River Average Inflow at 65 Miles[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 13 Daily Green River Flows under the Seasonally Adjusted High Fluctuating Flow Scenario during a Moderate Water Year

Month	Daily Reservoir Release (cfs)		Daily Flows at 48 and 58 Miles[a] (cfs)				Yampa River Average Inflow at 65 Miles[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	3,500	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 14 Daily Green River Flows under the Seasonally Adjusted Moderate Fluctuating Flow Scenario during a Moderate Water Year

| Month | Daily Reservoir Release (cfs) | | Daily Flows at 48 and 58 Miles[a] (cfs) | | | | Yampa River Average Inflow at 65 Miles[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	2,380	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[b]	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.

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