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GLEN CANYON DAM
Beach/Habitat-Building Test Flow

AN *EX POST* ANALYSIS OF HYDROPOWER COST

April 1997

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A 7-day controlled release was made from Glen Canyon Dam in late March and early April 1996 for research purposes. This beach/habitat-building test flow was conducted to test hypotheses about the dynamic nature of geomorphic processes and the aquatic and terrestrial habitats which are dependent on them. This report describes the economic and financial impact of the test flow on the hydropower system.

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EXECUTIVE SUMMARY

GLEN CANYON DAM BEACH/HABITAT-BUILDING TEST FLOW—AN *EX POST* ANALYSIS OF HYDROPOWER COST

Prior to construction of Glen Canyon Dam, the Colorado River transported tremendous amounts of sediment through Glen and Grand Canyons. Since dam construction, downstream tributaries have provided the only source of sediment. Operation of the dam to produce peaking power results in hourly fluctuations in release and river stage. Historically these fluctuations were constrained only by the physical limitations of the powerplant. The resulting fluctuations have been shown to significantly affect aquatic resources and sediment deposits on the channel margins. The elimination of large sediment laden floods has prevented the replenishment of high predam terrace deposits.

A 7-day controlled flood was conducted at Glen Canyon Dam in late March and early April of 1996 for research purposes. This short-duration high release was designed to rebuild high elevation sandbars, deposit nutrients, restore backwater channels, and provide some of the dynamics of a natural system. The goal was to test hypotheses about sediment movements and the response of aquatic and terrestrial habitats to controlled flood events.

There were two sources of economic and financial impact associated with the beach/habitat-building test flow—changes in the timing and amount of hydropower produced and the costs of the research associated with this experiment. The purpose of this report is to describe the economic and financial impacts of the test flow on the hydropower system. Research on the physical and biological aspects of this experiment is estimated to have cost an additional $1.5 million. These research costs are not considered in this document.

The annual amount of water released from Glen Canyon Dam during water year 1996 did not change as a result of the experimental flow. However, an additional 409,000 acre-feet of water were released during the months of March and April. Of this amount, approximately 217,000 acre-feet of water bypassed the powerplant during the test and the opportunity to generate 109,000 megawatt hours (MWhr) of electricity was foregone. Since water was reallocated to accommodate the test flow, there were hydropower effects across the entire water year.

The economic impacts of the test flow are measured by the dollar value of real resources committed by the United States, including the additional use of fuels such as gas and coal. As shown in Table EX1, the economic cost of the test flow was approximately $2.520 million. This represents a 3.3 percent decline in the economic value of hydropower produced during the year.

The financial cost, or impact on Western Area Power Administration's (Western) net revenue, is dependent on interpretation and implementation of section 1807 of the Grand Canyon Protection Act of 1992. If the costs of the test flow are determined to be reimbursable, or repayable by

project beneficiaries—primarily power users, the financial cost to Western and it's customers will be $2.524 million. This represents a 2.5 percent decline in net revenue. As shown in Table EX1, the potential effect of the test flow on Western's Salt Lake City Area Integrated Projects (SLCA/IP) wholesale power rate is $0.02/MWhr which represents a 0.1 percent increase. An increase in Western's SLCA/IP wholesale power rate could potentially cause an increase in the retail rates of end use power consumers. This is particularly true for small system power users who are heavily dependent on Federal power. The potential increase in small system retail rates is estimated to be $0.01/MWhr which represents a 0.01 percent change.

If the costs of the test flow are determined to be nonreimbursable, there will be no financial cost to Western and no impact on either wholesale power rates or small system retail rates. In this event, the incidence of the cost of the test flow is shifted to all taxpayers in the United States.

Table EX1. Summary of Economic and Financial Impacts of the Experimental Test Flow on the Hydropower System.

	Water Year 1996	Water Year 1996 Adjusted to Exclude Spill Reduction Measures
Economic Impact (million $)	2.520	1.300
[1]Financial Impact (million $)	2.524	1.179
[1]SLCA/IP Rate Impact ($/MWhr)	0.02	0.01
[1]Small System retail Rate Impact ($/MWhr)	0.01	0.01

[1]Financial costs, wholesale and retail rate impacts are dependent on interpretation and implementation of section 1807 of the Grand Canyon Protection Act of 1992. These costs may or may not be realized. See text for further details.

The impact of the test flow during water year 1996 was, in part, influenced by additional releases during the months of April, May, and June designed to reduce the risk of an uncontrolled spill at Lake Powell. If a spill occurred, the resulting high flows might erode newly reformed sediment deposits. Since the longevity of these sediment deposits is, in itself, a significant research question, a spill would have masked the effects of the experimental flood and decreased the scientific value of the experiment.

If risk of spill reduction releases had not been made in April, May, and June, the cost of a beach/habitat-building flow would have been less than experienced during water year 1996. A sensitivity analysis of the test flow, exclusive of these spill reduction measures, was undertaken.

The results are shown in the second column of Table EX1. As shown there, independent of these risk of spill reduction releases, the economic cost of the test flow would have been approximately $1.3 million and the financial cost would have been less than $1.2 million.

The estimated economic and financial costs of the water year 1996 test flow on the hydropower system reflect existing hydrologic conditions, the timing and design of the experiment, and current conditions in the electric power market. This experiment reduced the economic and financial value of the power produced at Glen Canyon Dam during the water year by 3.3 and 2.5 percent, respectively. The preliminary physical and biological results of this experiment indicate that controlled floods may be an effective tool for use in the management of the Colorado River in Glen and Grand Canyons. Future periodic beach/habitat-building flows are planned. Depending on the magnitude and duration of these flows, hydrologic conditions at the time, and conditions in the electric power market, the costs of future beach/habitat-building flows may be less than or greater than those of the water year 1996 experiment. Clearly, the tradeoff between the hydropower costs of such flows and the benefits to the downstream ecosystem must be carefully weighed.

GLEN CANYON DAM BEACH/HABITAT-BUILDING TEST FLOW—AN *EX POST* ANALYSIS OF HYDROPOWER COST

INTRODUCTION

Prior to construction of Glen Canyon Dam, the Colorado River transported tremendous amounts of sediment through Glen and Grand Canyons. Since dam construction, downstream tributaries have provided the only source of sediment. Operation of the dam to produce peaking power results in hourly fluctuations in release and river stage. Unconstrained fluctuations have been shown to significantly affect aquatic resources and sediment deposits on the channel margins. The elimination of large sediment laden floods has prevented the replenishment of high predam terrace deposits.

A 7-day controlled flood was conducted in late March and early April of 1996 for research purposes. This short-duration high release was designed to rebuild high elevation sandbars, deposit nutrients, restore backwater channels, and provide some of the dynamics of a natural system. The goal was to test hypotheses about sediment movements and the response of aquatic and terrestrial habitats to flood events. Approximately 217,000 acre-feet of water bypassed the powerplant during the test and the opportunity to generate 109,000 megawatt hours (MWhr) of electricity was foregone. Voluminous amounts of physical, biological, and economic data were collected.

This report describes the resultant economic and financial impact of the test flow on the hydropower system. There were two sources of economic and financial impact associated with the beach/habitat-building test flow—changes in the timing and amount of hydropower produced and the costs of the research. The purpose of this report is to describe the economic and financial impacts on the hydropower system. The research associated with this experiment is estimated to have cost an additional $1.5 million. The research projects carried out during the test flow and their estimated costs are described in Reclamation (1996). These costs are not considered in this document.

BACKGROUND AND SETTING

Glen Canyon Dam was completed by the U.S. Bureau of Reclamation in 1963. It is located on the Colorado River upstream from Grand Canyon National Park. This 710-foot high concrete arch dam controls a drainage basin of approximately 108,335 square miles. There are eight hydroelectric generators at the dam which can produce up to 1,288 megawatts (MW) of electric power.

The Operation of Glen Canyon Dam Environmental Impact Statement (GCDEIS) was initiated in 1989 to examine options which, "... minimize—consistent with law—adverse impacts on

downstream environmental and cultural resources and Native American interests..." (Reclamation 1995a p. 1). The environmental impacts of nine operational alternatives were examined in the final GCDEIS.

On October 5, 1996, the Secretary of the Interior issued a record of decision (ROD) on the future operations of Glen Canyon Dam. He announced that the facility will be operated according to the Modified Low Fluctuating Flow (MLFF) alternative described in the GCDEIS. Under MLFF, there are new restrictions on maximum flows, minimum flows, ramp rates, and the daily change in flow. MLFF were designed to reduce daily flow fluctuations well below historic levels with the goal of protecting downstream resources while allowing limited flexibility for power operations. The MLFF alternative also specifies a number of other management actions. Among these elements are beach/habitat-maintenance flows and beach/habitat-building flows. It is intended that these flows be implemented on a periodic basis.

The purpose of the 1996 experimental beach/habitat-building flow was to test hypotheses made in the GCDEIS. Periodic high flows occurred regularly prior to the construction of Glen Canyon Dam and are believed to be necessary to maintain ecosystem diversity. This proposed short-duration high release was hypothesized to rebuild high elevation sandbars, deposit nutrients, restore backwater channels, and restore some of the dynamics of a natural system.

PREVIOUS STUDIES

The approach used in this *ex post* or "after the fact" analysis is essentially the same as that employed in the *ex ante* or "before the fact" analysis found in the Environmental Assessment of the Beach/Habitat-Building Test Flow (Reclamation 1996). The *ex ante* analysis was based on projected hydrology and projected 1996 electricity prices. *Ex ante* estimates of water year 1996 economic and financial cost on the hydropower system were $1.848 and $2.746 million, respectively. This *ex post* analysis uses the actual hydrology and electricity prices observed during water year 1996. In addition, there are a number of methodological refinements between the *ex post* and *ex ante* analyses. The most important of these is a change in the methodology used for financial analysis. The similarities and differences between the *ex ante* and *ex post* analyses are compared in Appendix 8.

Both the *ex ante* and *ex post* analyses are similar in approach to previous *ex ante* analyses undertaken by Western Area Power Administration (Western) for potential water year 1994 and potential water year 1995 test flow events of various magnitudes (Western 1993a, 1993b, 1993c, 1994). The financial impact of a 45,000 cfs test flow release was estimated to be $1.4 to $2.1 million during water year 1994 (Western 1993c) and $3.0 to $3.7 million in water year 1995 (Western 1994). The assumptions made about load curves and prices in these Western analyses differ from those in both the *ex ante* and *ex post* Reclamation analyses. In addition, there were differences in the design of the test flow events analyzed, the volume of water released during the year, and reservoir elevations.

THE HYDROPOWER RESOURCE

Glen Canyon Dam and Powerplant are part of the Colorado River Storage Project (CRSP), one of the Federal projects from which Western markets power. The total annual amount of energy produced by the dam depends on actual water conditions. Western's Salt Lake City Area Integrated Projects (SLCA/IP) Office annually markets more than 4 billion kilowatt-hours (kWhr) from Glen Canyon Powerplant to 198 entities principally in the six-state area shown in Figure 1.

Hydropower plants such as Glen Canyon can generate electricity without causing air pollution or using nonrenewable fuels. They can rapidly respond to emergencies such as forced outages of other generating plants and downed power lines. Perhaps most importantly, they are able to rapidly change generation levels to satisfy changes in the demand for electricity. This capability is termed "load following."

Power is most valuable when it's most in demand—during the day when people are awake and when industry and businesses are operating. Water from Glen Canyon Dam is used for load following as much as possible, particularly during this onpeak period of the day. For purposes of this analysis, the onpeak period is defined as the hours from 7 a.m. to 11 p.m., Monday through Saturday.

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

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

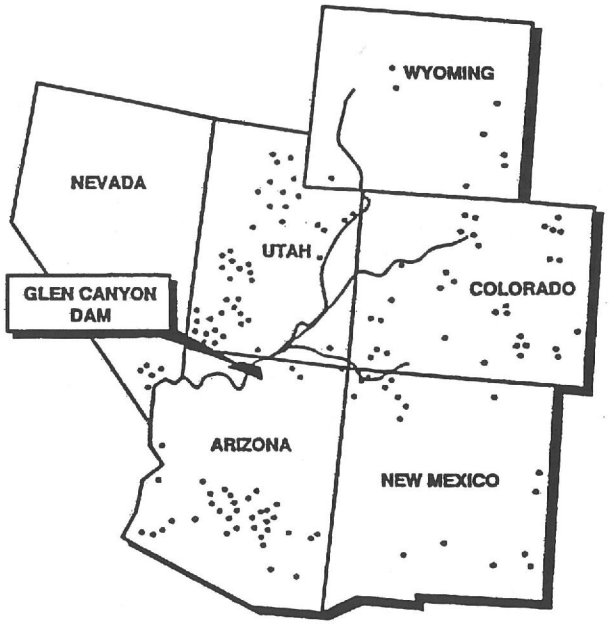

Figure 1. Power From Glen Canyon Dam is Sold Over a Six-State Area.

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

RATIONALE FOR THE TEST FLOW

The beach/habitat-building flow of 1996 was needed to test the hypotheses that the dynamic nature of fluvial landforms and aquatic and terrestrial habitats can be restored by short-duration releases substantially greater than powerplant capacity. This experiment provided an opportunity to measure essential geomorphic and ecologic processes during flood passage and recession. Data collected during the test flow provided the information needed to verify predictive models and to help establish an operational regime to maintain, manage, and protect the riparian and aquatic resources of the Colorado River in Glen and Grand Canyons.

DAM OPERATIONS DURING WATER YEAR 1996

In water year 1996, Glen Canyon Dam was operated under what is known as the Interim Operating Criteria. These criteria were established by the Secretary of the Interior in November 1991 and are described in further detail in Reclamation (1991). As summarized in Table 1, Interim Operating Criteria were designed to reduce daily flow fluctuations well below historic levels, with the goal of protecting or enhancing downstream resources while allowing limited flexibility for power operations. Minimum flows, maximum flows, ramp rates, and allowable daily fluctuations were established to protect downstream resources until the final GCDEIS was completed and a ROD had been signed. The ramp rate is the rate of change in discharge, either up or down, required to meet electrical load.

Annual and monthly releases are consistent with the Long-Range Operating Criteria objectives of 8.23-million acre-feet (maf) minimum annual release and equalized storage between Lake Powell and Lake Mead. Annual releases greater than the minimum are permitted to avoid anticipated spills and equalize storage. Monthly and annual release volumes are projected for different hydrologic conditions prior to the beginning of the water year and are described in the Annual Operating Plan (Reclamation 1995b).

Table 1. Summary of Interim Operating Criteria.

Minimum Releases (cfs)	Maximum Release (cfs)[1]	Allowable Daily Fluctuations (cfs/24 hrs)[2]	Ramp Rates (cfs/hr)
8,000 between 7 a.m. and 7 p.m. 5,000 at night	20,000	5,000 6,000 or 8,000	2,500 up 1,500 down

[1] The maximum flow constraint will be exceeded when dictated by high monthly release volumes and special management flows such as beach/habitat-building flows.
[2] Five-thousand cfs per 24 hours (cfs/24 hrs) for monthly release volumes of less than 600,000 acre-fee; 6,000 cfs/24 hrs for monthly release volumes between 600,000 and 800,000 acre-feet; and 8,000 cfs/24 hrs for monthly release volumes greater than 800,000 acre-feet.

Within these criteria (Table 1), the actual minimum and maximum releases from the dam during any given day depend on the monthly release volume, the allowable daily fluctuation, and the demand for hydroelectric power. Actual releases normally fall within the minimum and maximum allowed. The minimum release is maintained higher during the daytime hours to protect the aquatic food base from exposure to the elements. The maximum release was conservatively set to reduce sand transport in the river so that sand could accumulate along the riverbed. The allowable daily fluctuation (either 5,000, 6,000, or 8,000 cfs/24 hrs) depends on the monthly

release volume and was determined so that the daily change in river stage would be nearly the same during all months—about 3 feet in most reaches.

The down ramp rate was set to reduce seepage-based erosion of sandbars in Glen and Grand Canyons and to avoid stranding of fish. The up ramp rate was conservatively set to reduce potential operation-related impacts to canyon resources.

With the exception of the test flow period, Glen Canyon Dam was operated in accordance with the Interim Operating Criteria during water year 1996 (October 1995 through September 1996). In order to accommodate the test flow, water volumes had to be redistributed from January and February to March and April. The actual water release volumes in water year 1996 are shown in Table 2 (Peterson 1996). The corresponding end-of-month (EOM) reservoir elevations are shown in Appendix 3.

The timing of the beach/habitat-building test flow during the months of March and April was carefully considered. Specifically, this time frame was selected to reduce impacts on river resources by conducting the test flow (1) prior to native fish spawning and larval dispersal periods, (2) after the period when rainbow trout spawn at Lees Ferry, (3) after concentrations of wintering bald eagles and waterfowl have largely dispersed, (4) prior to the peak release of tamarisk seeds to reduce germination, (5) prior to the peak river rafting season, and (6) prior to nesting of the endangered southwestern willow flycatcher.

DESCRIPTION OF THE TEST FLOW

The test flow was carried out from March 22 to April 8, 1996. As shown in Figure 2, a 4-day period of 8,000 cfs low steady flows was initiated at approximately 0200 hours on 22 March. Beginning at approximately 0200 hours on 26 March, releases were increased by 4,000 cfs/hr until a maximum flow of 45,000 cfs was attained at 1200 hours on 26 March. This high release was maintained for 7 days. At approximately 1100 hours on 2 April, the flow rate was decreased by 1,500 cfs/hr until the discharge reached 35,000 cfs. At this point, flow rates were decreased by 1,000 cfs/hr until a discharge of 20,000 cfs was reached. Releases were then decreased at a rate of 500 cfs/hr until a discharge of 8,000 cfs was attained at 0800 hours on 4 April. A low steady release of 8,000 cfs was then maintained for 4 days. Interim operations were resumed at approximately 0200 hours on April 8, 1996.

Table 2. Monthly Release Volumes at Glen Canyon Dam With and Without the Test Flow.

Month	Forecast No Action Release Volume (acre-feet)	Actual With Test Flow Release Volume (acre-feet)	Release Volume Difference (acre-feet)
October	899,000	899,000	0
November	861,000	861,000	0
December	915,000	915,000	0
January	1,100,000	972,000	-128,000
February	950,000	807,000	-143,000
March	850,000	1,123,000	+273,000
April	825,000	1,092,000	+267,000
May	975,000	1,051,000	+76,000
June	1,000,000	1,033,000	+33,000
July	1,100,000	984,000	-116,000
August	1,100,000	910,000	-190,000
September	901,000	829,000	-72,000
ANNUAL TOTAL	11,476,000	11,476,000	0

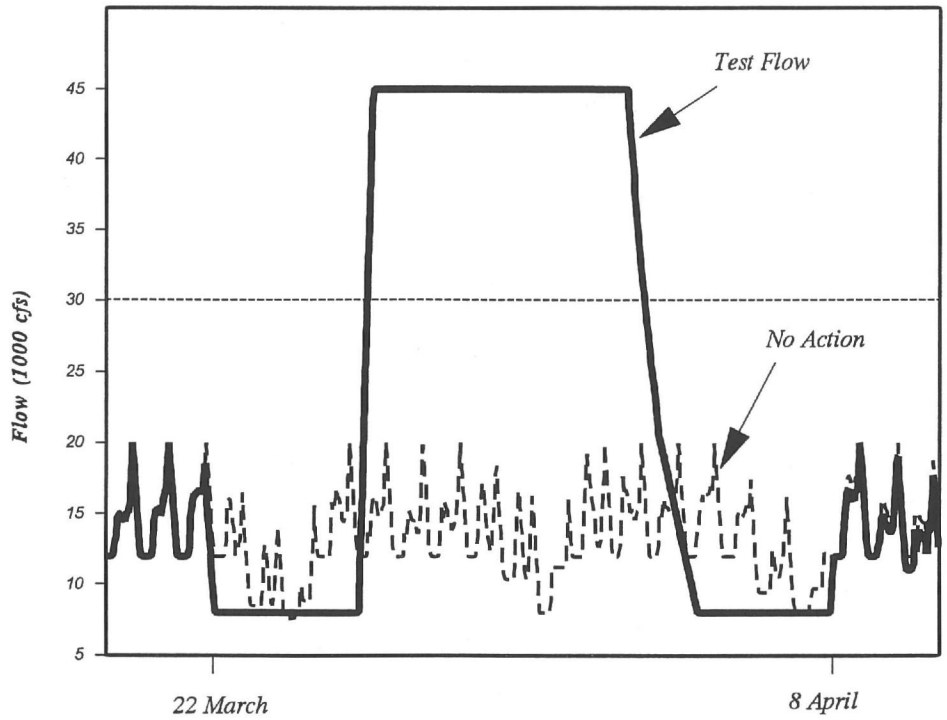

Figure. 2. Hydrograph of Beach/Habitat-Building Test Flow.

ECONOMIC AND FINANCIAL ANALYSES

Both economic and financial impacts on the power system resulted from the beach/habitat-building test flow. Due to the short-duration of the test flow, no new capital investments were expected and none were considered in this analysis.

An **economic** analysis illustrates the estimated cost to the Nation of implementing the proposed action. Economic impacts are the dollar value of real resources committed by the United States as a result of the test flow, including the additional use of fuels such as gas and coal. Explicitly omitted from this, and all economic analyses, is consideration of investments made prior to the period of analysis. These expenditures are considered sunk or fixed costs. This concept is relevant to the short-term analysis presented here because the contract price of replacement power may contain both a fixed and a variable cost component. The fixed cost component of replacement power is a prorated sunk cost. This component of the cost of purchased power was

excluded from the economic analysis through the use of spot market prices which reflect only the variable cost of generation.

A financial analysis focusses on the monetary impact to an identifiable entity or population group. The **financial** analysis described here provides an estimate of the monetary cost to Western and Western's power customers resulting from the test flow and does not account for those utilities beneficially affected. Financial impacts include both real resource (economic) costs and sunk costs.

ECONOMIC VALUE OF HYDROELECTRICITY

Historically, the electric utility industry has been heavily regulated by both state and Federal regulatory agencies. Transactions between utilities are shaped by regulatory policy and therefore unlikely to reflect economic value. In the absence of meaningful economic price data, the avoided cost, or the cost of the next least cost alternative source of supply has commonly been used as a proxy for the economic value for hydropower (Young and Gray 1972, Gibbons 1986).

The operational changes examined here result both in hourly changes in the timing of hydropower generation and in the amount of energy generated. Analysis of the economic impact of these changes requires price data which is similarly desegregated. Obtaining detailed site specific price data for analysis purposes has, up until quite recently, been extremely problematic. Formerly, two methods were used to construct vectors of economic value for analysis purposes—assumption and modeling. By far the most commonly used approach was to assume the economic value of onpeak and offpeak power. Although straightforward, questions about the validity of these assumptions were commonplace and it was difficult to defend them on empirical grounds. Alternatively, models such as the Spot Market Network Model (VanKuiken et al 1994) or commercially available production cost models such as PROSYM (The Simulation Group 1995) were used to estimate a price vector suitable for analysis. These models are both data and resource intensive. Although quite rigorous, the results obtained with both price forecasting models and production cost models are highly sensitive to the characterization of the power system, load growth assumptions, fuel costs, and escalation rates.

Sweeping changes in the functioning of electric utility industry and the manner in which electricity is marketed are occurring and are expected to continue. Detailed, site specific, spot market prices for electricity have recently become available. In 1995, the Federal Energy Regulatory Commission (FERC) issued orders 888 and 889 (FERC 1995). These two orders form the basis for a complete restructuring of the electric utility industry. Order 888 opens wholesale power sales to competition. It requires public utilities owning, controlling, or operating transmission lines to file nondiscriminatory open access tariffs that offers other entities the same transmission service they provide themselves. Order 889 establishes standards of conduct and requires utilities to post information about their available transmission capacity on real time computer systems.

Since FERC orders 888 and 889 were issued, wholesale transactions of electric power have become commonplace and electricity has become a commodity much like oil and gas, pork, and wheat. In fact, a futures market for wholesale bulk electricity traded at various locations has been established on the New York Mercantile Exchange (NYMEX). Prices for electricity are now more readily observed. At a given location and time, these observable market prices embody all of the characteristics of the underlying power system which heretofore could be approximated only with complex models. These observed prices reflect actual market transactions thus obviating the need for proxy measures or estimates derived using models.

ANALYSIS APPROACH

A three-step process was used for estimating the economic and financial impacts described in this analysis. First, the with and without test flow generation at Glen Canyon Dam was simulated on a monthly basis for each hour in water year 1996 (8,760 hours). Second, for both the economic and financial analyses, the resultant vectors of with and without hourly generation were evaluated using vectors of economic and financial prices, respectively. Finally, the hour by hour difference in both the economic and financial value was computed.

Simulating Hydrogeneration

For both the economic and financial analyses reported here, an aggregate hourly load curve was assumed to represent system demand during water year 1996. Monthly release volumes and EOM reservoir elevations with the test flow (actual) were obtained from existing records. Monthly release volumes and EOM reservoir elevations without the test flow (forecast) were obtained from Peterson (1996). Using these inputs, hourly power operations for all 12 months without the test flow and 10 months of the with test flow case were simulated using a variant of the peak-shaving model (Environmental Defense Fund 1995). For March and April with the test flow, the actual hourly pattern of releases shown in Figure 1 was used for the 22 March - 8 April period and the remaining hours were simulated using the peakshaving model. Additional background for this approach is contained in Appendix 9.

The peakshaving model, described in Appendix 1, is one of two widely used approaches for simulating hydroelectric generation. This methodology is used in a number of commercial power system models including PROSYM (The Simulation Group 1995). A discussion of this algorithm and a comparison with other methods can be found in Staschus, Bell, and Cashman (1990). A "hands on" educational version of the peakshaving model is provided by Harpman and Rosekrans (1996).

Economic Analysis

For the economic analysis, simulated vectors of with and without test flow generation were evaluated using a common vector of spot market prices. Purchases and sales over the 8,760 hours during the year were evaluated in this manner. Further information on the vector of spot market prices used in this analysis and their source is contained in subsequent sections of this report.

Financial Analysis

The focus of the financial analysis reported here is the revenue impacts to Western and ultimately—end use consumers of electricity produced at Glen Canyon Dam. This analysis estimates the impacts on Western's net revenue which is defined here as the revenue received from the sales of electricity produced at Glen Canyon, less the costs of replacement power. Appendix 4 provides additional background on Western and the sale of Federal power produced at Glen Canyon Dam.

For the purposes of the financial analysis, the electricity generated at Glen Canyon Dam was evaluated at the Salt Lake City Area Integrated Project (SLCA/IP) rate. The current SLCA/IP wholesale composite rate is $20.17/MWhr. Energy and capacity which Western guarantees to deliver is referred to as "firm load." Generation in excess of firm load was valued at the spot market price. It was assumed that if generation fell below firm load, power would be purchased to supply firm power obligations. Energy purchased to meet contractual obligations ("firming purchases") is termed "replacement" power. Depending on the market conditions during water year 1996, replacement power purchases were made either on the spot market or through pre-arranged replacement power contracts. This analysis mimics these purchases as closely as possible. Appendix 4 describes the methodology used in the financial analysis in considerable detail. Appendix 5 illustrates the months in which contract purchases took place and the average contract price in those months.

Wholesale and Retail Rate Impacts

Wholesale and retail rate impacts are another measure of financial impact. In that sense, their inclusion here is redundant. However, rate impacts are a useful measure because they are a monetary index familiar to the average citizen.

For this analysis, potential impacts on the SLCA/IP wholesale composite rate were estimated using Western's Personal Computer Based Power Rate Study Model. Potential rate impacts were determined by estimating the SLCA/IP rate with and without the additional financial costs resulting from the test flow.

Small system end users comprise 7 percent of all end use consumers in the six-state area where electricity from Glen Canyon Dam is sold. Due to their high reliance on Federal power, the retail rates of these end users may well be affected to some degree by changes in the SLCA/IP rate. The extent of this effect, if any, depends on the proportion of Federal hydropower used by the customer's utility to meet their power needs, the wholesale rate, the magnitude of the underlying retail rate, and the cost of purchasing electricity from other sources.

Retail rates for electricity are based not only on the production cost electricity, but all of the costs associated with delivering it to the end use consumer. These costs reflect substantial outlays for constructing, operating, and maintaining the retail electricity distribution system. In addition, many towns and municipalities levy fees on electric power users to support local services such as local government administration, fire protection, police services, and various other initiatives. Consequently, retail rates are typically much higher than wholesale power rates. To provide some perspective on the relative difference, the national average retail electric rate was approximately $69.00/MWhr in 1995 (Energy Information Administration 1996).

For this analysis, effects on the retail rates of small system end users were estimated using spreadsheets developed for the GCDEIS. Without the test flow, the weighted average small system retail rate estimated with these spreadsheets is $69.60/MWhr. Retail rate impacts were calculated as the difference between the SLCA/IP rate with and without the test flow.

INPUT DATA

Hydrology

The underlying hydrology, shown in Table 2, forms the basis for this analysis. As might be expected, both the with and without test flow hydrology critically influence the estimates of economic and financial impact which are described in this report. The with test flow hydrology (second column in Table 2) reflects the actual monthly releases and EOM elevations of Lake Powell observed during the water year. The without test flow monthly releases and reservoir elevations were furnished by Peterson (1996).

As reported in Reclamation (1996, Table 2, page 6), in November 1995 the most probable release forecast for Lake Powell was 11.3 MAF. Although the forecast changed a number of times during the year, actual releases from Lake Powell in water year 1996 were 11.476 MAF—remarkably close to the November 1995 forecast.

The annual release volumes for both the with test flow case and the without test flow case are the same by design—to reflect compliance with "The Law of the River" Operating Criteria. A useful reference to CRSP operations, pertinent treaties, and regulations which comprise the "Law of the River," is Reclamation (1980).

In the absence of the test flow, monthly releases from Glen Canyon Dam would have corresponded with the pattern of releases shown in Table 2 (Peterson 1996). As shown in Table 2, the October through December releases are the same in both the with test flow and without test flow cases, since the final decision to proceed with the test was not made until after December. With the test flow, less water was released in January and February than otherwise would have been the case. This water was stored in Lake Powell and then released during March and April to accommodate the beach/habitat-building flow.

As originally planned, the only differences between the with test flow and without test flow monthly release patterns would have been in January, February, March, and April. However, management and scientific concerns following the experiment converged with forecast error to produce the more complex pattern of differences shown in Table 2. During most of the spring, the inflow forecast was for 115 percent of normal and Lake Powell was projected to come within 5 feet of filling. At the time, there was some indication that higher than normal precipitation would continue. This increased the possibility that unexpectedly high inflows could result in an uncontrolled spill if the reservoir was not evacuated to accommodate them.

An unanticipated spill immediately following the test flow would likely have eroded newly reformed sediment deposits. The longevity of these reformed sediment deposits in a "natural" state is a critical research and management question. Information about the temporal nature and topography of these dynamic sediment features is crucial for determining the magnitude, duration, and perhaps most importantly—the periodicity of future beach/habitat-building flows. An unplanned spill following the experiment would not only have reversed the environmental benefits achieved by the test flow but would have significantly reduced the scientific value of the experiment.

Consequently, additional releases (beyond those originally planned) were made in April, May, and June, to ensure that an unplanned spill did not occur. Unfortunately, beginning in mid-June and continuing through the summer, the basin experienced severe drought conditions. Actual runoff dropped to subnormal levels. Because inflows did not reach the levels initially forecast, the release volumes for the remainder of the water year, July through September, had to be curtailed by 100,000 to 200,000 acre-feet per month. As a result, there are differences in the with and without test flow monthly release patterns from January through September of water year 1996.

Aggregate Load

In this analysis, an aggregate hourly load curve was assumed to represent system demand during water year 1996. This aggregate load curve was constructed from 1994 hourly load data reported by Salt River Project, Platte River Power Authority, Colorado Springs Utilities, and Deseret Generation and Transmission. This publicly available data was obtained from information provided to the FERC on form 714. The 1994 load data was escalated by 2 percent per annum to

account for load growth and adjusted for the number of days and the pattern of weekdays and weekends in 1996. Descriptive statistics for these data are reported in Appendix 7.

Although these aggregate load data are the best available data, they do not perfectly represent, on an hour by hour basis, the aggregate load in water year 1996. In particular, the variation in load caused by temperature, unit outages, and other events is not accurately captured. Ideally, aggregate load for water year 1996 would have been used for analysis purposes. Unfortunately, utilities are not required to report these data to FERC until June 1997. Since it seemed unlikely that water year 1996 data could be obtained prior to the filing deadline, the data described were utilized to complete this analysis in a timely manner.

Firm Load

Hourly firm load data were used only in the financial analysis. During months in which contract purchases were made, it was assumed that when generation at Glen Canyon Dam was insufficient to meet firm load, replacement power was purchased at contract prices. Hourly firm load data for this purpose were obtained from Western. The data used represent actual water year 1996 scheduled firm load deliveries as recorded on line 1172 of Western's Supervisory Control and Data Acquisition (SCADA) system. Descriptive statistics for this data are found in Appendix 7.

Prices Used in Economic Analysis

Mean daily onpeak and offpeak spot market (non-firm) prices were used to value the simulated generation for this analysis. These data are specific to the Palo Verde and Westwing, Arizona, interchange. This location is a transaction accounting point for electricity which is ultimately used elsewhere in the southwest. The price data for October 1995 through December 1995 were obtained from Economic Insight, Inc. These data represent the price of wholesale bulk on and offpeak power scheduled for delivery the next day. The data for January 1996 through September 1996 were furnished for this analysis by the Dow Jones and Company, Inc., Energy Service. Through contractual arrangement, Dow Jones, Inc., obtains real time onpeak and offpeak transaction data from a number of participating utilities and power wholesalers. These proprietary data are then sales volume weighted. These weighted average daily onpeak and offpeak prices are made available to subscribers of the Dow Jones Telerate Service and are later published in *The Wall Street Journal*. Although the market for wholesale bulk power is new and therefore somewhat thinly traded, these data represent actual observations of electricity prices at a level of accuracy, spacial location, and disaggregation which was heretofore unavailable. Descriptive statistics for these data are found in Appendix 6.

Contract Prices Used in Financial Analysis

During Water Year 1996, contract purchases were made during the months of February, March, April, July, and August. For purposes of the financial analysis reported here, if contract purchases were made during the month, all required replacement power purchases were made at the average cost of replacement power for that month. The average cost of replacement power purchased under contract is shown in Appendix 5.

RESULTS

Qualitative Effects on Hydropower

The test flow affected power operations in two periods: the 2 months when the test flow occurred and the other 10 months in the water year.

The impacts during the test flow period were:

- During the 4 days of steady flows preceding the high release, on average, less power was generated than needed to supply firm load (see Figure 2).
- During the high release, the outlet works were used to release flows in excess of 30,000 cfs, bypassing the powerplant (Figure 2). Water released through the outlet works is considered "spilled" and is unavailable to produce electricity at Glen Canyon Dam.
- During the high release, more power was generated than was needed to supply firm load.
- During the 4 days of steady flows following the high release, on average, less power was generated than needed to supply firm load (see Figure 2).

Impacts on the power system also occurred during the other months in water year 1996. These impacts occurred because water volumes were shifted from the months of January and February to March and April for the test flow. From a power perspective, the resulting pattern of monthly release volumes was less desirable. For example, there was less water available in January—a peak power demand month—than there would have been without the test flow.

Hydrology and Energy Effects

Hourly operations under the proposed action were simulated using the same methods described for no action for 10 months of water year 1996. With the exception of the test flow period in

March and April, the hourly pattern of flow and generation was simulated using the peak shaving model. During the test flow period, the hourly pattern of releases described under the proposed action was used. An example parameter file is contained in Appendix 10.

Measured over the period 0200 hours on March 22 through 0200 hours on April 8, the test flow required 408,826 acre-feet of additional water—318,311 acre-feet in March and 90,515 in April. Of the 408,826 acre-feet, 216,876 acre-feet were spilled—167,585 in March and 49,291 in April.

As shown in Table 3, approximately 109,000 MWhr less energy (2 percent less) was generated as a result of the test flow. The difference between the with and without test flow cases reflects the approximately 217,000 acre-feet of water that was released through the outlet works or "spilled" during the test flow.

Table 3. Energy Generated at Glen Canyon Dam by Month With and Without the Test Flow.

	Without Test Flow (MWhr)	With Test Flow (MWhr)	Delta From Without (MWhr)
October	443,326	443,326	0
November	423,264	423,264	0
December	448,163	448,163	0
January	534,911	473,458	(61,453)
February	459,489	391,779	(67,710)
March	410,050	462,118	52,068
April	399,249	505,826	106,577
May	479,833	514,776	34,943
June	498,441	512,375	13,934
July	546,303	486,923	(59,380)
August	540,755	447,603	(93,152)
September	440,008	404,846	(35,162)
TOTAL	5,623,792	5,514,457	(109,335)

Economic Effects

As shown in Table 4, compared to no action there was no economic impact from the test flow during the months of October, November, and December. Compared to no action, additional economic costs were incurred during the months of January, February, July, August, and September. The costs during these months resulted from unfavorable shifts in monthly release volumes. Economic benefits were realized during the months of March, April, May, and June primarily due to additional spot market sales during these months. As discussed in previous and subsequent sections of this report, compared to no action, additional releases were made during the months of April, May, and June. This resulted in additional generation in these 3 months. Unfortunately, these releases were made in lieu of releases in July and August which are peak power demand months. Consequently, these additional releases had a marked economic impact.

Table 4. Economic Impact of Test Flow.

	Without Test Flow ($)	With Test Flow ($)	Delta ($)
October	5,996,602	5,996,602	0
November	5,493,721	5,493,721	0
December	4,820,530	4,820,530	0
January	7,062,147	6,261,675	(800,472)
February	5,157,175	4,425,779	(731,396)
March	4,292,289	4,861,921	569,632
April	4,889,132	6,126,815	1,237,683
May	5,239,161	5,646,230	407,069
June	6,213,590	6,388,805	175,215
July	8,999,129	8,015,148	(983,982)
August	10,671,828	8,849,360	(1,822,468)
September	6,908,529	6,337,683	(570,846)
TOTAL	75,743,833	73,224,268	(2,519,564)

Across the water year, the economic cost of the test flow was $2.520 million. This represents a 3.3 percent reduction in the economic value of the power produced at Glen Canyon during water year 1996. An example economic output file is contained in Appendix 13.

Financial Effects

As shown in Table 5, there was no financial impact from the test flow during the months of October, November, and December. Compared to no action, additional financial costs were incurred during the months of January, February, July, August, and September. The costs during these months resulted from unfavorable shifts in monthly release volumes. There were additions to revenues during the months of March, April, May, and June. These financial benefits resulted from additional spot market sales.

Table 5. Financial Impact of Test Flow.

	Net Revenue Without Test Flow ($)	Net Revenue With Test Flow ($)	Delta ($)
October	7,966,170	7,966,170	0
November	7,677,101	7,677,101	0
December	8,069,262	8,069,262	0
January	9,384,467	8,583,988	(800,479)
February	7,735,884	6,916,960	(818,924)
March	6,901,915	7,746,368	844,453
April	7,198,798	8,449,748	1,250,950
May	8,191,217	8,598,295	407,078
June	8,890,853	9,066,068	175,215
July	10,426,209	9,365,329	(1,060,881)
August	10,607,424	8,657,270	(1,950,154)
September	8,312,804	7,741,947	(570,857)
TOTAL	101,362,105	98,838,507	(2,523,599)

As discussed in previous and subsequent sections of this report, compared to no action, additional releases were made during the months of April, May, and June. This resulted in additional generation in these 3 months. Unfortunately, releases during April, May, and June were made in lieu of releases in July and August which are peak power demand months. Consequently, these releases had a significant financial impact.

This estimate of the financial cost of the test flow includes both the cost of foregone generation and the cost of purchasing replacing power to meet contractual obligations. For water year 1996, this cost is estimated be $2.524 million. To place this in perspective, without the test flow approximately $101.4 million in revenues would be expected in water year 1996. The estimated financial cost of the test flow represents a 2.5 percent decline in net power revenues.

Comparing the Economic and Financial Impacts

As shown in Tables 4 and 5, there is considerable difference between the financial and economic value of the energy produced at Glen Canyon Dam. Without the test flow, the economic value of generation is $75.744 million and the financial value is $101.362 million. This difference is due primarily to the relatively high SLCA/IP wholesale price used in the financial analysis compared to the generally lower spot market prices used in the economic analysis. See, for example, average spot market prices in Appendix 6. The SLCA/IP rate is a long-term contract price whereas spot market prices represent the short-run market value. For this reason, the difference between these two analyses is not surprising.

The financial impact of the test flow and the economic impact of the test flow are nearly identical—$2.524 million and $2.520 million, respectively. The slight difference between these estimates is due to the purchase of replacement power through contractual arrangement. With the benefit of hindsight, it is clear that the contracts which Western entered into specified prices which (see Appendix 5) far exceeded the market price. Given the large discrepancy between contract prices and spot market prices, the relatively small difference between the economic and financial cost of the test flow surely reflects the limited use of existing contracts. If more of the replacement power had been purchased at contract prices, the difference between the economic and financial cost of the test flow would have been much more pronounced. Some additional discussion is contained in Appendix 9.

Financial Impacts and the Grand Canyon Protection Act

Ordinarily, if additional financial costs, such as those associated with the test flow, were incurred by Western, these costs would eventually be reflected in charges to end use consumers of the electricity they produce. In other words, these additional costs would impact the SLCA/IP wholesale rate. In this case however, section 1807 of the Grand Canyon Protection Act of 1992 provides that all costs of the GCDEIS, including supporting studies and long-term monitoring,

shall be nonreimbursable except during the years 1993-1997. In those years, the Secretary of the Interior must total the budget impact of all titles in the act and determine whether the receipts exceed all annual costs, including the environmental impact statement, related studies, and subsequent monitoring.

Should the Secretary determine that the net offsetting receipts for fiscal year 1996 have increased, the costs of the test flow would be considered a nonreimbursable expense. As such, these funds would be treated as having been repaid and returned to the general fund. Under this condition, the test flow would have no financial impact on Western and consequently would have no impact on the SLCA/IP firm power rate.

If the Secretary determines that a reduction in net offsetting receipts has occurred in fiscal year 1996, the total financial costs would be considered reimbursable. In that event, the test flow would, at least conceptually, result in an SLCA/IP power rate increase.

A final Secretarial determination has not yet been made at the time this report was written. It is of some importance to note that if the additional purchased power costs are determined to be nonreimbursable, there would be no financial impact on Western, no change in Western's wholesale rate, and the test flow would have no effect on the retail rates of end users.

Rate Impacts

If the Secretary determines that a reduction in net offsetting receipts has occurred in fiscal year 1996, the total financial costs would be considered reimbursable. In that event, the test flow would, at least conceptually, result in an SLCA/IP power rate increase of 0.02 $/MWhr (0.1 percent increase) compared to no action (Tafoya 1997).

If the SLCA/IP wholesale rate were to increase, there could be a small impact on the retail rates of end users in the region. Using the spreadsheet for interim operations and inserting the increased SLCA/IP rate yields a weighted average small system retail rate of $69.61/MWhr. This represents a $0.01/MWhr (0.01 percent) increase.

DEVIATIONS FROM PROJECTED WATER YEAR 1996 RELEASES

Reduction in Risk of Spill

The economic and financial impact of the beach/habitat-building test flow reported here are, to some extent, confounded by a management decision made following the experiment. As described in a previous section entitled "INPUT DATA Hydrology," during water year 1996 releases greater than those initially planned were made in the months of April, May, and June. These additional releases were made to reduce the risk of unanticipated spills. In addition to

placing downstream resources at risk, should such a spill have occurred, it might have reduced the scientific value of the experiment. As a consequence of this decision and less than perfect knowledge about future inflows (otherwise known as forecast error), releases were curtailed during the months of July and August—peak power demand months. As shown in Tables 4 and 5 the effects were significant.

Arguably, although there will be beach/habitat-building flows in the future, the information gained during the 1996 experiment makes it unlikely that similar risk of spill reduction releases would be made in the future. Consequently, the cost of future beach/habitat-building flows is likely to be less than the water year 1996 experiment suggests.

Impact of Risk Reduction Releases

In order to examine the effects of the test flow, independent of subsequent decisions to reduce the probability of a spill, a sensitivity analysis was undertaken. The approach used for this sensitivity analysis is identical to that previously described except that the monthly release volumes shown in Table 2 and the EOM reservoir elevations shown in Appendix 3 were used.

The monthly release volumes illustrated in Table 6 have been constructed, in so much as possible, to reflect the effects of the test flow only. Compared to the releases shown in Table 2, the monthly release volumes (and associated reservoir elevations) in April, May, June, have been adjusted downward and the monthly release volumes in July, August, and September have been correspondingly increased

Table 6. Monthly Release Volumes With and Without the Test Flow Without Measures to Reduce the Probability of Spill.

Month	No Action Release Volume (acre-feet)	With Test Flow Release Volume (acre-feet)	Release Volume Difference (acre-feet)
October	899,000	899,000	0
November	861,000	861,000	0
December	915,000	915,000	0
January	1,100,000	972,000	(128,000)
February	950,000	807,000	(143,000)
March	850,000	1,123,000	273,000
April	825,000	915,515	90,515
May	975,000	882,485	(92,515)
June	1,000,000	1,000,000	0
July	1,100,000	1,100,000	0
August	1,100,000	1,100,000	0
September	901,000	901,000	0
ANNUAL TOTAL	11,476,000	11,476,000	0

Using the adjusted monthly release volumes (Table 6) and reservoir elevations, the monthly economic impact of the test flow, independent of the decision to reduce the risk of a spill, was estimated. The results are shown in Table 7. As shown in Table 7, the estimated economic impact of the test flow alone is $1.3 million. This is $1.22 million or 48 percent less than the cost of both the test flow and spill reduction releases together

Table 7. Economic Cost of Test Flow Without Spill Risk Reduction Measures Following The Experiment.

	Without Test Flow ($)	With Test Flow ($)	Delta ($)
October	5,996,602	5,996,602	0
November	5,493,721	5,493,721	0
December	4,820,530	4,820,530	0
January	7,062,147	6,261,675	(800,472)
February	5,157,175	4,425,779	(731,396)
March	4,292,289	4,861,921	569,632
April	4,889,132	5,083,610	194,479
May	5,239,161	4,706,391	(532,771)
June	6,213,590	6,213,590	0
July	8,999,129	8,999,129	0
August	10,671,828	10,671,828	0
September	6,908,529	6,908,529	0
TOTAL	75,743,833	74,443,305	(1,300,527)

A corresponding sensitivity analysis of the financial cost was also undertaken. The results of the financial analysis are very similar to the economic results. As shown in Table 8, the financial impact of the test flow alone is $1.179 million. This is $1.345 million or 53 percent less than the test flow and spill reduction measures together.

Table 8. Financial Cost of Test Flow Without Spill Risk Reduction Measures Following The Experiment.

	Net Revenue Without Test Flow ($)	Net Revenue With Test Flow ($)	Delta ($)
October	7,966,170	7,966,170	0
November	7,677,101	7,677,101	0
December	8,069,262	8,069,262	0
January	9,384,467	8,583,988	(800,479)
February	7,735,884	6,916,960	(818,924)
March	6,901,915	7,746,368	844,453
April	7,198,798	7,327,597	128,799
May	8,191,217	7,658,455	(532,762)
June	8,890,853	8,890,853	0
July	10,426,209	10,426,209	0
August	10,607,424	10,607,424	0
September	8,312,804	8,312,804	0
TOTAL	101,362,106	100,183,193	(1,178,913)

If these financial impacts were to be realized, they would result in an SLCA/IP rate impact of 0.009 $/MWhr. This represents a 0.04 percent increase. This increase in the wholesale rate would also affect retail rates of end use consumers. Small systems would be most affected because of their heavy reliance on Federal power. Small system rate impacts are estimated to be 0.01 $/MWhr. This represents a 0.01 percent increase.

COMPARISON OF THE *EX ANTE* AND *EX POST* RESULTS

The *ex ante* estimates of economic and financial impact on the hydropower system for an 11.3 MAF release year were $1.848 million and $2.746 million, respectively. The *ex post* estimates of economic and financial impact were $2.520 million and $2.524 million for water year 1996 (an 11.47 MAF release year). The differences between the *ex ante* and *ex post* estimates are due to a

number of factors including changes in analysis methodologies between these two analyses. These factors affect the difference between these estimates in different ways. As noted in previous sections of this report, the forecast release in water year 1996 was 11.3 MAF and the actual release was 11.47 MAF. While remarkably similar, the actual release was higher than the forecast release. All other things being the same, this would cause a reduction in the *ex post* economic and financial impact relative to the *ex ante* estimates. The *ex post* pattern of monthly water release during the water year differed considerably from *ex ante* projections. In particular, during water year 1996, actual releases during the months of April, May, and June substantially exceeded the forecast releases. All other things being equal, these additional releases resulted in an increase in the *ex post* economic and financial impact relative to the *ex ante* analysis. As documented in the sensitivity analysis, adjusted for post experiment spill reduction releases, the *ex post* estimate of economic impact would be $1.3 million and the financial impact estimate would be $1.179 million. In addition to these factors, there were differences in the prices used in the *ex ante* and *ex post* analyses as well as some changes in the approach and methodologies. These methodological differences are summarized further in Appendices 4 and 8.

ANALYSIS LIMITATIONS

The short-run estimates of financial and economic value presented here are sensitive to the timing of the experimental flow, the quantity and pattern of water release across the year, the reservoir elevations used, and conditions in the electric power market which are reflected by spot market prices. Additionally, these estimates are based on an underlying optimization model. Unlike an optimization model, human operators do not have perfect foresight and are unable to perfectly anticipate weather and market conditions. In contrast with human operators, the simulation model is unaware of and incapable of simulating opportunities for energy interchange (trades) with other utilities. All other factors being the same, these two factors make it unlikely that simulated operations will exactly duplicate actual operations. The modeling framework used here simulates the operation of Glen Canyon Dam in isolation from the other CRSP units. Admittedly, the opportunity to manage other CRSP units in a discretionary manner is limited. However, to the extent that operational flexibility exists, these units could be used to partially offset the power system impacts of the beach/habitat-building flow. Finally, this analysis is restricted to direct power system impacts. Although the beach/habitat-building test flow also has potential impacts on economic use value (Bishop et al 1987), total economic value (Welsh et al 1995) and on air quality in the region (Reclamation 1995, PRC 1996)—these topics are not addressed here.

CONCLUSIONS

The beach/habitat-building flow of 1996 was conducted to test hypotheses about the dynamic nature of geomorphic processes and the aquatic and terrestrial habitats which are dependent on them. This experiment provided an unparalleled opportunity to measure large river sediment erosion, transport, and deposition processes, to observe the effects on the aquatic and terrestrial

ecosystems, and to measure the economic and financial effects of a controlled flood event on the power system. As described in detail in this report, the economic and financial costs of the experimental test flow reflect releases made to reduce the risk of a spill at Lake Powell. This experiment reduced the economic value of the power produced at Glen Canyon Dam during water year 1996 by $2.520 million (3.3 percent) and the financial value by $2.524 million (2.5 percent). Although not discussed in this report, research on the physical and biological effects of this experiment is estimated to have cost an additional $1.5 million. Depending on the design of future beach/habitat-building flows, and the hydrologic and power market conditions at the time, the hydropower cost of future events may be less than or greater than those of the water year 1996 experiment. As with any such decision, the tradeoff between downstream ecosystem effects and the cost should be carefully weighed.

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APPENDIX 1. THE PEAKSHAVING MODEL.

Introduction

Given knowledge about the generation resources owned by competitors, the expected aggregate demand or load, the amount of water available for release, and the engineering limitations of their own plant, the problem faced by the profit maximizing hydropower producer is to generate power during the onpeak hours, when it is most valuable.

Peakshaving is one of two widely used approaches for simulating limited energy hydroelectric dispatch. The methodology has been extended by the Environmental Defense Fund (EDF) to incorporate operational constraints. The general peakshaving model is a standalone module of EDF's Elfin model, a state-of-the-art electric resource planning and production cost model (EDF 1995).

The peakshaving model simulates the cost minimizing use of a hydroelectric resource given an hourly load curve and the volume of water available for release. The objective is to reduce the peaks in the aggregate demand curve by using hydropower to supply energy at periods when the demand is greatest. The remaining load is met by other generation facilities such as coal, nuclear, gas, and oil plants which are either more expensive to operate or respond to changes in demand more slowly.

The peakshaving model uses the hydroelectric resource most effectively within the constraints of the capacity and energy available. The existence of a storage reservoir means that there is operational flexibility with regard to the timing of water releases. However, this flexibility is limited by the amount of water available for release. In general, there is not enough water to support releases at a hydro unit's maximum capacity level throughout a month. Effective use of such a flexible, energy-limited resource means that the use of a hydroelectric facility should be maximized during peak periods and reduced during offpeak periods.

The peakshaving model is particularly valuable for analyzing the behavior of a hydroelectric plant with environmental constraints such as those studied extensively in the GCDEIS (Reclamation 1995). For purposes of the GCDEIS, ramp rates, maximum flows, minimum flows, and maximum daily changes in flow were constrained to varying degrees. A graphical exposition of the model as well as several recent applications are discussed in Harpman and Rosekrans (1996).

Formulation

The peakshaving model can be formulated as follows. First, as with most real world applications, it is necessary to convert the natural units; flow rates, measures of volume, and energy, to a common metric in order to formulate the problem. To facilitate these conversions, two functions

are employed. The first function, fv[], calculates the flow rate (cfs) required to produce a given amount of energy (mw) at a particular reservoir elevation. This relationship is obtained by solving the generation equation shown in Appendix 2 for flow. The second function, fv[], converts a flow rate (cfs) to a volume measure (af).

The goal of the profit maximizing hydropower producer is to identify the optimal pattern of hourly releases in cfs, $q_h(x)$, $\forall_h \in \{1,2,3,...H\}$. The function describing $q_h(x)$, the optimal series of flows, is shown in equation (1). Note that $q_h(x)$ is discontinuous and monotonically decreasing in x. In equation (1), expected aggregate load in hour (h) is L_h, the maximum generation release is c, and x is an arbitrary level of release.

$$q_h(x) = \begin{Bmatrix} minf_h, & if\ ef[L_h] \le x \\ ef[L_h]-x, & if\ x \le ef[L_h] \le x+c \\ c, & if\ ef[L_h] \ge x+c \end{Bmatrix} \tag{1}$$

To solve the peakshaving problem, find an x which satisfies equation (2), subject to the set of constraint equations (3-8):

$$\sum_{h=1}^{H} fv[q_h(x)] = mvol \tag{2}$$

st:

$$q_h(x) - q_{h+1}(x) \le uprate \tag{3}$$

$$q_{h+1}(x) - q_h(x) \le downrate \tag{4}$$

$$q_h(x) \le c \tag{5}$$

$$q_h(x) \ge minf_h \tag{6}$$

$$\max(q_h(x)...q_{h+k}(x)) - \min(q_h(x)...q_{h+k}(x)) \le mdc \tag{7}$$

$$c = \min(maxfc, potentialflow) \tag{8}$$

Where:

q_h = power release (cfs) at hour h.
L_h = expected aggregate load (mw) at hour h
maxfc = maximum flow constraint for the alternative (cfs).
$minf_h$ = minimum flow constraint in hour h for the alternative (cfs).
uprate = upramp rate (cfs).
downrate = downramp rate (cfs).
max() = maximum operator
min() = minimum operator
mdc = maximum daily change constraint for the alternative (cfs).
mvol = volume of water available for release during the month (af).
potential flow = the maximum flow which can physically be passed through the generators at a given lake elevation.
k = min(24,H-h)

APPENDIX 2. FLOW, HEAD, AND GENERATION

For this analysis, power generation at Glen Canyon Dam in MW was calculated from flow and reservoir elevation as shown in the equation below:

$$fe[flow, elevation] = \frac{\Gamma * eff * flow * head(elevation)}{hptokw * 1000} \quad \textbf{(9)}$$

Where:

$\Gamma = 62.40$, The specific weight of water at 50 degrees Fahrenheit (lbs/ft^3).
eff = 0.88872889 efficiency factor (dimensionless).
head(·) = effective head (feet).
flow = Water release (cfs).
hptokw = 737.5, Conversion factor (kw/ft-lbs).

The methods described in Reclamation (1988, sections 3.38.2-3.38.5 and 1987, sections 9.1-9.2) are used to calculate effective head.

Note that the efficiency rate used here differs from that used in preceding analyses. The efficiency rate used in this analysis was derived using data obtained during the test flow. The assistance of Rusty Gattis and Richard White is gratefully acknowledged.

APPENDIX 3. RESERVOIR ELEVATIONS USED IN ANALYSES

	Without Test Flow (Forecast)[1] EOM Reservoir Elevation (ft)	With Test Flow (Actual)[1] EOM Reservoir Elevation (ft)	With Test Flow (Adjusted)[2] EOM Reservoir Elevation (ft)
October	3684.6	3684.6	3684.6
November	3682.9	3682.9	3682.9
December	3680.9	3680.9	3680.9
January	3677.0	3677.9	3677.9
February	3674.1	3676.1	3676.1
March	3672.7	3672.7	3672.7
April	3674.4	3672.5	3673.9
May	3683.5	3680.9	3683.5
June	3690.5	3687.8	3690.5
July	3688.5	3686.5	3688.5
August	3682.9	3683.2	3682.9
September	3679.3	3679.3	3679.3

[1]Source: Peterson (1996)

[2]These reservoir elevations have been adjusted to remove the risk of spill reduction releases in April, May, and June. They correspond with the monthly release volumes shown in Table 6, column 2. Source: constructed by the author.

APPENDIX 4. FINANCIAL ANALYSIS—BACKGROUND AND APPROACH

The power produced in the SLCA/IP system and purchased by Western from other sources is sold primarily to about 180 long-term, firm power customers, which in turn, serve approximately 1.7 million residential, industrial, agricultural, and municipal end use customers across a six-state area. This power is provided to Western's customers under contracts which establish the terms for how capacity and energy are to be sold. These contracts also specify the levels of capacity and energy that Western agrees to offer for long-term (greater than 12 months) sale. In aggregate, these amounts constitute Western's "commitment level." The capacity and energy level is called firm when it is guaranteed to customers. Western agreed to deliver SLCA/IP winter and summer capacity to long-term firm power customers in a marketing arrangement known as the Post-1989 Allocation (Western 1989). That planned marketing arrangement has been enjoined by court order pending completion of an Environmental Impact Statement (Western 1996), a ROD, and subsequent legal challenges, if any. The current contract rate of delivery (CROD) is known as the interim allocation. Aggregate capacity commitments for interim allocation are 1,291,232 kW (winter) and 1,269,891 kW (summer) and for the Post-1989 Allocation are 1,406,532 kW (winter) and 1,314,130 kW (summer). These contractual arrangements, the methodology used for determining firm capacity and energy levels, and the amount of energy and capacity allocated to each customer are described in detail in Western (1989) and preceding documents.

Regardless of the CROD commitment level eventually implemented, the power sold to Western's customers is priced administratively to recover production costs, maintenance costs, and CRSP costs allocated to power. The administrative price may be less than, greater than, or equal to the market value of this power. The current SLCA/IP composite rate of $20.17 /MWhr was established on December 1, 1994. This wholesale rate is often compared with current spot market prices (Appendix 6). However, because of the long-term nature of these contract allocations, the SLCA/IP price is more correctly compared with the price of long-term thermal capacity which is approximately $60.00 to $90.00 /MWhr.

Western sells power to its firm customers at the SLCA/IP rate up to the amount of their allocation. If customers require additional energy, and additional generation is available, Western may sell short-term power to them at a price ranging from the SLCA/IP rate to the spot market rate, depending on market conditions. If generation exceeds the needs of firm power customers, energy may be exchanged with other suppliers or sold on the spot market. If SLCA/IP generation is less than long-term firm power commitments, Western must purchase replacement power on the spot market, make short-term contractual purchases, or borrow energy from other suppliers to make up the deficit. A more detailed discussion and a simulation of contract and spot market transactions may be found in Veselka, Hamilton, and McCoy (1995).

As might be expected from the preceding discussion, simulation of the financial impacts of the test flow was a relatively complex undertaking. Under the best of circumstances, it would be difficult, if not impossible, to duplicate all of the aspects of Western's financial interactions with various

entities. For analysis purposes, a number of simplifying assumptions were made. Following the test flow, the assumptions and methods used were re-evaluated.

In many respects, the *ex post* financial analysis benefited greatly from information collected during water year 1996. For example, in the *ex ante* analysis, all replacement power purchases were assumed to be made at contract prices. However, in water year 1996 only limited amounts of onpeak energy and no offpeak energy were purchased through replacement power contracts. As a consequence of these and other observations, the methodology used for financial analysis was refined.

There are a number of suppositions on which the *ex post* financial analysis is based. These are:

- For purposes of this financial analysis, net revenue is defined as revenues derived from the sale of electricity produced at Glen Canyon Dam less the cost of replacement power purchased.

- The financial analysis of the test flow is based on the difference in net revenue with and without the flow.

- Glen Canyon provides approximately 70 percent of the SLCA/IP generation capacity. For purposes of this analysis, Glen Canyon's share of firm load commitments was defined as 70 percent.

- For purposes of this analysis, Western's firm load commitment was defined as actual water year 1996 hourly deliveries to firm load.

- Power generated, up to 70 percent of the firm power obligation, was valued at the SLCA/IP composite rate ($20.17/MWhr).

- Power generated, in excess of 70 percent of the firm power obligation, was valued at the spot market price.

- A replacement power purchase was triggered if simulated Glen Canyon Dam generation fell below 70 percent of the SLCA/IP firm power delivery for that hour.

- The amount of the replacement power purchase in any hour was defined as the difference between simulated generation and 70 percent of the SLCA/IP firm load in that hour.

- For those months in which contract purchases for replacement power actually occurred, all simulated replacement power purchases were assumed to be made at the average contract price during that month (see Appendix 5).

- For months in which no contract purchases for replacement power were actually made, all simulated replacement power purchases were made a spot market prices (see Appendix 6).

Evaluation of the simulated generation is based on the above points. If contract purchases were not made during a month when replacement purchases were needed—the energy supplied during the month was valued as shown in equations (10) and (12).

$$NR_i = \begin{cases} (gcfl_i * 20.17) + (gen_i - gcfl_i) * sp_i, & if\ gen_i \geq gcfl_i \\ (gen_i * 20.17) + (gcfl_i - gen_i) * (20.17 - sp_i), & if\ gen_i < gcfl_i \end{cases} \quad \textbf{(10)}$$

If contract purchases were made during a month when replacement purchases were required—the energy supplied during the month was valued as shown in equations (11) and (12).

$$NR_i = \begin{cases} (gcfl_i * 20.17) + (gen_i - gcfl_i) * sp_i, & if\ gen_i \geq gcfl_i \\ (gen_i * 20.17) + (gcfl_i - gen_i) * (20.17 - Cp_i), & if\ gen_i < gcfl_i \end{cases} \quad \textbf{(11)}$$

$$TotNR = \sum_{i=1}^{H} NR_i \quad \textbf{(12)}$$

where:

TotNR = total net revenue for a given month
NR_i = net revenue in hour i
$gcfl_i$ = 0.70 * the SLCA/IP firm load in hour i
gen_i = simulated Glen Canyon generation in hour i
sp_i = spot market price in hour i
Cp_i = contract (replacement power) price in hour i
H = the number of hours in the month

Note that the chief difference between equations (10) and (11) is the use of contract prices (Cp) to value purchases of replacement power.

APPENDIX 5. CONTRACT POWER PURCHASES IN WATER YEAR 1996

	Contract Power Purchases	Onpeak Purchase (MWhr)	Average Onpeak Price ($/MWhr)	Offpeak Purchase (MWhr)	Average Offpeak Price ($/MWhr)
October					
November					
December					
January					
February	YES	205	26.16	0	n/a
March	YES	3,045	24.98	0	n/a
April	YES	3,460	25.59	0	n/a
May					
June					
July	YES	24,987	25.82	0	n/a
August	YES	21,501	26.97	0	n/a
September					
TOTAL		53,198		0	

Source: Calculated from data furnished by Scott Sorensen, Western Area Power Administration, Salt Lake City, Utah.

APPENDIX 6. DESCRIPTIVE STATISTICS—SPOT MARKET PRICES

	Onpeak Prices [1] ($/MWhr)			Offpeak Prices ($/MWhr)		
	MIN	MEAN	MAX	MIN	MEAN	MAX
October	13.50	14.42	15.75	10.50	11.84	15.50
November	12.00	14.24	16.50	8.50	11.19	14.50
December	9.00	11.99	13.75	7.00	8.76	12.50
January	9.61	14.76	21.00	8.60	10.58	17.21
February	8.82	12.85	21.31	5.39	8.27	14.38
March	8.24	11.72	16.22	5.43	8.53	11.52
April	10.03	14.14	17.97	5.52	8.71	13.58
May	7.86	12.44	16.32	4.98	8.18	14.07
June	10.80	14.48	23.08	6.70	9.04	17.14
July	9.84	18.87	23.65	8.37	12.03	21.57
August[2]	14.14	22.17	46.19	9.39	15.19	56.85
September	13.52	17.60	26.75	10.06	12.79	16.96

[1] Onpeak hours are defined as the hours from 7 a.m. to 11 p.m., Monday through Saturday.

[2] The power system disruption of August 10 - 12 is responsible for the high maximum onpeak and offpeak spot market prices shown here.

Source: Calculated from input data files. See data description in text.

APPENDIX 7. DESCRIPTIVE STATISTICS—AGGREGATE LOAD, FIRM LOAD

	Aggregate Load (MW)			Firm Load (MW)		
	MIN	MEAN	MAX	MIN	MEAN	MAX
October	1795	2620	4038	434	567	877
November	1860	2546	3570	442	618	1029
December	1940	2772	3699	484	669	1090
January	2034	2712	3719	475	663	1031
February	1915	2743	3812	435	606	1010
March	1804	2451	3379	422	615	1033
April	1361	2508	3598	424	625	970
May	1791	2610	3605	445	633	904
June	1927	3185	4780	460	717	1113
July	2300	3554	5019	513	834	1170
August	2543	3715	4821	461	799	1209
September	2027	3268	4622	460	683	1052

Source: Calculated from input data files. See description of data in text.

APPENDIX 8. DIFFERENCES BETWEEN *EX POST* AND *EX ANTE* ANALYSES

	EX ANTE ANALYSIS	*EX POST* ANALYSIS
simulated generation	-monthly peakshaving model	-monthly peakshaving model
aggregate load curves	-same as *ex post* analysis	-same as *ex ante* analysis
annual release volume	11.300 MAF	11.476 MAF
monthly releases	-both no action and with test flow monthly releases differ from *ex post* analysis	-both no action and with test flow monthly releases differ from *ex ante* analysis
valuation approach	-evaluated differences between no action and test flow (only) -value of no action case not available	-evaluated both no action and test flow -then calculated difference -value of no action case is available
efficiency rate	0.82299200	0.88872889
spot price data	-average day for each month -forecast by Argonne Spot Market Network Model (Van Kuiken et al 1994)	-daily onpeak and off peak prices -observed market prices from Palo Verde/Westwing Interchange
financial analysis	-less sophisticated method used compared to *ex post* analysis -did not make use of firm load data	-more refined method used compared to *ex ante* analysis -used firm load data in analysis
sensitivity analyses	-evaluated minimum probable and maximum probable hydrologies	-evaluated cost of the test flow independent of releases to reduce risk of spill

APPENDIX 9. FREQUENTLY ASKED QUESTIONS

Q1. Why model the with test flow case?

A1. The objective of this analysis was to (a) simulate the hour by hour generation at Glen Canyon Dam with and without test flow, (b) calculate the hour by hour difference, and (c) to estimate the economic and financial value of this difference. Since we can not observe the without test flow case, there is no question that this case must be modeled. One might imagine that since the with test flow case was observed, it need not be modeled. Unfortunately, this is not the case. A model, such as the peakshaving model, can never perfectly predict actual hour by hour generation. Suppose we simulated only the without test flow case. If we subtracted the actual pattern of generation from the simulated without test flow pattern of generation—the resulting difference would have two components—a modeling error component and the true difference between the two cases. Because these two components could not be separated, we would be unable to tell how much of the difference we observed was modeling error and how much of the difference was due to the test flow. To avoid this problem, both the no action and test flow cases were modeled.

Q2. The estimated economic and financial impacts are virtually identical. Why bother to estimate both?

A2. Reclamation feels that there are several reasons for estimating both the economic and financial impacts. First, as evidenced by the results of the *ex ante* analysis, the financial impacts could have been substantially different from the economic impacts. Indeed, comparing the contract prices (Appendix 5) and the observed spot market prices (Appendix 6), it seems quite fortuitous that the *ex post* financial impacts were not significantly larger than they are. Secondly, depending on the final interpretation of section 1807 of the Grand Canyon Protection Act of 1992, there may be no financial impacts on Western or the end use consumers of electricity produced at Glen Canyon Dam. If so, the only impacts will be the economic cost of the test flow. For these reasons it was important to estimate both the economic and financial impacts of the test flow.

Q3. What factor influenced the costs of the test flow the most?

A3. The single most important factor which influences the economic and financial cost of the test flow is monthly release volumes. This is made particularly evident in the sensitivity analysis described in this report.

Q4. Could the cost of future beach/habitat-building flows be higher/lower than the 1996 test flow?

A4. In short—yes. The cost of the 1996 test flow is shaped by its timing, design, and by market conditions. If the design configuration of future beach/habitat-building flows differs from the 1996 event, for example if it is of longer (shorter) duration or greater (smaller) magnitude, then, of course, it will cost more (less). Additionally, in 1996 there is considerable excess capacity in the power system. In future years, this excess capacity may no longer exist. In that case, market prices for electricity will be higher and the cost of a beach/habitat-building flow could be substantially higher. Conversely, competitive changes in the utility industry could cause the price of electricity to fall. In that case, the cost of a future beach/habitat-building flow could be less than the 1996 experiment.

APPENDIX 10. EXAMPLE PARAMETER FILE

```
filename = JUL96_0.PAR
D_HARPMAN
10/11/96
PARAMETER FILE FOR GCPS02g ver 1.2
REMARK: USED FOR EX-POST COST ANALYSIS
REMARK: JULY 1996 (WY96)
REMARK: WITHOUT TEST FLOW (0)
```

```
*
1100000     {release volume (af/month)}
2500        {upramp rate (cfs/hr)}
1500        {downramp rate (cfs/hr)}
20000       {maximum flow constraint (cfs)}
8000        {maximum daily change constraint (cfs)}
3688.5      {reservoir elevation (ft above msl)}
5000        {hour  1 minimum flow (cfs) }
5000        {hour  2 minimum flow (cfs) }
5000        {hour  3 minimum flow (cfs) }
5000        {hour  4 minimum flow (cfs) }
5000        {hour  5 minimum flow (cfs) }
5000        {hour  6 minimum flow (cfs) }
5000        {hour  7 minimum flow (cfs) }
8000        {hour  8 minimum flow (cfs) }
8000        {hour  9 minimum flow (cfs) }
8000        {hour 10 minimum flow (cfs) }
8000        {hour 11 minimum flow (cfs) }
8000        {hour 12 minimum flow (cfs) }
8000        {hour 13 minimum flow (cfs) }
8000        {hour 14 minimum flow (cfs) }
8000        {hour 15 minimum flow (cfs) }
8000        {hour 16 minimum flow (cfs) }
8000        {hour 17 minimum flow (cfs) }
8000        {hour 18 minimum flow (cfs) }
8000        {hour 19 minimum flow (cfs) }
5000        {hour 20 minimum flow (cfs) }
5000        {hour 21 minimum flow (cfs) }
5000        {hour 22 minimum flow (cfs) }
5000        {hour 23 minimum flow (cfs) }
5000        {hour 24 minimum flow (cfs) }
→
```

APPENDIX 11. EXAMPLE AGGREGATE LOAD FILE

filename = JUL96.MLD
D_HARPMAN
01/30/96
LOAD FILE FOR GCPS PROGRAM
UNITS: mw
REMARK: JULY 1996 (WY96) AGGREGATE LOAD CURVE
REMARK: USED FOR TEST FLOW ANALYSIS

ndays = 31

*	1	2	3	4	5	6	7	8	9	10	11	12
701961	3091	2900	2721	2628	2534	2454	2503	2739	3061	3397	3698	3934
701962	4139	4295	4422	4532	4612	4636	4548	4406	4336	4168	3839	2447
702961	3183	2997	2885	2840	2848	2908	3151	3378	3613	3843	4011	4047
702962	4054	4114	4180	4305	4445	4478	4429	4287	4229	4054	3676	3305
703961	3066	2888	2766	2711	2713	2780	2995	3272	3552	3816	4063	4259
703962	4446	4609	4730	4835	4838	4849	4742	4553	4436	4231	3872	3507
704961	3240	3065	2939	2853	2840	2920	3147	3423	3724	4035	4319	4552
704962	4693	4843	4935	5008	5019	4939	4794	4644	4522	4298	3934	3552
705961	3292	3133	3034	2929	2919	2991	3195	3444	3735	4003	4255	4410
705962	4460	4517	4532	4517	4532	4477	4380	4293	4242	4081	3751	3409
706961	3181	2981	2915	2834	2812	2869	3058	3285	3518	3762	4007	4121
706962	4183	4318	4433	4533	4576	4548	4416	4245	4164	3993	3724	3404
707961	3142	2966	2818	2741	2675	2608	2659	2895	3210	3549	3803	3993
707962	4111	4226	4295	4356	4360	4347	4254	4098	4034	3865	3590	3307
708961	3059	2894	2755	2667	2598	2530	2555	2750	3017	3325	3563	3725
708962	3869	3968	4050	4105	4138	4137	4027	3902	3805	3625	3347	3044
709961	2795	2624	2487	2416	2361	2300	2345	2548	2851	3181	3453	3629
709962	3754	3866	3948	4044	4097	4066	3963	3753	3666	3472	3312	3018
710961	2809	2625	2534	2471	2462	2551	2769	3083	3388	3641	3869	4022
710962	4124	4259	4332	4406	4438	4426	4287	4146	4069	3884	3528	3166
711961	2916	2716	2601	2514	2492	2553	2761	3018	3253	3497	3720	3881
711962	3981	4123	4231	4286	4316	4322	4182	4014	3935	3716	3343	2968
712961	2732	2558	2441	2370	2362	2422	2630	2874	3109	3338	3565	3707
712962	3842	4009	4157	4257	4328	4331	4232	4025	3926	3745	3384	3001
713961	2800	2619	2504	2419	2429	2475	2681	2940	3175	3434	3665	3872
713962	4039	4204	4336	4423	4461	4431	4285	4111	3976	3780	3486	3172
714961	2932	2758	2629	2543	2497	2455	2526	2749	3059	3300	3574	3758
714962	3912	4059	4157	4238	4291	4313	4222	4027	3940	3752	3475	3202
715961	2957	2787	2668	2584	2512	2449	2482	2702	3021	3310	3560	3751

715962	3889	4034	4124	4225	4323	4341	4253	4113	4067	3898	3599	3264
716961	3016	2851	2744	2676	2661	2746	2976	3247	3519	3774	3976	4156
716962	4275	4407	4504	4583	4609	4602	4502	4333	4253	4070	3702	3327
717961	3066	2876	2739	2657	2642	2676	2893	3174	3443	3673	3933	4099
717962	4223	4347	4439	4503	4541	4524	4377	4186	4074	3857	3474	3091
718961	2827	2648	2535	2472	2440	2528	2719	2977	3226	3484	3750	3907
718962	4059	4203	4307	4432	4478	4488	4383	4218	4128	3906	3560	3221
719961	2964	2771	2675	2594	2586	2661	2854	3097	3337	3540	3749	3897
719962	4028	4145	4252	4345	4409	4396	4301	4154	4061	3864	3498	3160
720961	2913	2751	2608	2538	2509	2566	2766	3018	3269	3493	3703	3873
720962	3982	4098	4191	4257	4293	4238	4135	3973	3885	3711	3445	3134
721961	2890	2726	2593	2504	2461	2418	2473	2695	2972	3254	3452	3674
721962	3778	3883	3905	3925	3983	3986	3883	3778	3759	3612	3381	3128
722961	2928	2802	2686	2622	2602	2580	2596	2750	2952	3156	3314	3442
722962	3569	3645	3691	3647	3533	3409	3279	3271	3316	3211	3005	2755
723961	2598	2495	2424	2379	2431	2558	2789	2989	3196	3392	3507	3595
723962	3675	3782	3836	3852	3771	3766	3679	3603	3610	3498	3183	2921
724961	2718	2600	2509	2479	2500	2619	2824	3027	3264	3448	3654	3764
724962	3863	3911	3973	3995	4032	3984	3870	3744	3735	3582	3254	2952
725961	2737	2617	2522	2454	2481	2579	2840	3086	3318	3520	3717	3864
725962	3958	4047	4122	4183	4249	4250	4145	4004	3948	3768	3445	3114
726961	2910	2762	2661	2605	2632	2688	2928	3189	3407	3646	3842	3988
726962	4122	4263	4369	4445	4475	4460	4372	4217	4109	3974	3639	3295
727961	3083	2900	2797	2732	2711	2788	3015	3275	3550	3823	4041	4169
727962	4253	4394	4513	4555	4564	4507	4362	4189	4122	3970	3680	3416
728961	3172	3008	2894	2816	2798	2788	2832	3006	3284	3554	3786	4007
728962	4099	4197	4250	4299	4347	4330	4217	4061	4044	3855	3607	3323
729961	3134	3006	2895	2786	2726	2662	2699	2903	3197	3498	3716	3896
729962	4058	4174	4259	4317	4341	4310	4167	4046	4022	3852	3583	3237
730961	3043	2880	2796	2731	2739	2825	3078	3349	3636	3903	4121	4328
730962	4438	4543	4615	4643	4709	4679	4563	4427	4372	4175	3801	3470
731961	3191	3050	2924	2869	2874	2961	3159	3350	3508	3713	3893	4025
731962	4033	4061	4054	4079	4208	4230	4135	4050	4022	3888	3597	3253

→

APPENDIX 12. EXAMPLE PRICE FILE

filename = JUL96.HPR
D_HARPMAN
10/08/96
PRICE FILE FOR GCPS PROGRAM
UNITS: $/MWHR
REMARK: JULY 1996 (WY96) SPOT MARKET PRICES
REMARK: USED FOR EX-POST TEST FLOW ANALYSIS

ndays = 31

*	1	2	3	4	5	6	7	8	9	10	11	12
701961	8.63	8.63	8.63	8.63	8.63	8.63	8.63	22.02	22.02	22.02	22.02	22.02
701962	22.02	22.02	22.02	22.02	22.02	22.02	22.02	22.02	22.02	22.02	22.02	8.63
702961	11.63	11.63	11.63	11.63	11.63	11.63	11.63	20.13	20.13	20.13	20.13	20.13
702962	20.13	20.13	20.13	20.13	20.13	20.13	20.13	20.13	20.13	20.13	20.13	11.63
703961	11.75	11.75	11.75	11.75	11.75	11.75	11.75	9.84	9.84	9.84	9.84	9.84
703962	9.84	9.84	9.84	9.84	9.84	9.84	9.84	9.84	9.84	9.84	9.84	11.75
704961	8.37	8.37	8.37	8.37	8.37	8.37	8.37	13.27	13.27	13.27	13.27	13.27
704962	13.27	13.27	13.27	13.27	13.27	13.27	13.27	13.27	13.27	13.27	13.27	8.37
705961	8.53	8.53	8.53	8.53	8.53	8.53	8.53	12.92	12.92	12.92	12.92	12.92
705962	12.92	12.92	12.92	12.92	12.92	12.92	12.92	12.92	12.92	12.92	12.92	8.53
706961	8.81	8.81	8.81	8.81	8.81	8.81	8.81	18.08	18.08	18.08	18.08	18.08
706962	18.08	18.08	18.08	18.08	18.08	18.08	18.08	18.08	18.08	18.08	18.08	8.81
707961	8.75	8.75	8.75	8.75	8.75	8.75	8.75	14.73	14.73	14.73	14.73	14.73
707962	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	8.75
708961	8.90	8.90	8.90	8.90	8.90	8.90	8.90	18.06	18.06	18.06	18.06	18.06
708962	18.06	18.06	18.06	18.06	18.06	18.06	18.06	18.06	18.06	18.06	18.06	8.90
709961	9.21	9.21	9.21	9.21	9.21	9.21	9.21	16.94	16.94	16.94	16.94	16.94
709962	16.94	16.94	16.94	16.94	16.94	16.94	16.94	16.94	16.94	16.94	16.94	9.21
710961	9.92	9.92	9.92	9.92	9.92	9.92	9.92	20.06	20.06	20.06	20.06	20.06
710962	20.06	20.06	20.06	20.06	20.06	20.06	20.06	20.06	20.06	20.06	20.06	9.92
711961	10.16	10.16	10.16	10.16	10.16	10.16	10.16	18.61	18.61	18.61	18.61	18.61
711962	18.61	18.61	18.61	18.61	18.61	18.61	18.61	18.61	18.61	18.61	18.61	10.16
712961	9.54	9.54	9.54	9.54	9.54	9.54	9.54	18.54	18.54	18.54	18.54	18.54
712962	18.54	18.54	18.54	18.54	18.54	18.54	18.54	18.54	18.54	18.54	18.54	9.54
713961	11.06	11.06	11.06	11.06	11.06	11.06	11.06	17.66	17.66	17.66	17.66	17.66
713962	17.66	17.66	17.66	17.66	17.66	17.66	17.66	17.66	17.66	17.66	17.66	11.06
714961	10.37	10.37	10.37	10.37	10.37	10.37	10.37	11.67	11.67	11.67	11.67	11.67
714962	11.67	11.67	11.67	11.67	11.67	11.67	11.67	11.67	11.67	11.67	11.67	10.37
715961	10.54	10.54	10.54	10.54	10.54	10.54	10.54	17.17	17.17	17.17	17.17	17.17

715962	17.17	17.17	17.17	17.17	17.17	17.17	17.17	17.17	17.17	17.17	17.17	10.54
716961	10.19	10.19	10.19	10.19	10.19	10.19	10.19	17.92	17.92	17.92	17.92	17.92
716962	17.92	17.92	17.92	17.92	17.92	17.92	17.92	17.92	17.92	17.92	17.92	10.19
717961	11.13	11.13	11.13	11.13	11.13	11.13	11.13	19.58	19.58	19.58	19.58	19.58
717962	19.58	19.58	19.58	19.58	19.58	19.58	19.58	19.58	19.58	19.58	19.58	11.13
718961	9.63	9.63	9.63	9.63	9.63	9.63	9.63	20.67	20.67	20.67	20.67	20.67
718962	20.67	20.67	20.67	20.67	20.67	20.67	20.67	20.67	20.67	20.67	20.67	9.63
719961	9.55	9.55	9.55	9.55	9.55	9.55	9.55	20.29	20.29	20.29	20.29	20.29
719962	20.29	20.29	20.29	20.29	20.29	20.29	20.29	20.29	20.29	20.29	20.29	9.55
720961	9.20	9.20	9.20	9.20	9.20	9.20	9.20	15.92	15.92	15.92	15.92	15.92
720962	15.92	15.92	15.92	15.92	15.92	15.92	15.92	15.92	15.92	15.92	15.92	9.20
721961	9.45	9.45	9.45	9.45	9.45	9.45	9.45	15.62	15.62	15.62	15.62	15.62
721962	15.62	15.62	15.62	15.62	15.62	15.62	15.62	15.62	15.62	15.62	15.62	9.45
722961	9.53	9.53	9.53	9.53	9.53	9.53	9.53	20.11	20.11	20.11	20.11	20.11
722962	20.11	20.11	20.11	20.11	20.11	20.11	20.11	20.11	20.11	20.11	20.11	9.53
723961	14.01	14.01	14.01	14.01	14.01	14.01	14.01	23.65	23.65	23.65	23.65	23.65
723962	23.65	23.65	23.65	23.65	23.65	23.65	23.65	23.65	23.65	23.65	23.65	14.01
724961	13.06	13.06	13.06	13.06	13.06	13.06	13.06	20.40	20.40	20.40	20.40	20.40
724962	20.40	20.40	20.40	20.40	20.40	20.40	20.40	20.40	20.40	20.40	20.40	13.06
725961	13.35	13.35	13.35	13.35	13.35	13.35	13.35	20.17	20.17	20.17	20.17	20.17
725962	20.17	20.17	20.17	20.17	20.17	20.17	20.17	20.17	20.17	20.17	20.17	13.35
726961	13.09	13.09	13.09	13.09	13.09	13.09	13.09	22.12	22.12	22.12	22.12	22.12
76962	22.12	22.12	22.12	22.12	22.12	22.12	22.12	22.12	22.12	22.12	22.12	13.09
727961	13.44	13.44	13.44	13.44	13.44	13.44	13.44	18.53	18.53	18.53	18.53	18.53
727962	18.53	18.53	18.53	18.53	18.53	18.53	18.53	18.53	18.53	18.53	18.53	13.44
728961	14.22	14.22	14.22	14.22	14.22	14.22	14.22	21.57	21.57	21.57	21.57	21.57
728962	21.57	21.57	21.57	21.57	21.57	21.57	21.57	21.57	21.57	21.57	21.57	14.22
729961	13.52	13.52	13.52	13.52	13.52	13.52	13.52	21.56	21.56	21.56	21.56	21.56
729962	21.56	21.56	21.56	21.56	21.56	21.56	21.56	21.56	21.56	21.56	21.56	13.52
730961	17.57	17.57	17.57	17.57	17.57	17.57	17.57	22.28	22.28	22.28	22.28	22.28
730962	22.28	22.28	22.28	22.28	22.28	22.28	22.28	22.28	22.28	22.28	22.28	17.57
731961	14.85	14.85	14.85	14.85	14.85	14.85	14.85	23.10	23.10	23.10	23.10	23.10
731962	23.10	23.10	23.10	23.10	23.10	23.10	23.10	23.10	23.10	23.10	23.10	14.85

APPENDIX 13. EXAMPLE ECONOMIC OUTPUT FILE

PROGRAM GCPS02g.PAS USBR-EDF PEAK SHAVING MODEL VER_1.3 10/16/96

parameter file = jul96_0.par
price file = jul96.hpr
load file = jul96.prn

run date = 10/16/1996
run time = 10:13:41
iter = 15

lake elevation (ft) = 3688.5
upramp rate (cfs/hr) = 2500
downramp rate (cfs/hr) = 1500
max flow constr. (cfs) = 20000
min flow constr. (cfs) = hourly
maximum daily change (cfs) = 8000

actual maxflow (cfs) = 20000
actual minflow (cfs) = 12000
max generation (mw) = 820.89
min generation (mw) = 492.54
total energy (mwhrs) = 546303.05
dump energy (mwhrs) = 0.00

available volume (af) = 1100000.00
volume released (af) = 1099996.28

price factor = 1.00000
economic value ($) = 8999129.26

WARNING: none

SIMULATED FLOW (CFS)

id	1	2	3	4	5	6	7	8	9	10	11	12
701961	13186	12000	12000	12000	12000	12000	12500	15000	17500	20000	20000	20000
701962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
702961	18500	17000	15500	14000	12500	15000	17500	20000	20000	20000	20000	20000
702962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	18500
703961	17000	15500	14000	12500	12000	12596	15096	17596	20000	20000	20000	20000
703962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
704961	18500	17000	15500	14000	12500	15000	17500	20000	20000	20000	20000	20000
704962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
705961	18500	17000	15500	14000	12500	15000	17500	20000	20000	20000	20000	20000
705962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
706961	18500	17000	15500	14000	12500	12913	15413	17913	20000	20000	20000	20000
706962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
707961	18500	17000	15500	14000	12500	12000	12500	15000	17500	20000	20000	20000
707962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	18500
708961	17000	15500	14000	12500	12000	12000	12000	13887	16387	18887	20000	20000
708962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	19423	17923
709961	16423	14923	13423	12000	12000	12000	12000	12500	15000	17500	20000	20000
709962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	18570	17070
710961	15570	14070	12570	12000	12000	12500	15000	17500	20000	20000	20000	20000
710962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	18500
711961	17000	15500	14000	12500	12000	12000	12500	15000	17500	20000	20000	20000
711962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	19326	17826
712961	16326	14826	13326	12000	12000	12000	12000	14204	16704	19204	20000	20000
712962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	18500
713961	17000	15500	14000	12500	12000	12000	12500	15000	17500	20000	20000	20000

713962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	18500
714961	17000	15500	14000	12500	12000	12000	12000	13278	15778	18278	20000	20000
714962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	18500
715961	17000	15500	14000	12500	12000	12000	12000	13522	16022	18522	20000	20000
715962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	18500
716961	17000	15500	14000	12500	12000	12500	15000	17500	20000	20000	20000	20000
716962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	18936
717961	17436	15936	14436	12936	12000	12500	15000	17500	20000	20000	20000	20000
717962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	18500
718961	17000	15500	14000	12500	12000	12000	12500	15000	17500	20000	20000	20000
718962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	18500
719961	17000	15500	14000	12500	12000	12000	14180	16680	19180	20000	20000	20000
719962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	18500
720961	17000	15500	14000	12500	12000	12000	12523	15023	17523	20000	20000	20000
720962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	18500
721961	17000	15500	14000	12500	12000	12000	12000	12500	15000	17500	20000	20000
721962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	18500
722961	17000	15500	14000	12500	12000	12000	12000	12000	13619	16119	18619	20000
722962	20000	20000	20000	20000	20000	20000	18500	17572	18668	17168	15668	14168
723961	12668	12000	12000	12000	12000	12000	12500	15000	17500	20000	20000	20000
723962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	18500	17000
724961	15500	14000	12500	12000	12000	12000	12500	15000	17500	20000	20000	20000
724962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	18500	17000
725961	15500	14000	12500	12000	12000	12000	13717	16217	18717	20000	20000	20000
725962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	18500
726961	17000	15500	14000	12500	12000	12500	15000	17500	20000	20000	20000	20000
726962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	18500
727961	17000	15500	14000	12500	12000	12669	15169	17669	20000	20000	20000	20000
727962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
728961	18500	17000	15500	14000	12500	12000	12888	15388	17888	20000	20000	20000
728962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	18838
729961	17338	15838	14338	12838	12000	12000	12500	15000	17500	20000	20000	20000
729962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	18500
730961	17000	15500	14000	12500	12000	14472	16972	19472	20000	20000	20000	20000
730962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
731961	18500	17000	15500	14000	12500	14496	16996	19496	20000	20000	20000	20000
731962	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	18500

SIMULATED GENERATION (MW)

id	1	2	3	4	5	6	7	8	9	10	11	12
701961	541.22	492.54	492.54	492.54	492.54	492.54	513.06	615.67	718.28	820.89	820.89	820.89
701962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89
702961	759.33	697.76	636.19	574.63	513.06	615.67	718.28	820.89	820.89	820.89	820.89	820.89
702962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	759.33
703961	697.76	636.19	574.63	513.06	492.54	517.00	619.61	722.22	820.89	820.89	820.89	820.89
703962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89
704961	759.33	697.76	636.19	574.63	513.06	615.67	718.28	820.89	820.89	820.89	820.89	820.89
704962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89
705961	759.33	697.76	636.19	574.63	513.06	615.67	718.28	820.89	820.89	820.89	820.89	820.89
705962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89
706961	759.33	697.76	636.19	574.63	513.06	530.00	632.61	735.22	820.89	820.89	820.89	820.89
706962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89

707961	759.33	697.76	636.19	574.63	513.06	492.54	513.06	615.67	718.28	820.89	820.89	820.89
707962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	759.33
708961	697.76	636.19	574.63	513.06	492.54	492.54	492.54	570.00	672.61	775.22	820.89	820.89
708962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	797.22	735.65
709961	674.08	612.52	550.95	492.54	492.54	492.54	492.54	513.06	615.67	718.28	820.89	820.89
709962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	762.22	700.65
710961	639.08	577.52	515.95	492.54	492.54	513.06	615.67	718.28	820.89	820.89	820.89	820.89
710962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	759.33
711961	697.76	636.19	574.63	513.06	492.54	492.54	513.06	615.67	718.28	820.89	820.89	820.89
711962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	793.22	731.65
712961	670.08	608.52	546.95	492.54	492.54	492.54	492.54	583.00	685.61	788.22	820.89	820.89
712962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	759.33
713961	697.76	636.19	574.63	513.06	492.54	492.54	513.06	615.67	718.28	820.89	820.89	820.89
713962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	759.33
714961	697.76	636.19	574.63	513.06	492.54	492.54	492.54	545.00	647.61	750.22	820.89	820.89
714962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	759.33
715961	697.76	636.19	574.63	513.06	492.54	492.54	492.54	555.00	657.61	760.22	820.89	820.89
715962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	759.33
716961	697.76	636.19	574.63	513.06	492.54	513.06	615.67	718.28	820.89	820.89	820.89	820.89
716962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	777.22
717961	715.65	654.08	592.52	530.95	492.54	513.06	615.67	718.28	820.89	820.89	820.89	820.89
717962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	759.33
718961	697.76	636.19	574.63	513.06	492.54	492.54	513.06	615.67	718.28	820.89	820.89	820.89
718962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	759.33
719961	697.76	636.19	574.63	513.06	492.54	492.54	582.00	684.61	787.22	820.89	820.89	820.89
719962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	759.33
720961	697.76	636.19	574.63	513.06	492.54	492.54	514.00	616.61	719.22	820.89	820.89	820.89
720962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	759.33
721961	697.76	636.19	574.63	513.06	492.54	492.54	492.54	513.06	615.67	718.28	820.89	820.89
721962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	759.33
722961	697.76	636.19	574.63	513.06	492.54	492.54	492.54	492.54	559.00	661.61	764.22	820.89
722962	820.89	820.89	820.89	820.89	820.89	820.89	759.33	721.22	766.22	704.65	643.08	581.52
723961	519.95	492.54	492.54	492.54	492.54	492.54	513.06	615.67	718.28	820.89	820.89	820.89
723962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	759.33	697.76
724961	636.19	574.63	513.06	492.54	492.54	492.54	513.06	615.67	718.28	820.89	820.89	820.89
724962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	759.33	697.76
725961	636.19	574.63	513.06	492.54	492.54	492.54	563.00	665.61	768.22	820.89	820.89	820.89
725962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	759.33
726961	697.76	636.19	574.63	513.06	492.54	513.06	615.67	718.28	820.89	820.89	820.89	820.89
726962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	759.33
727961	697.76	636.19	574.63	513.06	492.54	520.00	622.61	725.22	820.89	820.89	820.89	820.89
727962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89
728961	759.33	697.76	636.19	574.63	513.06	492.54	529.00	631.61	734.22	820.89	820.89	820.89
728962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	773.22
729961	711.65	650.08	588.52	526.95	492.54	492.54	513.06	615.67	718.28	820.89	820.89	820.89
729962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	759.33
730961	697.76	636.19	574.63	513.06	492.54	594.00	696.61	799.22	820.89	820.89	820.89	820.89
730962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89
731961	759.33	697.76	636.19	574.63	513.06	595.00	697.61	800.22	820.89	820.89	820.89	820.89
731962	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	820.89	759.33

********** end of output **********

MISSION STATEMENTS

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

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