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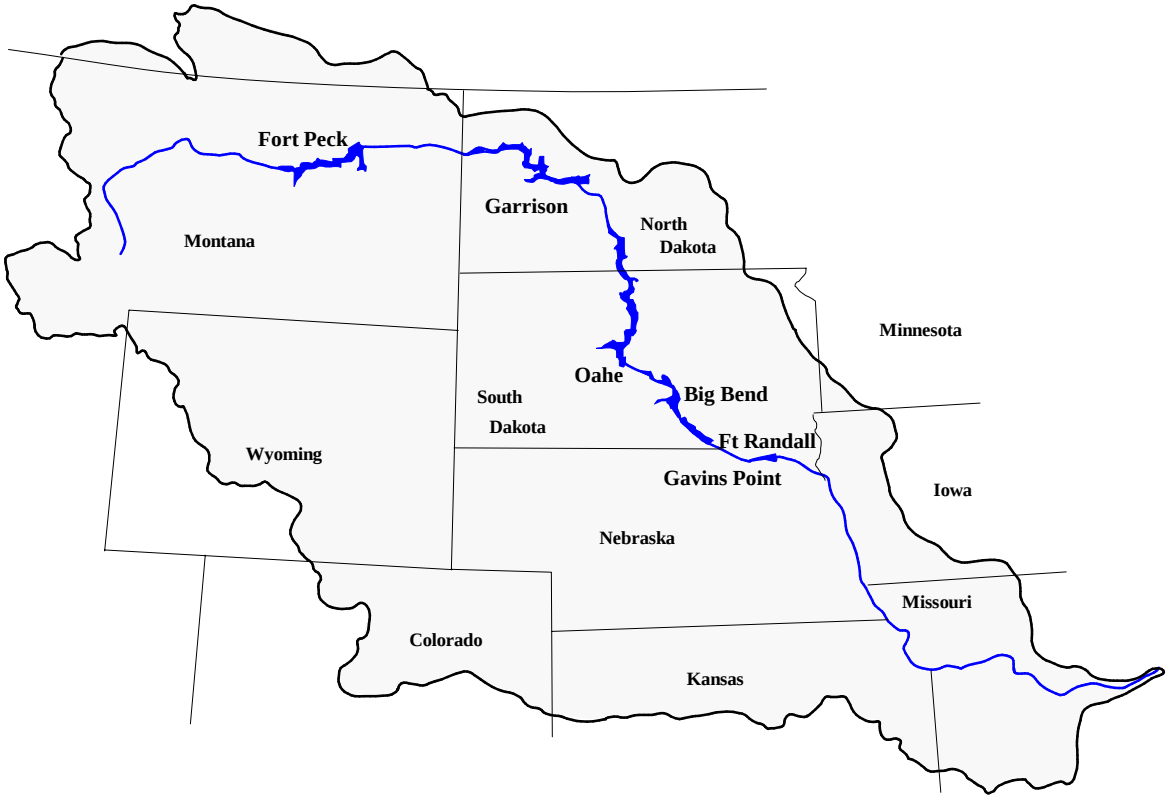

Future Depletions and Sedimentation Effects on the Missouri River Mainstem System

RCC Technical Report Je-08

Future Depletions and Sedimentation

Effects on the Missouri River Mainstem System

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Missouri River Basin Water Management Division
Northwestern Division
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INTRODUCTION

The amount of available storage space in the Missouri River Mainstem Reservoir System (System), the amount of runoff into the System, and the volume of water stored in the System annually affect the various uses and resources that rely on the quantity of flow between and downstream from the dams and reservoirs and the reservoir levels. In a given year, the volume of storage space remains relatively constant, and the amount of water in storage varies within individual reservoirs and the entire System. Over time, the volume of storage space diminishes as sediments are transported into and deposited within the reservoirs. Also, the volume of water moving through the System for a given set of meteorologic and runoff conditions may diminish due to either the additional consumptive use of the water before it reaches the System or the withdrawal of water from within the System. This reduction of the volume of water available for use is referred to as the depletion of water. These sedimentation and depletion factors affect the reservoir water surface elevations and river reach flows on the Missouri River. The effects of future expected depletions and sediment accumulation were analyzed by the Northwestern Division of the Corps of Engineers (Corps) to obtain a better understanding of the effects of these two processes and to provide long-range hydropower data to the Western Area Power Administration (Western).

In October 2006, Western contacted the Corps to request hydropower data for its marketing and rate analyses. The information requested by Western was a regeneration of data provided by the Corps in a report entitled "Missouri River Main Stem Reservoir Regulation Studies, Series 8-83" (8-83 Report), dated April 1984. An update of the 8-83 Report was delayed for many years due to the conduct of the Missouri River Master Manual Review and Update Study (Master Manual Study) from 1989 through 2004, which resulted in the development of a revised Water Control Plan for the System. Also, the Bureau of Reclamation (Reclamation), which had not done a major update of existing and future depletions since 1987, recently completed a depletions analysis for its Red River Valley Water Supply Project (Red River project) Draft Environmental Impact Statement. This depletion update was based on 2002 agricultural census data, a review of potential projects within the basin, review of state forecasts of future population growth within the basin (led to an estimate of associated municipal and industrial water depletions), and an estimate of water use for the Red River project. The completion of the Corps' Master Manual Study and Reclamation's depletions analysis provided an updated data set on which to update the 8-83 report.

A draft report with the same title as this one was provided to Western in December 2007, and the report was finalized in February 2008 with no change in the data. In April 2008, a detailed review of the depletion files used in the hydrologic and power modeling determined that the historic (1930-2002) depletion input file was incorrect. This required that a supplemental report be prepared for the Red River project Environmental Impact Statement and that the February 2007 report for Western be revised.

This report summarizes the Corps' 2008 reanalysis of the effects of forecasted depletions and sedimentation on the System for Western, particularly related to hydropower production. Potential effects on some of the other authorized project purposes are also discussed. The report is organized to present information on the depletion and sedimentation data used in the analysis, discuss the modeling process used, and summarize the results and conclusions of the analysis.

METHODOLOGY

DEPLETIONS

The depletions data were supplied by Reclamation for the historic period, 2002, and 2050. The distribution between 2002 (assumed to be 2010 for this analysis) and 2050 was assumed to be linear for the future projects depletions (155,400 acre-feet (ac-ft)) and the increased depletions associated with future population growth within the Missouri River basin (402,200 ac-ft). An assumption was made that the Red River project would be on-line by 2020 at the full level of 80,200 ac-ft annually. For additional depletions beyond 2050, only those associated with additional Missouri River basin population growth would increase, and the increase, 300,000 ac-ft, would change linearly between 2050 and 2110. The resulting total depletion values in the nine study years of 2010, 2015, 2020, 2025, 2030, 2050, 2070, 2090, and 2110 (years selected by Western) are shown in Table 1. Data files received from Reclamation provided monthly and reach breakdown of these values, which became the additional depletion input files for the nine modeling studies. Table 1 also lists the breakdown in the depletion values by reach, which indicates that 31 percent of the forecasted depletions are from the Missouri River basin above and within the System and 69 percent are from the portion of the Missouri River basin feeding into the river downstream from the System. The majority of the lower basin depletions are the required municipal and industrial use waters to serve future population growth in the basin.

SEDIMENTATION

Sediment surveys are conducted periodically for each of the six reservoirs comprising the System. As these surveys are completed, the sedimentation rates are available for various studies, including the modeling of the System. As sediments accumulate in each reservoir, the amount of storage available at a given water surface elevation diminishes. Thus, the water surface elevation versus storage volume files (capacity files) must be

Table 1. Amount of future Missouri River basin depletions (KAF)

Study Years	Basin Projects	Population Growth M&I	Red River Valley	Total
		Total Missouri River Basin Depletions		
2010	0	0	0	0
2015	19.4	49.9	0	69.2
2020	38.8	99.7	80.2	218.7
2025	58.1	149.6	80.2	288.0
2030	77.5	199.5	80.2	357.2
2050	155.4	402.2	80.2	637.8
2070	155.4	502.2	80.2	737.8
2090	155.4	602.2	80.2	837.8
2110	155.4	702.2	80.2	937.8
		Depletions to River Upstream from Gavins Point Dam		
2015	17.5	4.8	0	22.3
2020	35.0	9.7	80.2	124.9
2025	52.4	14.5	80.2	147.2
2030	69.9	19.3	80.2	169.5
2050	140.2	39.0	80.2	259.4
2070	140.2	48.7	80.2	269.1
2090	140.2	58.4	80.2	278.8
2110	140.2	68.1	80.2	288.5
		Depletions to River Downstream from Gavins Point Dam		
2015	1.9	45.0	0	46.9
2020	3.8	90.1	0	93.9
2025	5.7	135.1	0	140.8
2030	7.6	180.1	0	187.7
2050	15.2	363.2	0	378.4
2070	15.2	453.5	0	468.7
2090	15.2	543.8	0	559.0
2110	15.2	634.1	0	649.3

updated following the sediment survey of each reservoir. For the purpose of the modeling studies, the rate of storage loss indicated for each storage zone in each reservoir by the last two sediment surveys is assumed to continue into the future. Input files to the hydrologic model are, therefore, based on a constant rate of storage loss for each reservoir. Table 2 presents the storage volume in each of the four storage zones based on the projection of the current sedimentation rates out to 2110.

Table 2 presents the cumulative storage values for each of the four storage zones, with the values for each storage zone being the total storage for the zones up to the top of that zone for each reservoir. Summation of the exclusive flood control zone values for the six reservoirs results in the total System storage capacity. The historic sedimentation rates were used for all of the nine studies, including that for 2010. System storage in 2010 totals 71.6 million ac-ft (MAF), and the total System storage is reduced by 2110 to 62.8 MAF. This is a net loss of 8.8 MAF over the 100-year period of analysis.

Table 2 also includes the total System storage in each of the four storage zones. The top two zones, the Exclusive Flood Control and the Flood Control and Multiple Use Zones provide for System flood control storage. The decline in total flood control storage increases from 0.24 percent to 1.10 percent as sedimentation continues from 2015 to 2110. The amount of storage space in the Carryover Multiple Use Zone and the Permanent Pool decreases from 2015 to 2110 by 3.05 percent to 15.23 percent and 3.28 percent to 16.13 percent, respectively. Future adjustments to storage levels may be required to maintain flood control capability if sediment accumulations in the exclusive or annual flood control zones increase. It appears to date that little change is occurring to the total flood control storage volume, possibly due to wind and water erosion of the shoreline compensating for sediment accumulation in the headwater areas of the reservoirs; therefore, no change in flood control storage zones to allow continued flood control capability was required for this study

Figures 1 through 6 show the resulting capacity curves that served as model input files for each of the six System reservoirs for each of the nine studies. The four points shown in the figures are just four of many values that would result in smoother curves if all were shown. These figures include the storage at the elevation corresponding to the top of each storage zone for the years 2010, 2030, 2050, 2070, 2090, and 2110. The most noticeable feature of the plots is the relative difference from year to year. Only the Gavins Point Dam plot, Figure 6, has a slightly reduced rate of change over the preceding 20-year period for the 2090 and 2110 plots. This was required to allow the hydrologic modeling of the System to proceed with more reasonable results for the 2090 and 2110 studies. These two changes have essentially no effect on the modeling results presented in this report because of the relatively minor role the volume of storage in the Gavins Point project has in total System regulation.

Table 2. Future System reservoir storage.

Zone*	Reservoir Elevation	Reservoir Storage to Top of Zone (KAF) 2010	2030	2050	2070	2090	2110
			Fort Peck				
Exclusive FC	2250	18253.3	17891.3	17529.3	17167.3	16805.3	16443.3
FC and MU	2246	17279.1	16917.1	16555.1	16193.1	15831.1	15469.1
Carryover MU	2234	14561.3	14199.3	13837.3	13475.3	13113.3	12751.3
Permanent	2179	5994.3	5831.4	5668.5	5505.6	5342.7	5179.8
			Garrison				
Exclusive FC	1854	23250.9	22732.9	22214.9	21696.9	21178.9	20660.9
FC and MU	1850	21773.2	21265.6	20757.9	20250.3	19742.6	19235
Carryover MU	1837.5	17602.5	17141.5	16680.4	16219.4	15758.4	15297.4
Permanent	1792	7357.9	7259.5	7161.1	7062.7	6964.3	6865.8
			Oahe				
Exclusive FC	1620	22721.2	22325.2	21929.2	21533.2	21137.2	20741.2
FC and MU	1617	21619.2	21223.2	20827.2	20431.2	20035.2	19639.2
Carryover MU	1607.5	18389.1	17965.4	17541.7	17117.9	16694.2	16270.5
Permanent	1559	7696.1	7506	7316	7125.9	6935.8	6745.7
			Big Bend				
Exclusive FC	1423	1777.5	1691.5	1605.5	1519.5	1433.5	1347.5
FC and MU	1422	1717	1631	1545	1459	1373	1287
Carryover MU	1420	1599.9	1513.9	1427.9	1341.9	1255.9	1169.9
Permanent	1415	1329.4	1243.4	1157.4	1071.4	985.4	899.4
			Fort Randall				
Exclusive FC	1375	5162	4796	4430	4064	3698	3332
FC and MU	1365	4176.8	3810.8	3444.8	3078.8	2712.8	2346.8
Carryover MU	1350	2868.2	2502.2	2136.2	1770.2	1404.2	1038.2
Permanent	1320	1371.5	1162.8	954.2	745.6	537	328.4
			Gavins Point				
Exclusive FC	1210	430.9	378.9	326.9	274.9	289.4	274.4
FC and MU	1208	374.4	325.6	276.7	227.8	241.4	227.3
Carryover MU	1204.5	289	246.4	203.7	161.1	173	160.7
Permanent	1204.5	289	246.4	203.7	161.1	173	160.7
			Total System				
Exclusive FC		4656.1	4642.5	4629.1	4615.6	4606.2	4594.9
FC and MU		11629.7	11604.6	11579.5	11554.4	11537.1	11516.4
Carryover MU		31271.8	30319.2	29366.3	28413.5	27460.8	26508.2
Permanent		24038.2	23249.5	22460.9	21672.3	20938.2	20179.8
Total		71595.8	69815.8	68035.8	66255.8	64542.3	62799.3

* FC = Flood Control, MU = Multiple Use

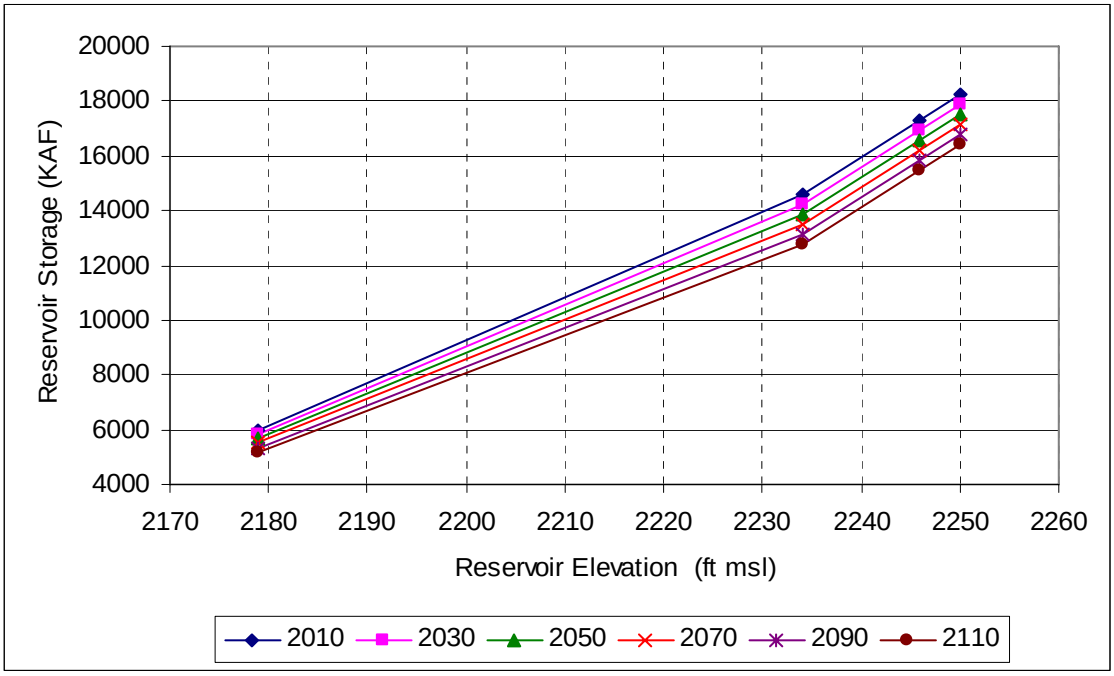

Figure 1. Storage capacity curves for Fort Peck.

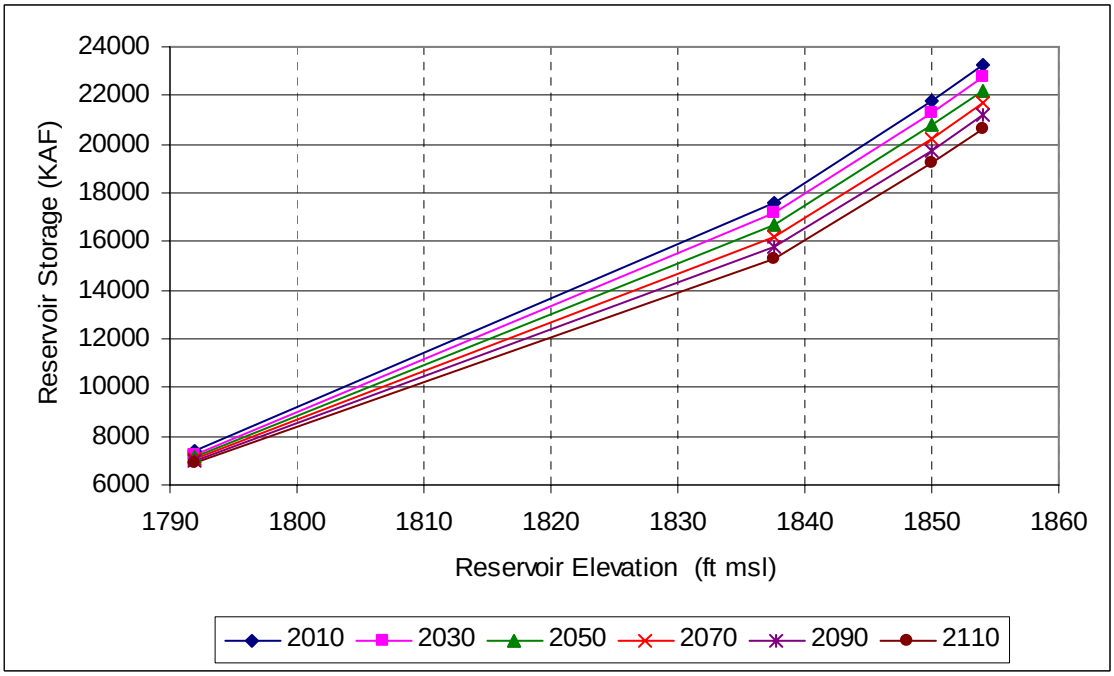

Figure 2. Storage capacity curves for Garrison.

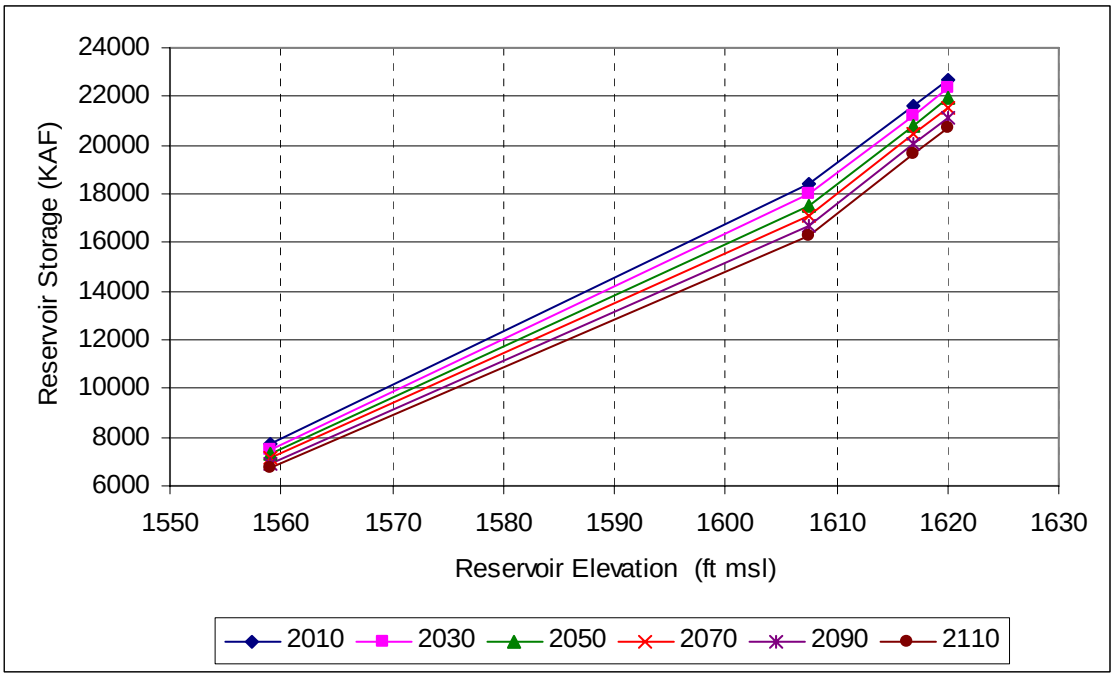

Figure 3. Storage capacity curves for Oahe.

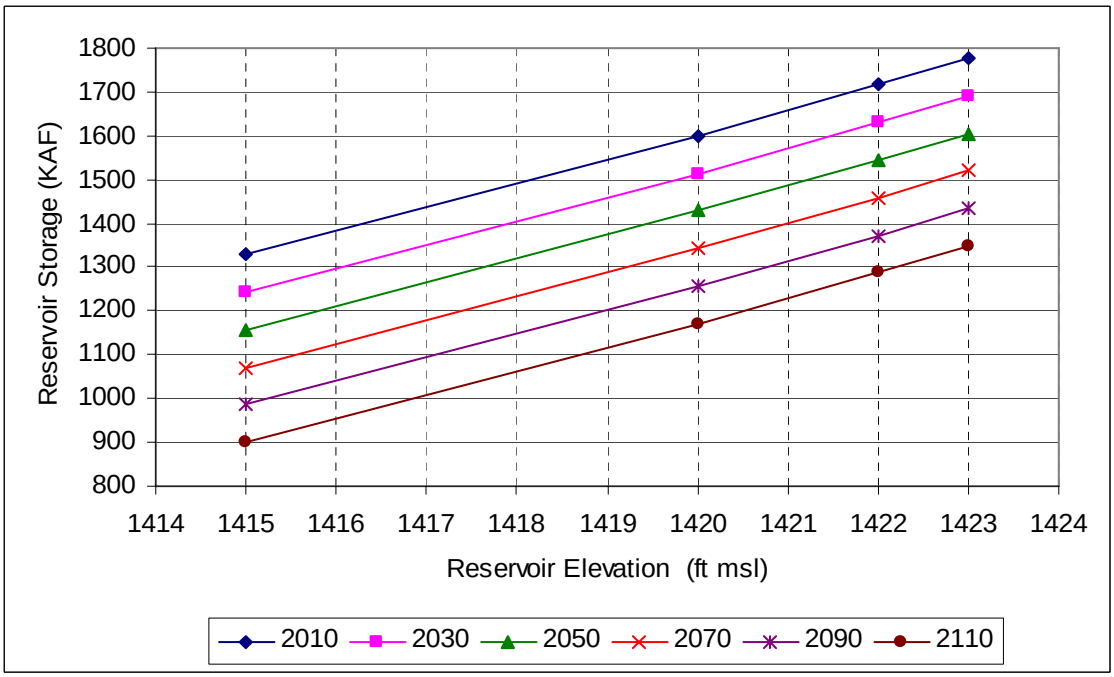

Figure 4. Storage capacity curves for Big Bend.

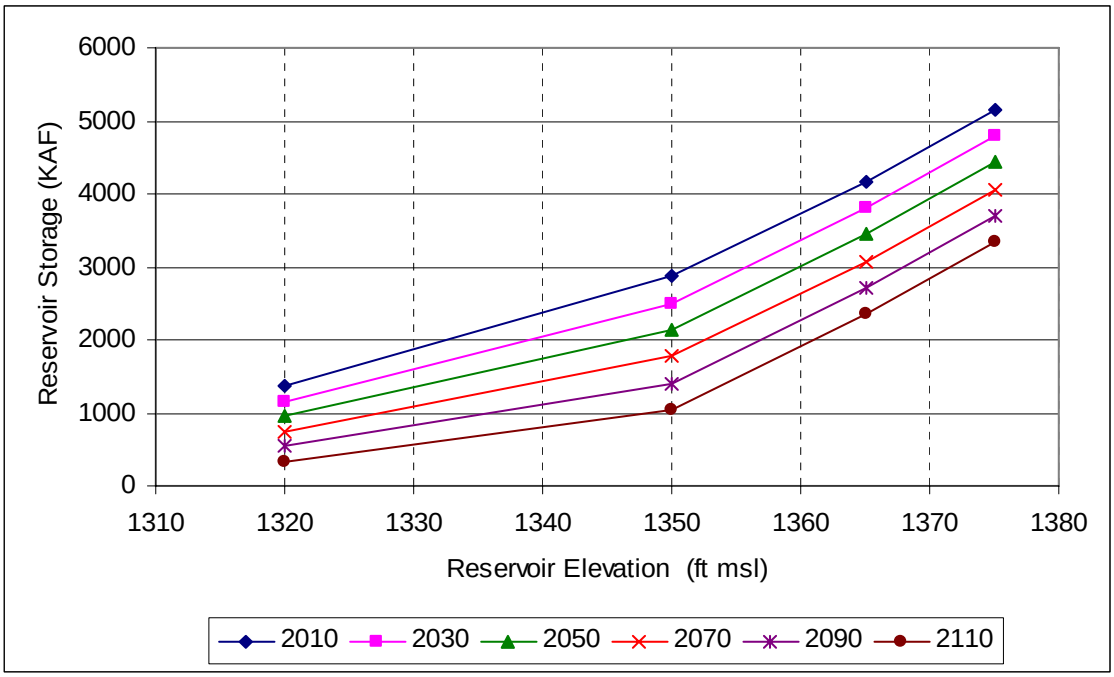

Figure 5. Storage capacity curves for Fort Randall.

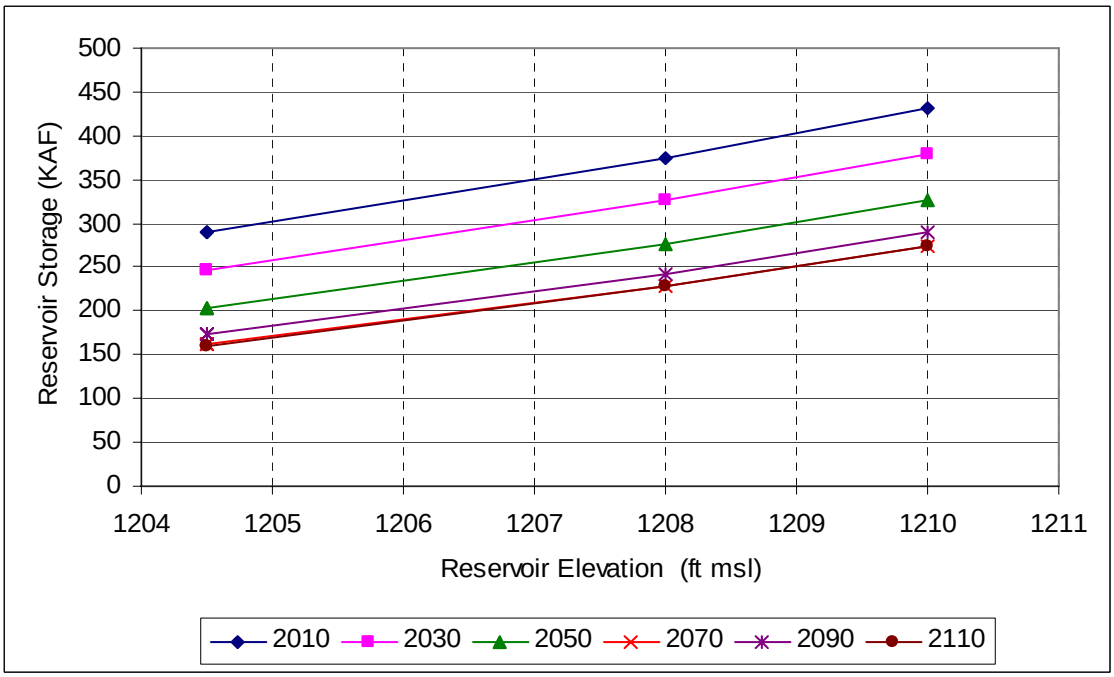

Figure 6. Storage capacity curves for Gavins Point.

HYDROLOGIC MODELING

Modeling of the movement of the water through the System was accomplished using the Corps' Daily Routing Model (DRM) that was developed for the Master Manual Study. Because the Reclamation data for estimated depletions were available from 1930 to 2002, this 73-year period was selected as the period of analysis for each of the nine future levels of depletions and sedimentation. The depletion and capacity curve data (computed using the sedimentation rate data) were the input files that were varied among the nine years selected for modeling. The first 20 years of the 100-year period were modeled in 5-year increments from 2010 to 2030, and the remaining four study years were 20 years apart.

The DRM provides hydrologic data on a daily basis for each of the 73 years modeled from 1930 through 2002 (model assumes the entire System was in place and fully operational for the full 73-year period). As the depletion and capacity curve data are varied between the study years (i.e., 2010, 2015, 2020, etc.), the DRM computes the System storage, reservoir elevation, reservoir release, and river flow data for each day of the modeling period assuming that the historic System inflow data, adjusted for depletions, occurred over the 73-year modeling period. The source of the actual System inflow data are the U.S. Geological Survey daily data acquired beginning in late 1929. The DRM reduces these inflow data by the difference in the amount of depletions that have been estimated to occur between each year and 2002. The depletions were provided by Reclamation on a monthly basis, and these monthly data were further separated to daily values for use in the DRM. Inflow and depletion data are available for each of the DRM modeling reaches. The 2002 data are used for the 2010 run (assumes no change from 2002 to 2010 for depletions) and the depletion data for 2002 of the next run (2015) are adjusted up to the 2015 level. This adjustment continues for each of the other seven runs.

MODELING OF THE RESULTING EFFECTS

Many users and environmental resources rely on the water that is stored in the System or that flows through the open Missouri River reaches. The effects of future depletions coupled with future sedimentation were computed using the economic and environmental impacts models developed for the Master Manual Study. Table 3 lists the Missouri River economic uses and environmental resources for which effects were computed for this analysis. This table also includes the units for each of the uses or resources. A brief description of each use and resource follows.

Flood control (FC) National Economic Development (NED) benefits are damages prevented by the construction and regulation of the six dams on the Missouri River. The benefits computed represent the difference between the damages that would have occurred had the dams and reservoirs not been constructed and those with these projects in place.

Table 3. Missouri River economic uses and environmental resources evaluated for the depletions and sedimentation analysis.		
Use/Resource Category	Abbreviation	Unit
Flood Control	FC	$ million
Missouri River Navigation	NAV	$ million
Hydropower	HYD	$ million
Water Supply	WS	$ million
Recreation	REC	$ million
Total Economics	TOT	$ million
Reservoir Coldwater Habitat	CS	million acre-feet
Riverine Coldwater Habitat	CR	miles
Riverine Warmwater Habitat	WR	miles
Reservoir Young Fish Production	YOY	index
Riverine Fish Physical Habitat	PH	index
Riverine Tern and Plover Habitat	TP	acres
Wetland Habitat	WT	1000 acres
Riparian Habitat	RP	1000 acres
Historic Properties	HS	index

Missouri River navigation NED (NAV) benefits represent the cost savings provided by navigation on the Missouri River from Sioux City, Iowa to the mouth versus movement of those commodities by the next least costly mode of transportation, which in the case of down-bound movements is generally rail or truck transport to St. Louis where Mississippi River navigation is used to transport the commodity to the ultimate destination and vice versa for up-bound movements.

Hydropower NED (HYD) benefits are computed for the capacity provided and the energy generated by the hydropower units at the six Missouri River dams. The benefits represent the cost savings provided by generating the electricity at the dams versus building additional generating facilities in the basin. These additional facilities would be a mix of base load and peaking powerplants, and the cost for the power from them would be more costly than the hydropower.

Water supply NED (WS) benefits are computed based on costs for water supply facilities that depend on the Missouri River or the System as a direct source of water. Typically, the costs increase during extended droughts when the reservoir levels drop and the river flows are reduced. Increased costs occur when the users must increase efforts to ensure that the water intakes continue to operate as the water surface drops toward the top of intakes during the droughts. In some cases, the intakes must be modified to ensure that the user has continued access to the water throughout the drought. In the case of powerplants that rely on once-through cooling, the cost for intake modifications are compared to the costs associated with meeting discharge requirements for the waste heat as it is returned to the Missouri River in the form of warmer water. Both the intake limitation and the discharge limitation generally result in reduced power generation. To meet the greater limitation of the two in any given month, replacement energy would

need to be purchased from the power grid, which means that additional generating capability must be constructed to provide the capacity needed in the region during power shortfalls. The cost of providing this additional capacity was included in the water supply benefits for the powerplants in the reach downstream from Garrison Dam in North Dakota and along the Lower Missouri River from Gavins Point Dam, the lower most of the six dams, to the mouth of the river. The greater of the two costs (intake versus discharge limitations) is used to compute the benefits for the thermal powerplants.

Recreation NED (REC) benefits are based on the value of the various forms of recreation provided on the Missouri River and the Corps' six System reservoirs. This value is generally based on the amount of money the users are willing to spend to travel to the recreation facilities. Reductions in benefits are computed to reflect increased costs during abnormally high and low reservoir levels. Benefits, therefore, fluctuate as the visitation varies, and the costs increase during extreme events such as extended droughts and very wet years in the upper Missouri River basin.

Total NED (TOT) benefits are just a summation of the benefits for the five economic uses described above. All of these economic benefits are computed in millions of dollars.

Reservoir coldwater fish habitat (cold storage, or CS) is the volume of habitat in millions of acre-feet (MAF) that meets the temperature and oxygen requirements of the coldwater species in the four larger Missouri River reservoirs (behind Fort Peck, Garrison, Oahe, and Fort Randall Dams). The requirements for these two parameters vary from month to month, and the month with the least amount of habitat meeting the requirements for each year is the value selected for presentation. A value is computed for each year of the period of analysis, and this value normally diminishes during droughts.

Riverine coldwater habitat (CR) is the number of river miles meeting specified temperature and dissolved oxygen requirements extending downstream from Fort Peck and Garrison Dams in specified months, with the requirements varying from month to month. The month with the lowest number is the value selected for each year. As the coldwater habitat in the upstream reservoirs diminishes during droughts, the number of river miles of coldwater habitat generally diminishes. The lower flows in the river reaches during droughts also allow additional warming of the water above those levels that would occur in higher flow years.

At some point downstream from Fort Peck and Garrison Dams, the water in the Missouri River warms up enough to meet the temperature and oxygen requirements for warmwater fish species. The number of river miles from that point downstream to the next reservoir is computed for each month, and the month with the lowest number of miles being the value that is used for each year for warmwater fish habitat (WR). This resource value generally increases during droughts when the coldwater input from the reservoirs is diminished and the flows in these two river reaches are relatively low because flow support downstream from the System is reduced.

Another measure of appropriateness of habitat for reservoir fish is the success of young-of-year production (YOY). Data on young of year were obtained for each of the six reservoirs from the corresponding State game and fish agency. Various hydrologic parameters and combinations of parameters were then used to develop regression equations with these parameters as variables. Multiple regressions were used to determine the combination of these variables that best predicted young-of-year catch in a reservoir. Various species were selected for each reservoir on which to conduct the analyses. The species selected were generally a combination of game and forage fish. The net output from this model is an index for each reservoir, and the six individual reservoir indices are combined to come up with a total index for each year that is an indicator of relative fish production for that year. The higher the value is, the greater the likelihood for successful young-of-year fish production.

The success of native riverine fish to produce and recruit was measured by comparing the cross-section depth or velocity in a given river reach under current conditions for each year to the habitat that was available in a given reach prior to the construction of the six dams and reservoirs. The basic assumption is that the closer the existing habitat correlates to this historical habitat, the greater the likelihood for the native species to survive. The end product of this model is an index for each reach. The closer this reach index value is to 1.0, the closer the existing habitat in that year corresponds to the historical habitat. The index values for the nine modeled reaches are summed to provide a total physical habitat (PH) value for each year.

Terns and plovers use relatively bare sand habitat on islands in the river reaches for nesting and rearing of the young to the point of fledging. A model was developed to compute changes in this type of habitat on the four river reaches downstream from Fort Peck, Garrison, Fort Randall, and Gavins Point Dams. The amount of tern and plover habitat (TP) is affected by the elevation of the water on the sandbars and islands and the amount of encroachment or erosion of vegetation resulting from river flows. A third factor, rebuilding and erosion of sandbars and islands, could not be modeled; however, this model provides some insight on how flows affect the amount of habitat. The acres of suitable habitat that are available in June, July, and August are computed, and the values for the months with the lesser amount of habitat when June and July and July and August are compared are identified. The larger of these two minimums for each of the 2 months becomes the amount of habitat for each year for each reach. The annual total value is the sum of the four reach values. An important limitation of this analysis is that it does not consider habitat along the shorelines of the reservoirs.

Wetland and riparian habitats are representative of the range of vegetation that grows in areas identified as wetlands along the river reaches and the deltas of each reservoir. Forty-two sites were selected for inclusion in this model. The model tracks the changes between the more woody-type vegetation (riparian vegetation) and the more pulpy-type vegetation (wetland vegetation) as the water surface in the site varies from year to year. These sites were fixed in size and included bare sand and open water areas within the sites. In some years when water levels were higher, the sand, water, and riparian habitat portions of the site could convert to the wetland type. Conversely, drier years could lead

to a shift to riparian habitat in a given site. Overall, the models provided acreage values for both habitat types for each site that were summed to provide a value for each reach. The total yearly wetland habitat (WT) and riparian habitat (RP) values are a summation of the reach values.

Finally, the effect of reservoir levels on the known historic, cultural, and prehistoric sites around each of the upper three reservoirs was computed based on the potential for erosion of each site. If the water surface was within a specified distance above to some distance below each site, the potential accompanying wave action could be eroding the site. Each month was checked to determine if each site is experiencing erosive forces. The number of "hits" was summed (maximum of 12 per year, one for each month) for each site for each year. All known sites (from surveys) had annual values that were summed to arrive at an annual value for each of the upper three, larger reservoirs. The final total historic, cultural, and prehistoric sites annual value (HS) is computed based on an inverse relationship of the total number of hits each year. This inverse relationship was used to provide a final number that would increase if the number if hits decreased. An increase in the final number is, therefore, good for the known sites. This analysis accounts only for the effects to known sites and has no determination for currently unknown sites. It also does not account for the deterioration and looting of known and unknown sites when exposed due to low reservoir levels but not due to active erosion during drought.

RESULTS OF THE ANALYSIS

HYDROLOGIC EFFECTS

The DRM provides the hydrologic data for the amount of water in storage, reservoir levels, reservoir releases, and Missouri River flows. This section of the report focuses on the hydrologic effects resulting from increasing Missouri River flow depletions and sedimentation in the six System reservoirs.

System Storage and Releases

System storage and releases will be discussed together because the System releases from Gavins Point Dam are based on System storage under the current Water Control Plan for the Missouri River System. System storages on March 1, March 15, and July 1 will be discussed because these are the three dates most affecting System regulation.

Figure 7 presents the total System storage data for March 1 of each year of the 73-year modeling period from 1930 through 2002 for five of the nine DRM runs – 2010, 2030, 2050, 2070, 2090, and 2110. This figure shows that the total System storage diminishes as the total depletions and sedimentation increase from 2010 through 2110. The only exception to this occurs during the 1935 through 1942 period when the number and sequence of non-navigation years during this extreme drought period are different among some of the alternatives. The runs up through 2050 have five non-navigation years, and

the ones from 2070 to 2110 have six non-navigation years, with 1935 and 1936 being non-navigation years in all six runs. The 2010 run has the other three non-navigation years in 1938, 1941, and 1942. The other three non-navigation years in the 2030 run are 1937, 1940, and 1941. Finally, the other four runs from 2050 to 2110 have the other three non-navigation years in 1937, 1938, and 1941, and the 2070 to 2110 runs have 1942 as the additional non-navigation year. Because a non-navigation year saves water in System storage when compared to a navigation year, total System storage varies differently following 1936 among the six runs in the figure.

Three other notable total System storage features shown in Figure 7 are worthy of discussion. First, the differences in this storage diminish during the 1930s and 1950s droughts and in some lower runoff periods in the late 1979s and early 1980s. Second, the amount of water in System storage on March 1 diminishes with the increasing depletions and sedimentation amounts. Third, because the total System storage on March 1 is relatively close to the storage that would occur on March 15 (when System navigation service is determined for year up to July 1), navigation service begins to be reduced from full service towards minimum service in more years for the initial 3 months of the navigation season.

The reduction in differences in the storage levels during extended droughts occurs because the reductions in the navigation service level and season length eventually diminish the storage differences as each drought persists. When a run goes into the drought with a higher System storage level, it will have a greater service level and longer season length in the initial drought years, which will reduce the System storage at a greater rate in those years and bring its System storage closer to that of another run that started at a lower System storage level. The only exception to this occurs when there are differences in the sequence of non-navigation years, as discussed above.

The differences in the storage levels on March 1 as the depletions and sedimentation continue to increase is readily explained. As the sedimentation continues in the reservoirs, their storage capacity diminishes, as discussed under the modeling inputs and shown in Table 2. Under the current Water Control Plan, the objective of System regulation on March 1 is to reduce the amount of water in System storage to the top of the Carryover Multiple Use Zone, unless drought has reduced the amount of water to within the Carryover Multiple Use Zone. As shown in Table 2, the top of the Carryover Multiple Use Zone is reduced in each of the reservoirs in each subsequent modeling run from 2010 to 2110. Target storage on March 1 diminishes from 55.3 MAF in 2010 to 46.7 MAF by 2110, a reduction of 16.7 percent (computed using values in Table 2). The amount of runoff into the System and downstream from the System affects the likelihood of reaching the target storage by March 1; however, one can readily see that the target storage is approximated in many of the non-drought years.

March 15 is the first time in each year that releases from the System are based on serving navigation. The current Water Control Plan navigation guide curves were followed for all of the modeling run years. If the March 15 volume of water in System storage is 54.5 MAF or greater, full service to navigation is provided until the second System storage

check on July 1, according to the current Water Control Plan. If the volume of water is less than 54.5 MAF, service to navigation is gradually reduced until 49.0 MAF of System storage is reached and minimum service (6,000 cubic feet per second (6 kcfs) less than full service) is provided that year up to July 1. Total System storage is generally above 54.5 MAF for the 2010 run in the non-drought years (based on March 15 storage being similar to March 1 storage); however, it begins to drop in many years for the runs as the depletion and sedimentation increase. For the 2110 run, almost all of the years may have a total System storage of less than 49.0 MAF; therefore, minimum service would be provided for the first 3 months of the navigation season in most of the model run years in the 2110 study year.

A simplistic way of viewing what is happening can be accomplished by comparing the reduction in the volume of System storage to that of a bowl that gets smaller and smaller as time progresses. The bowl will initially hold a gallon of water up to a line drawn in the bowl in 2010, and the bottom part of the bowl shrinks until 2110, when it holds only 7 pints up to the same line (about 0.88 gallons, or a reduction in capacity of 12 percent). If the target level of the bowl continues to remain "full" at the line, eventually a pint of its capacity up to the line will be gone. This basically describes what happens to the capacity to store water up to the top of the Carryover Multiple Use Zone (bottom of the combined flood control storage zones) as sedimentation continues to occur in the System reservoirs.

The volume of water moving through the System diminishes with time because of the depletions. This is readily shown by the data presented in Table 4, which shows the average annual release from Gavins Point Dam, the last System dam that water moves through as it continues down the Missouri River. This table shows that the average annual (over the entire modeling period of 1930-2002) releases diminish from 26.11 kcfs to 25.62 kcfs between 2010 and 2110, a reduction of 1.9 percent. It also shows that the reduced average annual release is only a portion of the average annual depletion increase; the difference most likely being reduced evaporation. The depletions increase at a rate similar to the evaporation decrease, as shown by the percent values in the last two columns of the table.

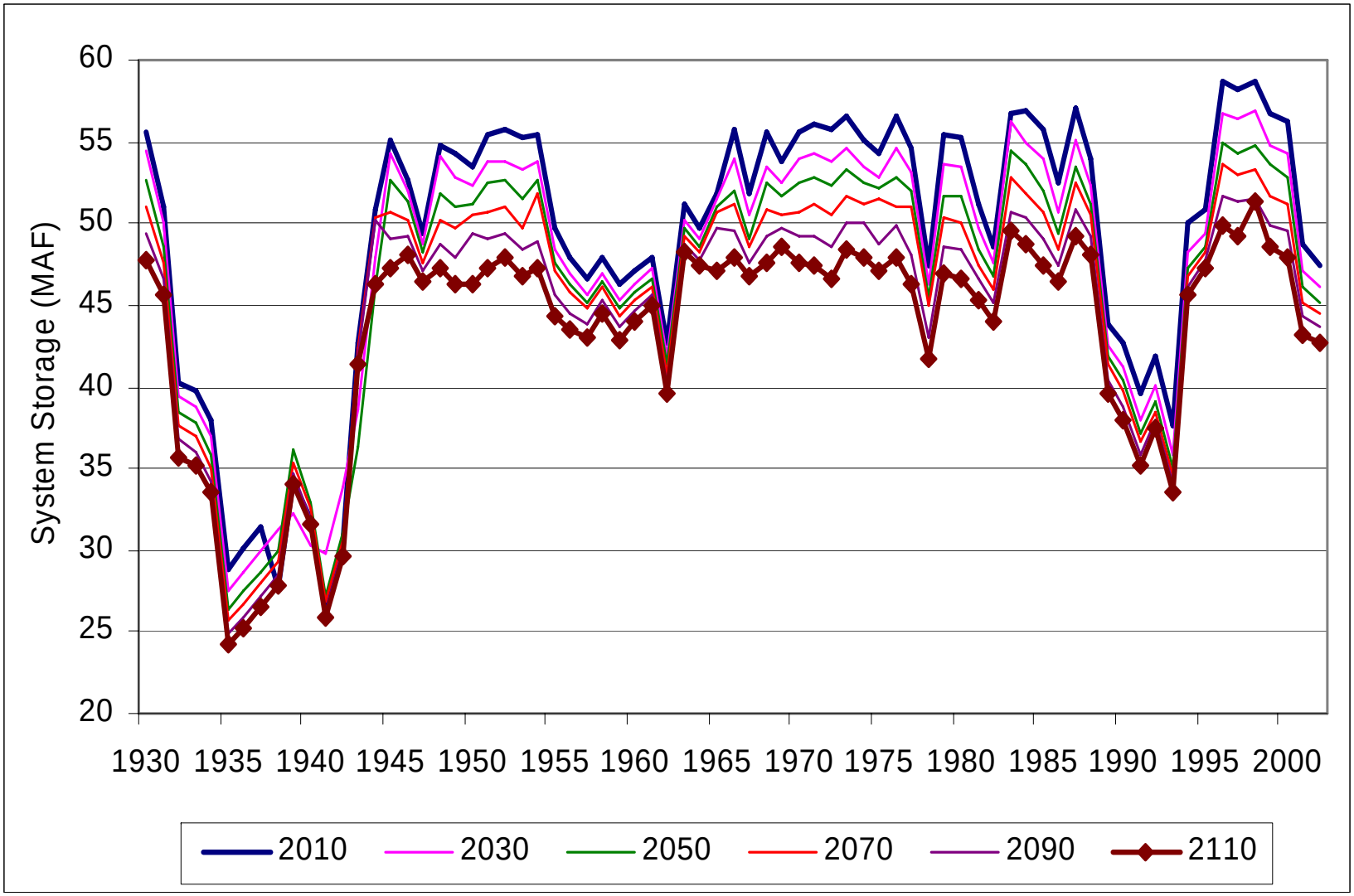

Figure 7. System storage on March 1 for the modeling runs for 2010, 2030, 2050, 2070, 2090, and 2110.

Table 4. Gavins Point Dam average annual releases and System depletions and evaporation.

Model Run Year	Ave. Ann. Gavins Pt. Release (kcfs)	Percent Red. of Gavins Pt. Release from 2010	Ave. Ann. Red. of Gavins Pt. Release from 2010 (kac-ft)	Ave. Ann. System Depletions from 2010 (kac-ft)	Ave. Ann. System Evaporation Decrease (kac-ft)	Percent of 2110 Depletion	Percent of 2110 Evap. Decr.
2010	26.11	--	--	--	--	--	--
2030	25.88	0.9	166	357	191	38	33
2050	25.74	1.4	266	638	372	68	64
2070	25.68	1.6	306	738	431	79	74
2090	25.65	1.7	326	838	512	89	88
2110	25.62	1.9	355	938	583	100	100

As shown in Figure 8, the Gavins Point Dam releases generally diminish primarily in the initial years of the extended droughts during the 73-year modeling period as the depletions increase. These differences occur as service level and season length are reduced more in the initial year or two of the droughts. Differences in the five non-navigation years of the 1930s drought, depending on which modeling study, are noticeable, with the 2010 and 2030 modeling run having some different non-navigation years than the other four runs.

Figures 9 and 10 show the average monthly releases for June and November, respectively, for six of the nine modeling runs. The differences shown in Figure 9 generally result from differences in the service level during the first part of the navigation season. The service levels differ by up to 6 thousand cubic feet per second (kcfs) in many of the years. Figure 10 shows the differences in the November releases that are due to differences in the service levels in the second part of the navigation season and also season shortening in the more severe drought periods. Notable differences also occur in some of the high runoff years in the November figure as evacuation rates are higher for the higher depletion and sedimentation runs. This occurs because the DRM does not extend the navigation seasons out to December 10 before initiating evacuation releases for the higher sedimentation (and depletions) modeling runs. The evacuation rules in the model would need to be adjusted to include an extension at a lower System storage level to eliminate this situation. This happens in only a few years so that it likely does not have any noticeable effect on most of the modeling results, with navigation benefits, which will be presented later in this report, likely being affected the most.

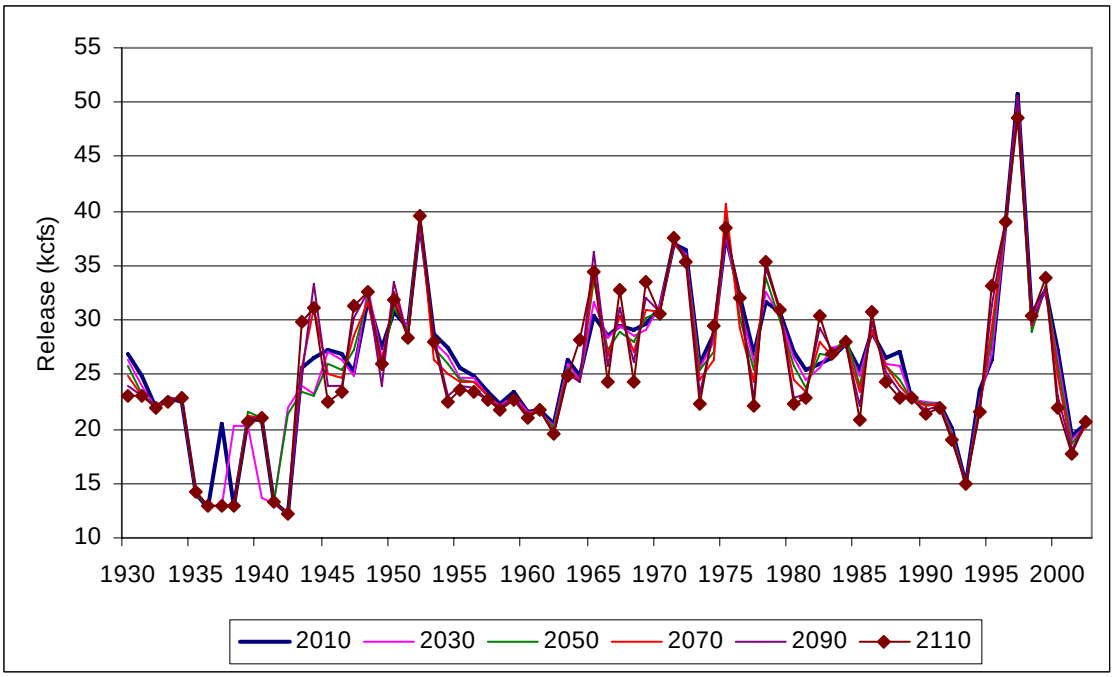

Figure 8. Gavins Point Dam average annual releases for the modeling runs for 2010, 2030, 2050, 2070, 2090, and 2010.

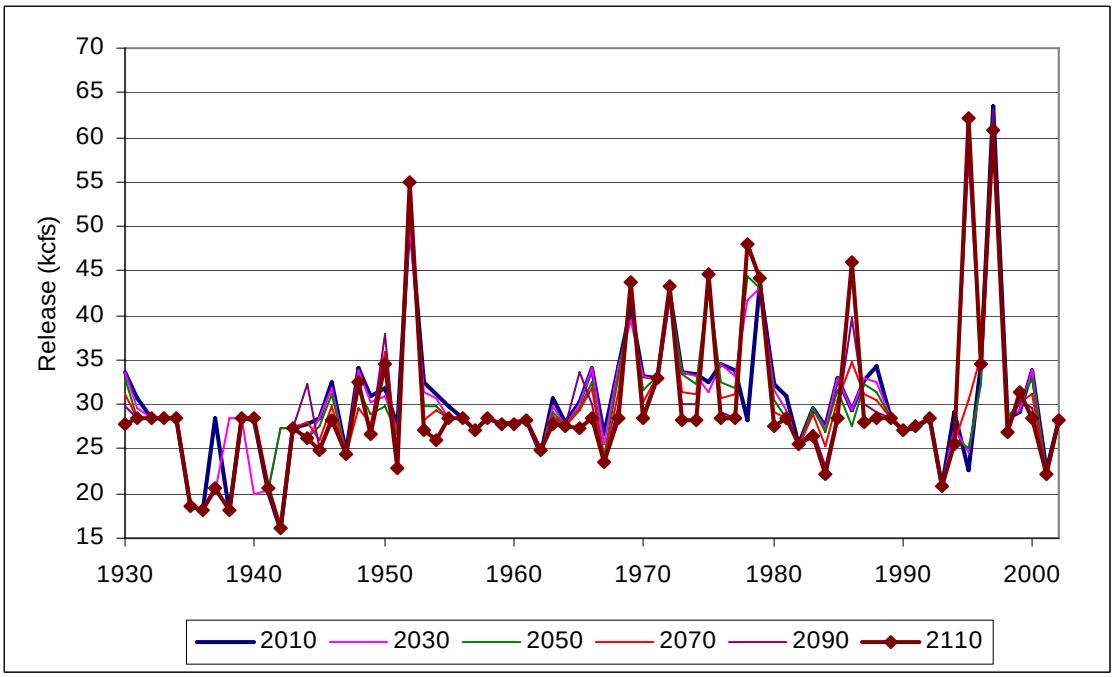

Figure 9. Gavins Point Dam average June releases for the modeling runs for 2010, 2030, 2050, 2070, 2090, and 2010.

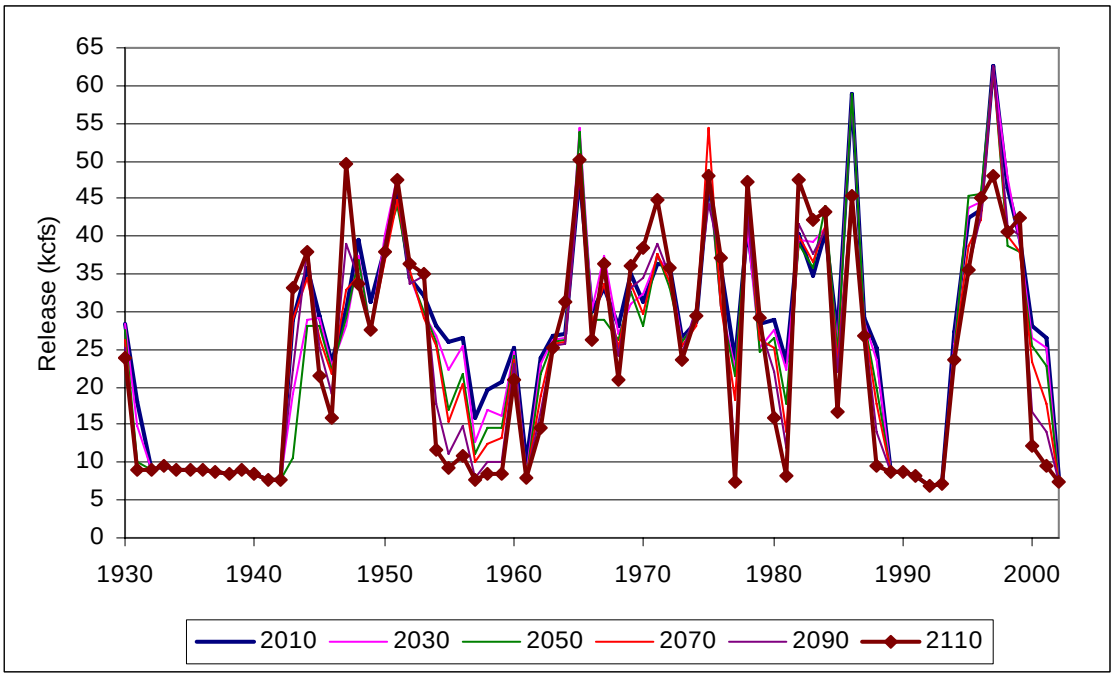

Figure 10. Gavins Point Dam average November releases for the modeling runs for 2010, 2030, 2050, 2070, 2090, and 2110.

Reservoir Levels

As depletions increase, the expected changes with a constant amount of storage space in the reservoirs (meaning no loss due to continued sedimentation) would be reduced reservoir levels during the modeling period. In reality, storage space is not constant and will continue to be lost with the continuing deposition of sediments into all six System reservoirs. Depending on the rates of sediment deposition and increased depletions, the reservoir water levels could end up being higher or lower during the modeling period. This section will identify which of these two options would occur with the depletion and sedimentation rates assumed for this analysis.

Figures 11 through 13 show the elevation of the water in storage in Fort Peck, Garrison, and Oahe, respectively. These figures show that these three reservoir water levels react in an opposite direction than the total System storage did. Instead of higher depletion studies resulting in lower reservoir elevations, they resulted in generally higher reservoir elevations. Also, instead of being relatively the same in droughts, they were most different in droughts. This different response is due to the increasing sedimentation among the nine modeling studies. Generally, as the sedimentation increased, the water surface elevations in the reservoirs increased relative to the declines in the System storage. The elevations changed up to about 10 feet between the 2010 and 2110 runs meaning that, when the System storage was similar in the drought periods, the water surface elevations were about 10 feet higher. Similarly, when the System storage was about 5 MAF lower in the non-drought periods between the 2010 and 2110 DRM runs, the water surface elevations were very similar.

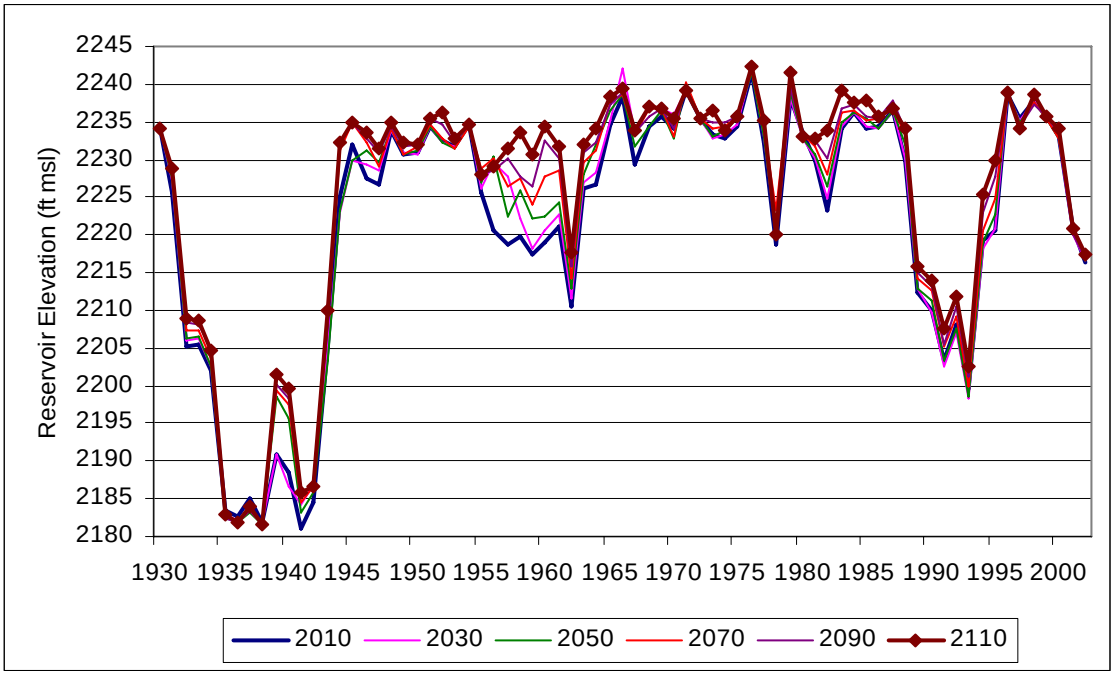

Figure 11. Fort Peck water surface elevations on March 1 for the modeling runs for 2010, 2030, 2050, 2070, 2090, and 2110.

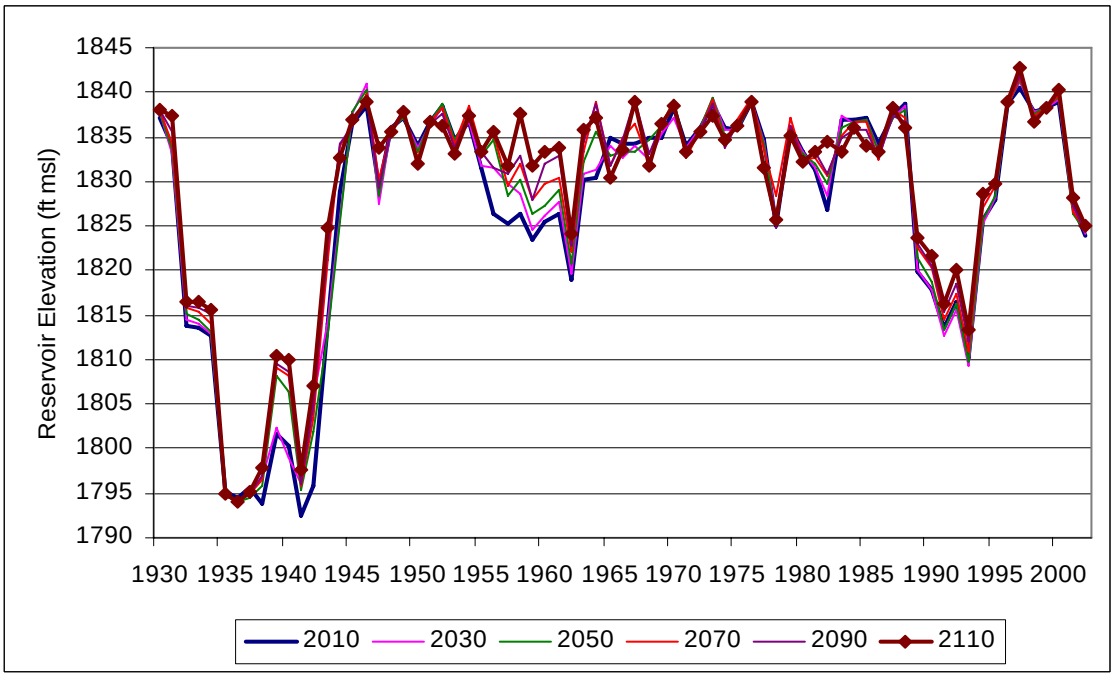

Figure 12. Garrison water surface elevations on March 1 for the modeling runs for 2010, 2030, 2050, 2070, 2090, and 2110.

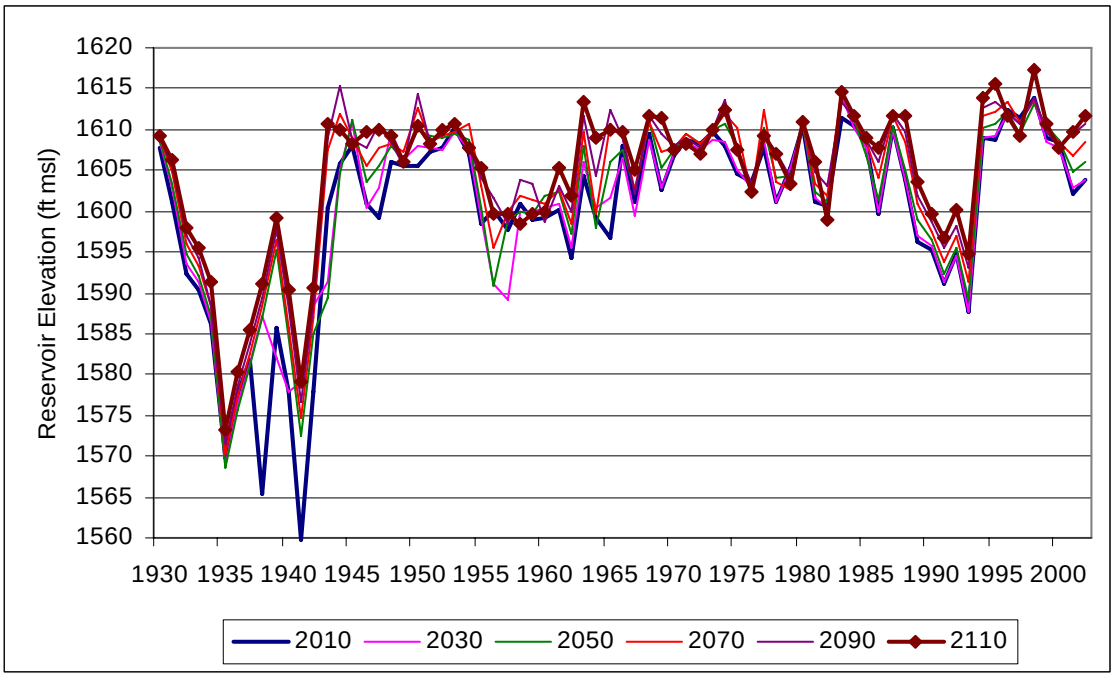

Figure 13. Oahe water surface elevations on March 1 for the modeling runs for 2010, 2030, 2050, 2070, 2090, and 2110.

The 5 MAF of storage difference would be distributed on March 1 on about an equal basis among the upper three reservoirs. This distribution would be less for Fort Peck because it is the smallest of the three reservoirs. Oahe and Garrison have similar sized reservoirs. Thus, the 5 MAF would be distributed such that the difference in storage at the two larger reservoirs would be under 2 MAF and over 1 MAF at Fort Peck. An understanding of the storage difference is important for this analysis; therefore, the next step is to revisit the storage capacity curves for these three projects. Using the storage capacity curves for Oahe (Figure 3), Table 5 was prepared. Two major points can be made from the data presented in the table. First, the net difference between the 2010 and 2110 curves diminishes as the storage value on Figure 3 diminishes (last column in Table 5 gets smaller as the storage value in column 1 gets smaller). Second and more important, a positive difference in the water surface elevation is possible. In the case of Table 5, if the net difference in the amount of water stored in Oahe is less than about 2000 thousand acre-feet (KAF), the elevation difference between the 2010 starting point of 1601.2 ft msl is 4.9 feet for a storage difference of only 1000 KAF (1 MAF) and drops to -0.2 feet at 2000 KAF. Based on this last point, the greater the depletion level, the greater the potential there will be a net negative elevation difference. The total difference between the 2010 and 2110 studies for this analysis is less than 1 MAF, which increases the likelihood of having some positive differences in water surface elevation at Oahe. Tables with corresponding data could be prepared for the other two reservoirs, and the results would be similar.

Table 5. Oahe water surface elevation versus storage.

Storage KAF	2010 Elevation ft msl	2110 Elevation ft msl	Difference From 1601.2 ft msl 2010 feet	2110 feet	Net Difference feet
17000	1601.2	--	--	--	--
16000	1596.7	1606.1	-4.5	4.9	9.4
15000	1592.1	1601.0	-9.1	-0.2	8.9
14000	1587.5	1596.0	-13.7	-5.2	8.5

HYDROPOWER GENERATION

Hydropower generation data are directly computed by the DRM. Peaking capability and energy generation values are computed on a daily basis; however, the current output files include the monthly average and total values, respectively. Table 6 presents the values for the full period of analysis for the nine modeling runs, and Table 7 presents similar data without the years with major drought impacts from 1934 through 1942. These "economic use" data are separated from the other effects data because these are the data that were requested by Western, and this request was the impetus for the conduct of this analysis at this time. Appendix A is comprised of the summaries of the monthly and annual data that are further summarized in Tables 6 and 7 for each of the nine studies.

Peaking capability, based on the depletion and sedimentation growth rates used in this analysis, are forecasted to increase between 2010 and 2110. This increase results from the higher levels that water will be stored in many years in the System reservoirs.

For the full period, the August average peaking capability values are forecasted to remain fairly constant between 2010 and 2030 and then steadily increase from 2030 through 2110. The total change presented in Table 6 is 47 megawatts (MW). Similar changes are also expected for the December average values, with the total change expected to be 43 MW.

For the partial modeling period, similar patterns to the full period hydropower average monthly peaking capability data are shown in Table 7. The net differences for the August and December averages are 39 and 34 MW, respectively.

In the early 1980s, Western elected to market hydropower from the System based on 1961 water conditions. For this reason, it is interested in the values for the summer and winter period in 1961, with the specific months being August and December. The values for these two months are presented in both Table 6 and 7, with the numbers being identical in both tables. The pattern of change is again similar to that for the full or partial periods, with the values remaining relatively constant over the next 20 years and gradually increasing over the next 80 years. The net differences over the 100 years are a positive 81 MW for the August value and a positive 85 MW for the December value.

Table 6. 1930-2002 hydropower generation data for the nine modeling runs.

Study Year	Peaking Capability				Service Generation			
Full	Megawatts				Summer	Winter	Annual (Jan-Dec)	
	Aug	Dec	Aug	Dec	Jun-Sep	Dec-Feb		Million
	Avg.	Avg.	1961	1961	MW	MW	MW	KW-Hours
2010	2248	2138	2130	2042	1270	880	1077	9434
2015	2250	2139	2134	2047	1270	876	1076	9425
2020	2250	2140	2134	2046	1265	869	1070	9376
2025	2256	2145	2138	2051	1266	870	1070	9371
2030	2256	2145	2143	2055	1261	866	1068	9354
2050	2265	2154	2161	2074	1268	844	1062	9304
2070	2279	2169	2173	2090	1279	824	1060	9290
2090	2288	2175	2187	2106	1291	801	1058	9266
2110	2295	2181	2211	2127	1300	779	1054	9234

Table 7. 1930-1933, 1943-2002 hydropower generation data for the nine modeling runs.

	Peaking Capability				Service Generation			
	Megawatts				Summer	Winter	Annual (Jan-Dec)	
	Aug	Dec	Aug	Dec	Jun-Sep	Dec-Feb		Million
Study Year	Avg.	Avg.	1961	1961	MW	MW	MW	KW-Hours
Partial								
2010	2298	2184	2130	2042	1344	930	1148	10054
2015	2300	2185	2134	2047	1345	926	1147	10044
2020	2300	2185	2134	2046	1340	916	1140	9989
2025	2301	2186	2138	2051	1338	916	1138	9970
2030	2302	2186	2143	2055	1333	912	1136	9950
2050	2310	2196	2161	2074	1340	887	1128	9886
2070	2323	2208	2173	2090	1358	865	1130	9902
2090	2331	2214	2187	2106	1371	838	1127	9871
2110	2337	2218	2211	2127	1381	812	1122	9832

Service generation numbers are based on the amount of hydropower energy that is produced during specified periods. The summer and winter average capabilities are based on the June through September and December through February months, respectively. Average summer capability is forecasted to remain relatively steady through 2050 and then steadily increase in the remaining years, with a net change of 30 or 37 MW. Average winter capability is expected to steadily decrease over the entire period, with the net change being 101 or 118 MW. The winter average capability is about 60 to 70 percent of the summer value, which would be expected as the summer releases are greater than the winter releases and the peaking capabilities during those two periods are very similar. The values for the full modeling period are all lower than for

the partial modeling period because the average generation during the extreme period of the 1930s drought would be relatively low, reducing the overall average.

Finally, total average annual generation diminishes as the depletions and sedimentation increase through the 100 years between 2010 and 2110 even though the peak generating capability increases. This loss of energy results because total water moving through the System will diminish with time due to the increasing depletions (see Table 8 and associated discussion below). The net effect on generation, whether the average annual capability or energy, will be -2.2 percent for both modeling periods. In terms of average annual capability, the losses would be 23 and 26 MW, respectively, for the full and partial periods. In terms of energy, the losses would be 200 million and 222 million kilowatt-hours (KW-hours) annually.

The DRM hydropower production values are based on the amount of the daily release that goes through the generators. In some cases, the releases would be in excess of the flow capacity of the generators, with these instances more likely at Gavins Point Dam. Table 8 presents the number of days over the 73-year period of analysis when the average daily release from Gavins Point Dam would exceed the generation unit release capability of 36 kcfs. The values for all of the modeling runs reflect what would happen without spring pulses included in the modeling. At this time, the exclusion of the spring pulses from the modeling would have a relatively small effect because the release-limiting criteria for the spring pulses, especially the May pulse that would have the greater release of the two pulses (late March being the second pulse period). Modeling for the Master Manual Study has shown that the May spring pulse would occur only about 30 percent of the years and at a relatively low rate due to the release restrictions that the downstream flow limits provide under the current criteria. The spring pulse version of the model was not used for this study due to concerns with some of the output files, especially the navigation files.

Table 8. Number of days that the Gavins Point Dam release exceeds 36 kcfs.

Model Run Year	Number of Days*	Change in days from 2010
2010	4308	--
2030	4231	-77
2050	4259	-49
2070	4573	265
2090	4856	548
2110	5011	703

* Over the 73-year modeling period.

In summary, peaking capability is expected to increase in the future by 1.5 to 2.0 percent, depending on which month or period is being used. Conversely, annual average capability and generation are expected to drop by 2.2 percent for both periods of analysis.

SUMMARY OF ECONOMIC AND ENVIRONMENTAL RESOURCE EFFECTS

The economic and environmental impacts models developed for the Master Manual Study compute the various absolute values described previously in this report. In some cases, the units are dollars, miles, MAF, etc., and in other cases, they are indices that have no units. Many of the impacts models are up to 15 years old, and revision should be made to them to have more appropriate absolute numbers for the effects. The process of revision would be very costly and time consuming; therefore, the existing models outputs on effects are the best available information at this time. One way to minimize concerns about the absolute numbers is to present the relative differences among the alternatives being modeled, in this case, the relative differences among the nine model runs for the depletion and sedimentation levels in 2010 through 2110. Table 9 presents the percent changes from current conditions, which is the 2010 modeling run for this study.

Table 9. Percent changes from the economic and environmental effects of 2010 levels of depletions and sedimentation.

	FC	NAV	HYD	WS	REC	TOT $	CS	CR	WR	YO	PH	TP	WT	RP	HS
2015	0	-2	0	0	0	0	1	0	0	1	0	-1	0	0	0
2020	0	-6	0	0	-1	0	0	0	0	1	0	12	-1	0	0
2025	0	-8	0	0	0	0	1	0	2	1	0	11	-1	0	0
2030	0	-11	0	0	0	0	2	0	1	2	0	12	-1	0	0
2050	0	-26	0	0	1	0	3	1	-1	2	0	11	-3	1	-2
2070	-1	-41	0	0	1	0	7	2	-1	4	0	29	-3	1	-4
2090	-1	-59	0	-1	1	-1	9	3	-6	5	0	38	-3	0	-5
2110	-1	-71	0	-1	1	-1	11	4	-3	7	0	36	-2	0	-7

Table 9 shows that the increasing depletions and sedimentation will have a positive effect (green/gray with black numbers) of greater than 0.49 percent in some or all of the runs on recreation (REC), coldwater reservoir fish habitat (CS), coldwater river fish habitat (CR), young-of-year fish production in the System reservoirs (YO), tern and plover habitat (TP), and riparian habitat. In the 2025 and 2030 runs, warmwater river fish habitat had a positive effect. Negative changes (red/black with white numbers) of greater than -0.49 percent in many or all of the runs from the 2010 modeling run effects will occur to flood control (FC), navigation (NAV), water supply, total economic dollars (TOT $), warmwater river fish habitat (WR), wetland habitat (WT), and historic sites (HS). Physical habitat for native river fish (PH) and hydropower (HP) appear to be relatively unaffected by the increased depletions and sedimentation.

MISSOURI RIVER NAVIGATION

Of the negative effects of future depletions and sedimentation, the most significant is to navigation. Examination of service level and season length data demonstrates why the economic benefits diminish so much. Table 10 summarizes the navigation service levels and season lengths for the 73-year modeling period for the nine modeling runs. Three

figures, Figures 14 through 16, were prepared using the navigation data in Table 10 to visually show the changes in service level and season length as the depletions and sedimentation increase from 2010 to 2110.

Figure 14 shows the service level changes for the April 1 through June 30 part of the season. It shows that the distribution of service levels among full, intermediate (0.01 to 5.99 kcfs less than full service), and minimum (6.00 kcfs less than full service) stays about the same through 2030 (first 20 years) and that a shift occurs toward more intermediate service years over the next 60 years (through 2090) and more minimum service years by 2110. Figure 15 shows the service level changes for the second "half" of the navigation season. There are more full service years through 2070, approximately equal distribution among the three service level categories by 2090, and more minimum service years by 2110.

Table 10. Navigation service level and season length data for the nine depletion and sedimentation studies.

	2010	2015	2020	2025	2030	2050	2070	2090	2110
	Service Level and Non-Navigation Seasons (based on March 15 System storage check)								
FULL	30	28	25	21	20	8	3	2	1
INTER	17	19	20	23	21	31	36	30	7
MIN	21	21	23	24	27	29	28	35	59
NONE	5	5	5	5	5	5	6	6	6
	Service Level (based on July 1 System storage check)								
FULL	35	35	34	33	32	27	25	18	18
INTER	18	18	17	18	18	20	21	24	21
MIN	15	15	17	17	18	21	21	25	28
	Season Lengths (based on July 1 System storage check)								
6.0-6.49	4	4	4	3	3	3	4	4	5
6.5-6.99	1	1	1	1	1	3	1	3	3
7.0-7.49	8	8	9	10	11	10	11	15	16
7.5-7.99	4	4	4	5	5	9	8	6	7
8	25	26	27	27	27	34	41	38	36
8.33	26	25	23	22	21	9	2	1	0

Figure 16 shows the season length changes for the nine modeling runs. It shows that the navigation season lengths stay relatively the same over the first 20 years (2010 through 2030); however, a dramatic loss of extended (8.33-month) seasons occurs over the next 20 years, with only a few to none of the extended seasons in the last 60 years of the analysis. The number of 8-month seasons, which are normal, full-length seasons, increases between the 2030 and 2070 model runs and diminishes slightly as even more shortened (less than 8 months long) seasons occur. Between 2010 and 2110, the number of shortened or no seasons increased from 22 (30 percent of 73-year modeling period) to 37 years (51 percent of modeling period). The number of extend seasons dropped from 26 to 0. When combined (37 plus 26 years), 63 of the 73 years (86 percent) experienced reduced season lengths in the 2110 run. As discussed earlier, the curve for season extensions needed to be "lowered" to allow some extensions in higher runoff years for

the later modeling years in this modeling analysis, which would result in fewer reduced season lengths than just identified.

The number of non-navigation years increase from 5 for the 2010, 2015, 2020, 2025, 2030, and 2050 modeling runs to 6 years for the other three study years. Of interest to those concerned about additional non-navigation years, the shift from 5 to 6 non-navigation years occurs at a depletion level of between 638 KAF and 738 KAF above the current, or 2010 level. A seventh non-navigation year does not occur for even the 2110 model run, which includes a total depletion level of 938 KAF, or about 1 MAF, above that included in the 2010 model run.

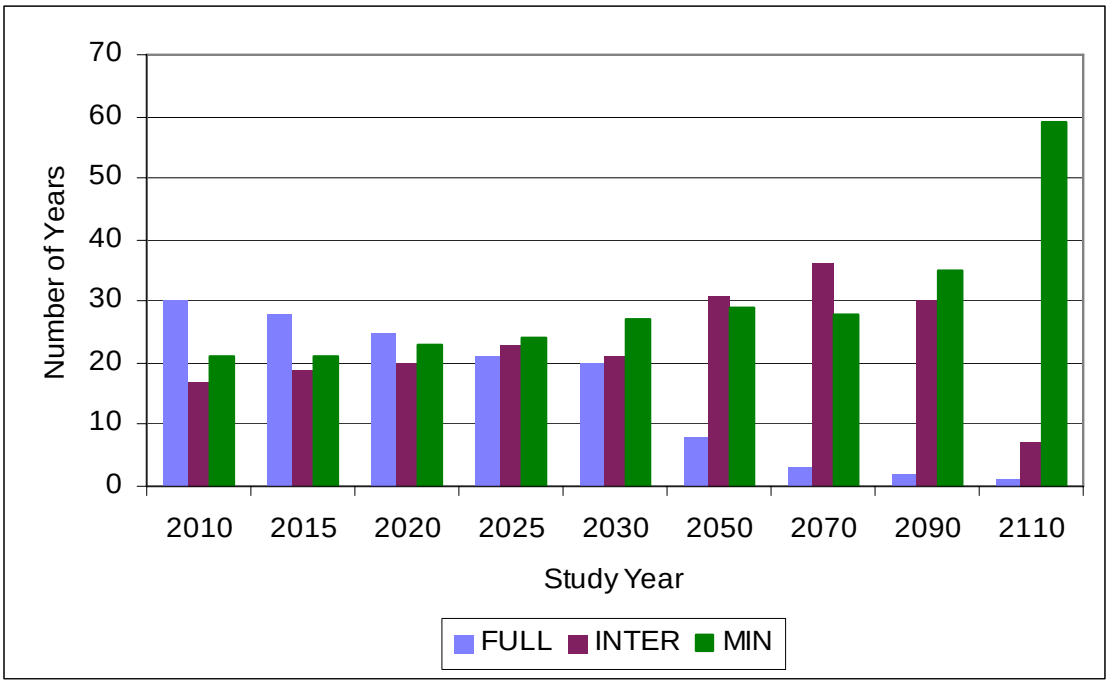

Figure 14. Navigation service level for the April 1 through June 30 period of the season based on the March 15 storage check.

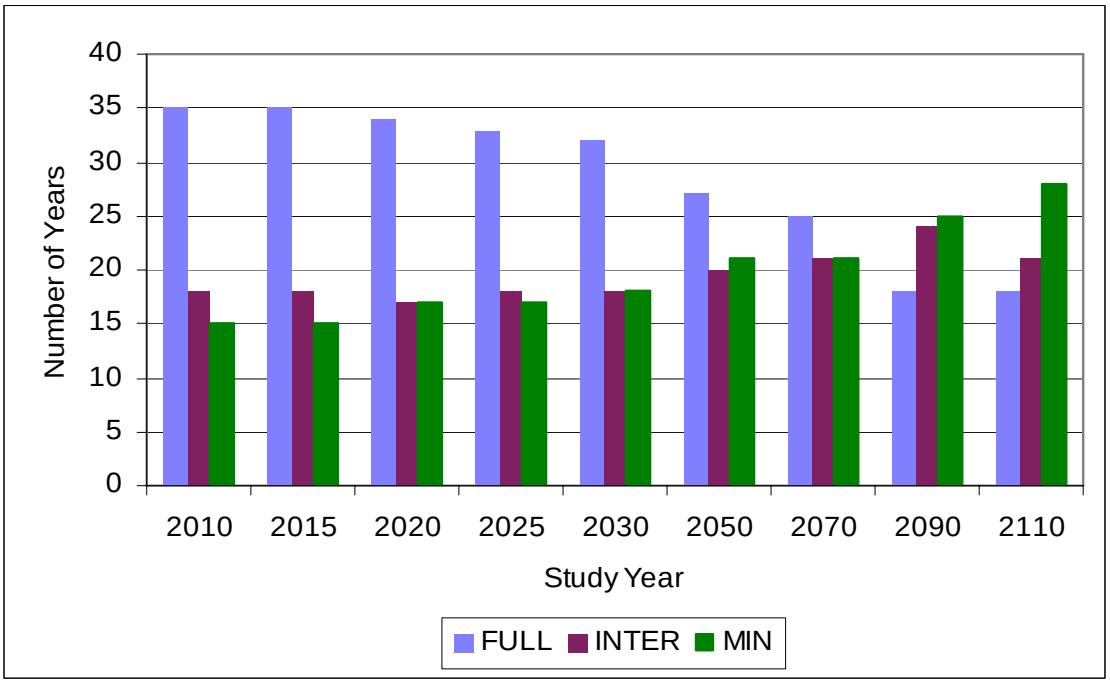

Figure 15. Navigation service level for the July 1 to end of the season period based on the July 1 storage check.

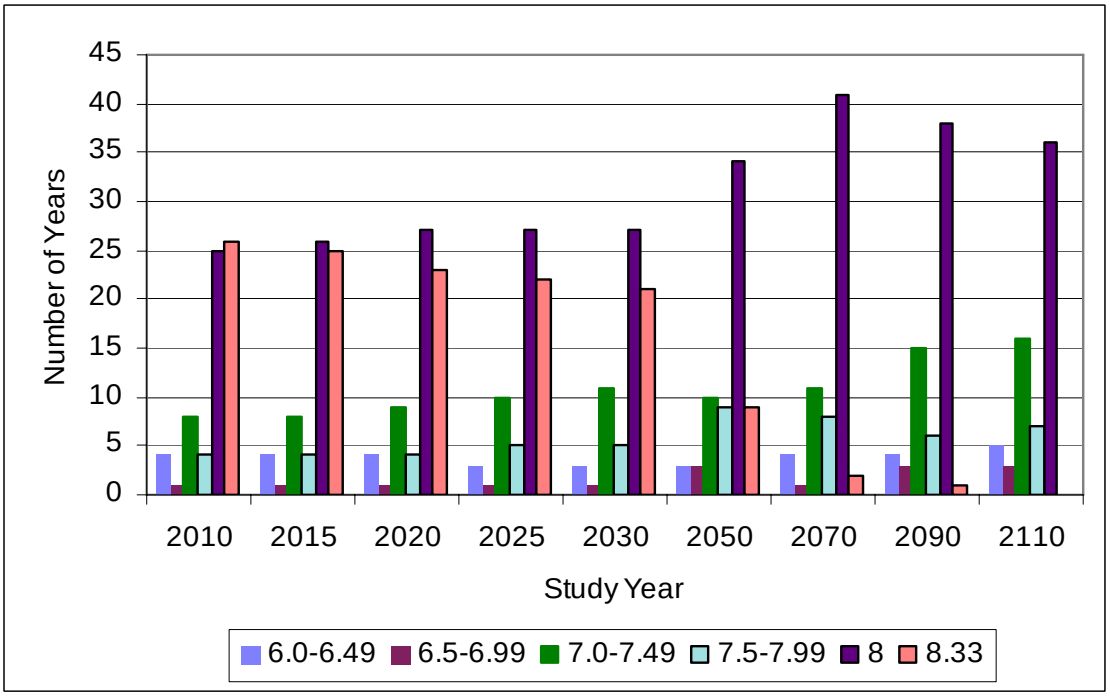

Figure 16. Navigation season lengths based on the July 1 System storage check (decision for no season is based on the March 15 storage check).

CONCLUSIONS

This depletions and sedimentation analysis examined the effects of up to 938 KAF of flow depletions to the System and up to about 8.8 MAF of additional sedimentation in the System. In normal to high inflow periods, System storage was up to 5 MAF lower on March 1 in many years for the 2110 modeling run. These differences in System storage levels in "normal" periods due to the increased depletions diminished during the droughts. Under the relatively high sedimentation to depletion ratio (8.8/.94 = 9.4 to 1), however, the resulting reservoir-levels would be higher through the drought periods and reservoir levels in "normal" periods would be very similar. Average annual releases from the System at Gavins Point Dam would also be reduced in many of the modeling period years due to reduced service to the downstream river and more reduced navigation season lengths as a result of the increasing depletions. Hydropower capability and energy generation values would increase by about 2 percent and decrease by about 2 percent, respectively, as the depletions and sedimentation increase between 2010 and 2110. The net effect on hydropower economics from the Master Manual Study economic impacts model is essentially no change over the period, however. Analysis of the other economic and the environmental effects using the Master Manual Study impacts models shows that the greatest relative economic impact would be to navigation (up to – 71 percent by 2110), and the greatest positive and negative environmental effects would be to tern and plover habitat and historic sites, respectively. The relatively large negative effect to navigation was further analyzed, and the increasing depletions and sedimentation lead to both service level and season length reductions. Overall, the depletions and continuing sedimentation will both be major factors causing adverse effects downstream from the System (primarily to Missouri River navigation), and the sedimentation will cause some positive economic use and environmental resource effects at the six System reservoirs.

Future Depletions and Sedimentation Effects on the Missouri River Mainstem System Technical Report Je-08

Missouri River Basin Water Management Division
Northwestern Division
Corps of Engineers

Appendix A

Detailed Data Tables on Hydropower Effects

Table A-1. Summary of Monthly and Annual Power Data for 2010 Depletion and Sedimentation Conditions.
(Based on average annual values for the 1930-2002 modeling period)

2010		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
System	Peak Power, MW	2143	2146	2046	1997	2120	2235	2257	2248	2078	2058	2143	2138	2257
	Average Power, MW	907	819	793	1069	1138	1208	1292	1271	1308	1176	1020	907	1077
	Energy, 1000 MWH	675.1	550.2	589.6	769.7	847.0	869.5	961.2	945.6	941.8	875.3	734.3	675.0	9434.4
Fort Peck	Peak Power, MW	195	194	177	171	197	200	202	202	194	185	192	197	202
	Average Power, MW	138	125	96	80	114	109	86	100	134	126	118	117	112
	Energy, 1000 MWH	102.5	84.2	71.2	57.9	84.7	78.1	64.3	74.0	96.7	93.8	85.2	86.9	979.5
Garrison	Peak Power, MW	349	341	338	312	354	390	412	408	349	346	372	361	412
	Average Power, MW	267	217	182	222	272	266	290	289	330	286	261	254	261
	Energy, 1000 MWH	198.3	145.8	135.1	159.7	202.4	191.5	215.6	214.8	237.4	212.8	187.7	189.2	2290.1
Oahe	Peak Power, MW	667	671	629	614	632	679	676	667	622	625	661	664	679
	Average Power, MW	238	222	209	331	322	353	405	383	354	313	264	251	304
	Energy, 1000 MWH	176.9	149.5	155.2	238.5	239.4	253.9	301.2	284.7	254.9	232.8	190.4	187.1	2664.4
Big Bend	Peak Power, MW	530	521	475	466	475	495	500	505	477	489	513	535	535
	Average Power, MW	94	85	79	124	116	124	141	136	129	121	107	103	113
	Energy, 1000 MWH	69.8	57.1	58.5	89.1	86.1	89.6	104.6	101.0	93.0	89.9	77.2	76.8	992.8
Fort Randall	Peak Power, MW	322	341	318	323	353	361	359	355	323	299	291	300	361
	Average Power, MW	116	113	156	219	222	258	271	263	260	233	184	123	202
	Energy, 1000 MWH	86.0	76.3	116.3	158.0	164.8	185.9	201.9	195.3	186.9	173.3	132.7	91.2	1768.6
Gavins Point	Peak Power, MW	81	78	110	110	110	109	109	111	113	114	114	82	114
	Average Power, MW	56	55	72	92	93	98	99	102	101	98	85	59	84
	Energy, 1000 MWH	41.6	37.3	53.5	66.5	69.5	70.4	73.7	75.8	72.9	72.8	61.0	43.8	739.0

Note: Each annual peak power value is the maximum of the 12 monthly values (based on average annual values for the 73-year modeling period).

Table A-2. Summary of Monthly and Annual Power Data for 2015 Depletion and Sedimentation Conditions.
(Based on average annual values for the 1930-2002 modeling period)

2015		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
System	Peak Power, MW	2145	2147	2047	1998	2122	2237	2259	2250	2079	2057	2144	2139	2259
	Average Power, MW	903	815	790	1070	1141	1213	1291	1268	1308	1174	1018	904	1076
	Energy, 1000 MWH	672.1	547.9	587.9	770.4	849.1	873.3	960.3	943.1	941.7	873.6	733.1	672.3	9424.9
Fort Peck	Peak Power, MW	195	194	177	171	197	200	202	201	193	185	192	197	202
	Average Power, MW	136	125	97	81	116	109	87	100	131	125	119	115	112
	Energy, 1000 MWH	101.5	84.3	71.9	58.0	86.6	78.3	64.6	74.3	94.7	93.1	85.4	85.9	978.5
Garrison	Peak Power, MW	349	342	338	313	355	391	413	408	350	346	373	362	413
	Average Power, MW	268	218	181	222	273	268	289	288	328	283	261	255	261
	Energy, 1000 MWH	199.1	146.3	134.4	159.9	202.9	192.8	215.1	214.0	235.9	210.7	187.6	190.1	2288.9
Oahe	Peak Power, MW	667	671	630	615	633	680	677	668	623	626	661	664	680
	Average Power, MW	236	220	208	332	322	354	404	382	357	315	264	250	304
	Energy, 1000 MWH	175.3	147.9	154.4	238.8	239.5	255.2	300.9	283.9	257.3	234.2	190.4	185.8	2663.8
Big Bend	Peak Power, MW	530	521	475	466	475	495	500	506	477	489	513	535	535
	Average Power, MW	93	84	78	124	116	125	140	135	130	121	107	102	113
	Energy, 1000 MWH	69.1	56.5	58.2	89.1	86.0	89.9	104.3	100.7	93.9	90.4	77.2	76.3	991.5
Fort Randall	Peak Power, MW	322	341	318	322	353	361	359	355	322	298	291	300	361
	Average Power, MW	115	113	155	220	221	259	271	262	260	232	183	122	201
	Energy, 1000 MWH	85.6	75.8	115.6	158.1	164.6	186.5	201.8	194.6	187.0	172.6	131.8	90.7	1764.7
Gavins Point	Peak Power, MW	81	78	110	110	110	109	109	111	113	114	114	82	114
	Average Power, MW	56	55	72	92	93	98	99	102	101	98	84	59	84
	Energy, 1000 MWH	41.5	37.1	53.3	66.5	69.5	70.5	73.7	75.6	72.9	72.6	60.6	43.6	737.5

Note: Each annual peak power value is the maximum of the 12 monthly values (based on average annual values for the 73-year modeling period).

Table A-3. Summary of Monthly and Annual Power Data for 2020 Depletion and Sedimentation Conditions.
(Based on average annual values for the 1930-2002 modeling period)

2020 All Years

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
System	Peak Power, MW	2145	2147	2048	1999	2122	2238	2260	2250	2078	2057	2144	2140	2260
	Average Power, MW	897	809	784	1075	1131	1202	1287	1263	1308	1177	1001	894	1070
	Energy, 1000 MWH	667.4	543.6	583.2	774.0	841.6	865.4	957.6	939.6	941.9	876.0	720.9	665.0	9376.1
Fort Peck	Peak Power, MW	195	194	177	171	197	200	202	201	193	185	192	197	202
	Average Power, MW	137	126	96	82	116	110	86	95	132	127	117	115	111
	Energy, 1000 MWH	102.0	84.4	71.2	58.9	86.4	79.3	64.0	70.9	95.1	94.3	84.0	85.8	976.3
Garrison	Peak Power, MW	349	341	338	312	354	391	414	410	350	346	373	361	414
	Average Power, MW	267	216	179	224	266	259	290	289	331	283	255	253	260
	Energy, 1000 MWH	198.5	145.5	133.3	161.6	198.0	186.6	215.5	215.2	238.4	210.6	183.9	188.6	2275.5
Oahe	Peak Power, MW	668	673	631	616	634	681	676	668	623	626	661	665	681
	Average Power, MW	233	217	206	333	320	352	403	381	356	317	261	246	303
	Energy, 1000 MWH	173.0	146.1	153.2	239.6	238.4	253.7	299.5	283.4	256.6	235.8	187.7	183.2	2650.1
Big Bend	Peak Power, MW	530	521	475	466	474	495	500	506	477	489	513	535	535
	Average Power, MW	92	83	78	124	115	124	140	135	130	122	106	101	113
	Energy, 1000 MWH	68.1	55.7	57.7	89.4	85.4	89.4	104.0	100.5	93.5	90.9	76.2	75.1	986.0
Fort Randall	Peak Power, MW	322	341	318	322	353	361	358	355	322	297	291	301	361
	Average Power, MW	114	112	154	219	221	258	270	261	258	231	180	120	200
	Energy, 1000 MWH	84.7	75.1	114.8	157.9	164.2	186.1	201.2	194.1	185.8	172.1	129.4	89.2	1754.5
Gavins Point	Peak Power, MW	80	78	110	110	110	109	109	111	113	114	114	82	114
	Average Power, MW	55	55	71	92	93	98	99	101	101	97	83	58	84
	Energy, 1000 MWH	41.1	36.9	53.0	66.5	69.3	70.4	73.5	75.5	72.5	72.3	59.8	43.1	733.7

Note: Each annual peak power value is the maximum of the 12 monthly values (based on average annual values for the 73-year modeling period).

Table A-4. Summary of Monthly and Annual Power Data for 2025 Depletion and Sedimentation Conditions.
(Based on average annual values for the 1930-2002 modeling period)

2025		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
System	Peak Power, MW	2150	2153	2053	2003	2128	2244	2266	2256	2084	2062	2149	2145	2266
	Average Power, MW	899	812	786	1074	1123	1199	1287	1271	1304	1173	999	895	1070
	Energy, 1000 MWH	668.5	545.7	584.6	773.1	835.8	863.1	957.7	945.8	938.8	873.0	719.6	665.6	9371.3
Fort Peck	Peak Power, MW	196	194	177	171	197	201	202	202	193	185	192	197	202
	Average Power, MW	138	126	97	83	113	108	85	96	133	125	117	117	111
	Energy, 1000 MWH	102.4	84.9	71.9	59.7	84.3	77.7	63.4	71.4	95.9	92.7	84.2	86.7	975.4
Garrison	Peak Power, MW	352	344	340	314	357	394	417	412	352	349	376	365	417
	Average Power, MW	271	221	182	220	265	259	292	294	326	276	256	255	260
	Energy, 1000 MWH	201.5	148.7	135.7	158.5	197.1	186.6	217.2	218.8	234.6	205.0	184.0	189.8	2277.6
Oahe	Peak Power, MW	669	674	633	619	636	682	678	670	625	628	662	666	682
	Average Power, MW	231	216	205	334	318	352	402	383	357	320	261	245	303
	Energy, 1000 MWH	171.9	145.3	152.7	240.5	236.8	253.4	299.3	285.1	257.1	237.9	187.7	182.5	2650.2
Big Bend	Peak Power, MW	531	521	476	467	475	497	501	507	478	490	514	536	536
	Average Power, MW	91	82	77	124	114	124	140	136	130	124	106	101	112
	Energy, 1000 MWH	67.6	55.2	57.6	89.5	84.7	89.2	103.9	101.0	93.5	91.9	76.2	74.8	985.2
Fort Randall	Peak Power, MW	322	341	317	322	353	360	358	354	321	296	290	300	360
	Average Power, MW	113	111	153	220	220	258	270	261	257	232	178	119	200
	Energy, 1000 MWH	84.2	74.8	114.0	158.2	163.7	185.8	200.6	194.1	185.3	172.7	128.2	88.8	1750.5
Gavins Point	Peak Power, MW	80	78	110	110	110	109	109	111	113	114	114	82	114
	Average Power, MW	55	55	71	93	93	98	99	101	101	98	82	58	84
	Energy, 1000 MWH	40.9	36.7	52.8	66.6	69.1	70.4	73.3	75.4	72.4	72.7	59.3	42.9	732.4

Note: Each annual peak power value is the maximum of the 12 monthly values (based on average annual values for the 73-year modeling period).

Table A-5. Summary of Monthly and Annual Power Data for 2030 Depletion and Sedimentation Conditions.
(Based on average annual values for the 1930-2002 modeling period)

2030		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
System	Peak Power, MW	2150	2152	2052	2003	2128	2244	2266	2256	2084	2062	2148	2145	2266
	Average Power, MW	895	812	795	1078	1121	1198	1282	1255	1307	1180	990	886	1068
	Energy, 1000 MWH	665.9	545.7	591.8	775.9	833.8	862.9	953.7	933.4	941.1	877.7	713.0	659.3	9354.1
Fort Peck	Peak Power, MW	196	194	177	172	197	201	202	202	194	186	193	197	202
	Average Power, MW	137	127	100	85	115	110	83	91	133	125	115	115	111
	Energy, 1000 MW	102.1	85.6	74.2	61.0	85.7	79.1	61.7	68.0	95.8	93.2	82.5	85.6	974.4
Garrison	Peak Power, MW	353	344	340	314	357	395	418	413	353	350	378	366	418
	Average Power, MW	273	225	189	222	262	259	289	286	327	277	250	255	260
	Energy, 1000 MW	202.7	151.0	140.6	159.5	195.2	186.5	215.4	212.5	235.7	205.9	180.1	189.8	2275.0
Oahe	Peak Power, MW	668	673	632	618	636	682	678	669	624	627	660	663	682
	Average Power, MW	228	214	205	335	317	351	403	381	359	323	261	242	302
	Energy, 1000 MW	169.9	143.5	152.6	240.9	236.1	252.5	299.5	283.3	258.2	240.4	187.8	179.8	2644.5
Big Bend	Peak Power, MW	530	521	476	466	474	497	501	506	479	490	514	536	536
	Average Power, MW	90	81	77	125	114	124	140	135	131	125	106	99	112
	Energy, 1000 MW	66.8	54.6	57.6	89.6	84.5	88.9	103.9	100.4	94.0	92.9	76.4	73.8	983.6
Fort Randall	Peak Power, MW	323	341	317	322	353	360	358	355	321	296	290	300	360
	Average Power, MW	113	111	153	220	219	258	269	261	257	232	177	118	199
	Energy, 1000 MW	83.8	74.4	114.0	158.2	163.2	185.7	200.2	193.9	185.2	172.7	127.3	87.8	1746.2
Gavins Point	Peak Power, MW	80	78	110	110	110	109	109	111	113	114	114	82	114
	Average Power, MW	55	54	71	92	93	98	98	101	100	98	82	57	83
	Energy, 1000 MW	40.7	36.6	52.8	66.6	69.0	70.3	73.1	75.3	72.3	72.6	58.8	42.5	730.5

Note: Each annual peak power value is the maximum of the 12 monthly values (based on average annual values for the 73-year modeling period).

Table A-6. Summary of Monthly and Annual Power Data for 2050 Depletion and Sedimentation Conditions.
(Based on average annual values for the 1930-2002 modeling period)

2050		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
System	Peak Power, MW	2160	2161	2061	2011	2136	2253	2275	2265	2092	2067	2154	2154	2275
	Average Power, MW	876	796	786	1073	1112	1196	1289	1266	1319	1194	967	855	1062
	Energy, 1000 MWH	652.0	534.8	585.0	772.2	827.5	860.9	959.4	941.9	949.5	888.6	696.2	636.3	9304.3
Fort Peck	Peak Power, MW	197	195	178	172	198	201	203	202	194	186	193	198	203
	Average Power, MW	132	127	99	84	112	107	84	95	131	123	117	113	110
	Energy, 1000 MWH	98.4	85.3	74.0	60.6	83.3	77.0	62.3	70.9	94.2	91.5	84.1	84.1	965.7
Garrison	Peak Power, MW	355	347	343	318	362	399	422	416	357	353	381	369	422
	Average Power, MW	271	222	181	218	260	263	297	292	327	277	246	255	259
	Energy, 1000 MWH	201.9	148.9	134.7	157.0	193.6	189.1	220.8	217.3	235.5	205.9	177.0	189.5	2271.1
Oahe	Peak Power, MW	673	679	637	622	639	686	683	675	629	630	664	668	686
	Average Power, MW	221	206	205	335	318	351	404	383	369	337	256	229	302
	Energy, 1000 MWH	164.5	138.5	152.6	241.4	236.4	252.5	300.7	285.2	265.7	250.9	184.0	170.6	2643.0
Big Bend	Peak Power, MW	530	521	476	466	474	496	500	506	479	491	514	536	536
	Average Power, MW	86	78	77	124	113	123	139	135	134	130	104	93	112
	Energy, 1000 MWH	64.2	52.3	57.3	89.3	83.9	88.3	103.7	100.3	96.8	96.9	74.9	69.5	977.4
Fort Randall	Peak Power, MW	325	342	317	322	353	361	359	355	319	294	288	302	361
	Average Power, MW	112	110	153	219	218	256	268	260	257	230	166	111	197
	Energy, 1000 MWH	83.0	73.6	113.8	157.5	162.0	184.5	199.3	193.4	185.1	171.1	119.8	82.4	1725.5
Gavins Point	Peak Power, MW	80	78	110	110	110	109	109	111	113	114	114	82	114
	Average Power, MW	54	54	71	92	92	97	98	100	101	97	78	54	82
	Energy, 1000 MWH	40.1	36.1	52.7	66.4	68.4	69.5	72.5	74.8	72.4	72.2	56.3	40.3	721.7

Note: Each annual peak power value is the maximum of the 12 monthly values (based on average annual values for the 73-year modeling period).

Table A-7. Summary of Monthly and Annual Power Data for 2070 Depletion and Sedimentation Conditions.
(Based on average annual values for the 1930-2002 modeling period)

2070		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
System	Peak Power, MW	2174	2175	2074	2024	2150	2267	2289	2279	2107	2081	2166	2169	2289
	Average Power, MW	857	778	774	1066	1105	1199	1307	1273	1336	1220	960	832	1060
	Energy, 1000 MWH	637.3	523.0	576.1	767.6	822.0	863.6	972.5	947.4	961.9	907.3	691.5	619.4	9289.5
Fort Peck	Peak Power, MW	198	196	179	173	199	202	203	203	195	187	194	199	203
	Average Power, MW	128	124	98	86	117	109	85	96	129	124	115	115	110
	Energy, 1000 MWH	95.0	83.4	73.2	61.7	86.8	78.6	63.0	71.4	93.2	92.2	82.7	85.7	966.9
Garrison	Peak Power, MW	361	352	348	324	368	407	429	424	364	359	387	375	429
	Average Power, MW	269	221	173	221	252	264	298	292	329	285	249	258	259
	Energy, 1000 MWH	199.8	148.5	128.9	159.3	187.2	190.2	222.0	216.9	237.2	212.3	179.1	191.7	2273.1
Oahe	Peak Power, MW	680	686	644	629	646	693	690	682	636	637	669	674	693
	Average Power, MW	214	198	205	332	318	353	416	389	383	351	254	216	303
	Energy, 1000 MWH	159.2	132.8	152.2	239.3	236.9	254.3	309.5	289.4	275.5	261.2	183.2	160.8	2654.4
Big Bend	Peak Power, MW	528	520	476	466	473	494	497	504	478	490	513	534	534
	Average Power, MW	82	74	76	122	112	122	141	135	138	135	103	87	111
	Energy, 1000 MWH	61.3	49.8	56.6	87.6	83.1	88.0	104.9	100.7	99.5	100.3	74.4	64.9	971.0
Fort Randall	Peak Power, MW	327	343	318	323	354	361	360	356	320	295	289	305	361
	Average Power, MW	111	108	152	214	216	255	270	262	257	229	162	105	195
	Energy, 1000 MWH	82.4	72.8	112.9	154.3	160.4	183.6	200.7	194.6	184.8	170.0	116.6	77.9	1711.1
Gavins Point	Peak Power, MW	80	78	110	110	110	109	109	111	113	114	114	82	114
	Average Power, MW	53	53	70	91	91	96	97	100	100	96	77	51	81
	Energy, 1000 MWH	39.6	35.6	52.3	65.4	67.6	68.8	72.3	74.4	71.7	71.4	55.5	38.3	713.0

Note: Each annual peak power value is the maximum of the 12 monthly values (based on average annual values for the 73-year modeling period).

Table A-8. Summary of Monthly and Annual Power Data for 2090 Depletion and Sedimentation Conditions.
(Based on average annual values for the 1930-2002 modeling period)

2090		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
System	Peak Power, MW	2181	2180	2079	2029	2156	2274	2297	2288	2114	2085	2170	2175	2297
	Average Power, MW	834	766	767	1065	1090	1206	1316	1279	1361	1239	951	800	1058
	Energy, 1000 MWH	620.8	514.8	570.9	766.7	811.3	868.5	979.4	951.3	980.2	922.0	684.4	595.2	9265.6
Fort Peck	Peak Power, MW	198	197	179	173	199	203	204	203	195	187	194	199	204
	Average Power, MW	125	123	98	90	119	113	90	98	124	121	116	113	111
	Energy, 1000 MWH	92.9	82.5	72.9	64.5	88.2	81.4	67.1	73.0	89.5	89.8	83.6	84.2	969.6
Garrison	Peak Power, MW	363	353	349	325	371	411	434	428	367	361	390	378	434
	Average Power, MW	268	225	171	219	245	264	301	295	331	288	249	257	260
	Energy, 1000 MWH	199.6	151.0	127.1	157.5	182.1	190.3	224.2	219.6	238.2	214.3	179.2	190.9	2273.9
Oahe	Peak Power, MW	683	690	648	633	650	697	693	685	641	640	670	676	697
	Average Power, MW	204	190	203	333	315	357	417	389	403	368	253	202	303
	Energy, 1000 MWH	151.8	127.5	151.0	239.6	234.5	257.1	310.6	289.4	290.4	273.6	182.3	150.2	2657.9
Big Bend	Peak Power, MW	527	519	476	465	472	493	497	505	479	490	513	534	534
	Average Power, MW	78	71	75	121	110	122	141	135	146	141	103	81	111
	Energy, 1000 MWH	58.1	47.5	55.9	87.0	81.7	88.0	104.9	100.7	104.9	105.1	74.1	60.4	968.3
Fort Randall	Peak Power, MW	329	343	318	323	354	362	360	355	319	293	289	306	362
	Average Power, MW	108	106	150	213	213	255	270	261	258	227	156	99	193
	Energy, 1000 MWH	80.0	71.4	111.9	153.1	158.2	183.5	200.7	194.4	185.5	168.6	112.0	73.3	1692.8
Gavins Point	Peak Power, MW	80	78	110	110	110	109	109	111	113	114	114	82	114
	Average Power, MW	52	52	70	90	90	95	97	100	99	95	74	49	80
	Energy, 1000 MWH	38.4	35.0	52.0	65.0	66.7	68.2	72.0	74.1	71.6	70.6	53.2	36.3	703.1

Note: Each annual peak power value is the maximum of the 12 monthly values (based on average annual values for the 73-year modeling period).

Table A-9. Summary of Monthly and Annual Power Data for 2110 Depletion and Sedimentation Conditions.
(Based on average annual values for the 1930-2002 modeling period)

2110		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
System	Peak Power, MW	2187	2186	2085	2036	2163	2283	2305	2295	2120	2090	2174	2181	2305
	Average Power, MW	814	742	762	1055	1092	1196	1332	1281	1390	1249	943	777	1054
	Energy, 1000 MWH	605.3	498.4	567.2	759.4	812.1	860.8	990.9	953.0	1000.6	929.5	679.0	578.3	9234.4
Fort Peck	Peak Power, MW	199	197	180	175	200	203	204	204	196	188	195	200	204
	Average Power, MW	122	121	100	90	120	111	92	99	126	119	114	113	111
	Energy, 1000 MWH	90.7	81.5	74.7	65.0	89.7	80.0	68.2	74.0	90.8	88.8	81.9	83.9	969.3
Garrison	Peak Power, MW	367	356	352	328	375	416	438	432	371	366	395	383	438
	Average Power, MW	270	228	173	213	245	265	311	292	330	281	246	261	260
	Energy, 1000 MWH	200.9	153.5	128.8	153.5	182.5	190.6	231.5	217.5	237.8	209.0	177.3	193.9	2276.8
Oahe	Peak Power, MW	683	692	650	635	652	699	696	689	642	640	669	675	699
	Average Power, MW	193	176	199	330	315	353	422	391	422	383	257	189	303
	Energy, 1000 MWH	143.9	118.1	148.2	237.8	234.2	253.9	314.0	291.2	303.6	285.3	184.9	140.3	2655.5
Big Bend	Peak Power, MW	526	519	475	465	471	493	497	504	479	490	513	533	533
	Average Power, MW	74	65	74	120	109	121	142	136	152	148	105	76	110
	Energy, 1000 MWH	54.8	44.0	54.7	86.1	81.3	86.8	105.5	100.8	109.5	109.9	75.3	56.3	965.1
Fort Randall	Peak Power, MW	331	344	318	323	354	362	360	355	318	292	288	309	362
	Average Power, MW	104	101	147	211	212	253	269	263	260	224	150	93	191
	Energy, 1000 MWH	77.6	67.8	109.6	152.1	158.0	181.8	200.0	195.4	187.1	166.8	108.0	69.4	1673.7
Gavins Point	Peak Power, MW	80	78	110	110	110	109	109	111	114	114	114	82	114
	Average Power, MW	50	50	69	90	89	94	96	99	100	94	72	46	79
	Energy, 1000 MWH	37.3	33.6	51.2	64.8	66.4	67.6	71.6	74.0	71.8	69.8	51.5	34.5	694.1

Note: Each annual peak power value is the maximum of the 12 monthly values (based on average annual values for the 73-year modeling period).

Table A-10. Summary of Monthly and Annual Power Data for 2010 Depletion and Sedimentation Conditions (Partial Period).
(Based on average annual values for the 1930-2002 modeling period minus 1934-1942)

2010		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
System	Peak Power, MW	2192	2195	2095	2043	2169	2285	2307	2298	2127	2105	2190	2184	2307
	Average Power, MW	950	785	842	1089	1203	1225	1357	1342	1367	1301	1089	964	1148
	Energy, 1000 MWH	706.6	583.9	626.7	810.0	895.2	911.3	1009.9	998.2	1017.1	967.7	810.1	717.3	10054.0
Fort Peck	Peak Power, MW	201	203	185	179	206	209	211	210	203	194	201	206	211
	Average Power, MW	145	121	102	85	122	112	92	106	142	138	127	125	120
	Energy, 1000 MWH	107.8	90.2	75.8	62.9	90.7	83.2	68.5	79.2	105.8	102.9	94.1	93.1	1054.1
Garrison	Peak Power, MW	374	373	369	340	383	420	443	440	378	375	404	392	443
	Average Power, MW	280	211	196	231	291	269	304	302	342	313	277	270	279
	Energy, 1000 MWH	208.5	156.9	145.5	172.1	216.2	200.0	225.9	224.6	254.5	232.6	206.4	200.7	2444.1
Oahe	Peak Power, MW	682	698	655	642	661	710	706	696	649	651	688	691	710
	Average Power, MW	251	214	221	337	342	362	431	410	373	348	283	270	326
	Energy, 1000 MWH	186.6	158.9	164.7	250.5	254.5	269.2	320.6	304.7	277.4	259.1	210.5	200.7	2857.3
Big Bend	Peak Power, MW	532	530	483	473	482	503	507	512	485	499	524	546	546
	Average Power, MW	98	81	83	124	120	125	147	143	134	134	114	110	120
	Energy, 1000 MWH	72.9	59.9	61.5	92.1	89.6	93.1	109.2	106.1	99.5	99.3	85.0	81.8	1050.2
Fort Randall	Peak Power, MW	319	345	323	328	359	366	365	362	330	303	292	300	366
	Average Power, MW	118	106	165	220	231	259	280	275	271	260	197	128	213
	Energy, 1000 MWH	88.0	79.1	122.8	163.4	171.7	192.4	208.6	204.3	201.9	193.3	146.8	95.0	1867.3
Gavins Point	Peak Power, MW	81	79	111	112	112	111	111	112	115	115	115	83	115
	Average Power, MW	57	52	76	93	97	99	104	107	105	108	90	62	89
	Energy, 1000 MWH	42.8	38.8	56.4	69.1	72.4	73.4	77.0	79.4	78.0	80.6	67.2	45.9	781.1

Note: Each annual peak power value is the maximum of the 12 monthly values (based on average annual values for the 73-year modeling period).

Table A-11. Summary of Monthly and Annual Power Data for 2015 Depletion and Sedimentation Conditions (Partial Period).
(Based on average annual values for the 1930-2002 modeling period minus 1934-1942)

2015		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
System	Peak Power, MW	2193	2197	2096	2044	2171	2287	2309	2300	2128	2104	2190	2185	2309
	Average Power, MW	946	782	840	1090	1206	1230	1356	1338	1368	1298	1087	960	1147
	Energy, 1000 MWH	703.8	581.7	624.8	810.7	897.0	915.5	1008.8	995.4	1017.4	965.5	808.8	714.4	10043.8
Fort Peck	Peak Power, MW	201	203	185	179	206	209	211	210	202	193	201	206	211
	Average Power, MW	144	122	103	85	124	112	93	107	139	137	127	124	120
	Energy, 1000 MWH	106.9	90.4	76.8	62.9	92.2	83.5	68.9	79.5	103.6	102.0	94.4	92.0	1053.1
Garrison	Peak Power, MW	374	373	370	341	384	421	444	440	380	376	405	393	444
	Average Power, MW	282	212	195	232	291	270	303	301	340	309	277	271	279
	Energy, 1000 MWH	209.7	157.7	144.9	172.3	216.8	201.2	225.3	223.9	252.9	229.7	206.4	201.8	2442.7
Oahe	Peak Power, MW	683	699	656	643	662	711	707	697	649	651	688	691	711
	Average Power, MW	249	211	220	337	342	364	431	408	377	351	283	268	326
	Energy, 1000 MWH	184.9	157.2	163.7	250.8	254.5	270.7	320.3	303.7	280.3	260.8	210.5	199.2	2856.7
Big Bend	Peak Power, MW	532	530	483	473	482	503	507	513	485	499	524	546	546
	Average Power, MW	97	80	82	124	120	126	146	142	135	134	114	109	120
	Energy, 1000 MWH	72.2	59.2	61.1	92.0	89.5	93.5	109.0	105.7	100.5	100.0	85.0	81.2	1048.8
Fort Randall	Peak Power, MW	320	346	323	328	358	366	365	362	329	302	292	300	366
	Average Power, MW	118	106	164	220	230	259	280	273	272	259	196	127	213
	Energy, 1000 MWH	87.6	78.6	122.1	163.5	171.5	193.1	208.4	203.4	202.1	192.6	145.7	94.4	1863.0
Gavins Point	Peak Power, MW	81	79	111	112	112	111	111	112	115	115	115	83	115
	Average Power, MW	57	52	76	93	97	99	103	106	105	108	90	61	89
	Energy, 1000 MWH	42.6	38.7	56.2	69.1	72.4	73.5	76.9	79.1	78.0	80.4	66.8	45.7	779.5

Note: Each annual peak power value is the maximum of the 12 monthly values (based on average annual values for the 73-year modeling period).

Table A-12. Summary of Monthly and Annual Power Data for 2020 Depletion and Sedimentation Conditions (Partial Period).
(Based on average annual values for the 1930-2002 modeling period minus 1934-1942)

2020		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
System	Peak Power, MW	2193	2196	2096	2044	2171	2286	2309	2300	2126	2103	2189	2185	2309
	Average Power, MW	938	773	834	1094	1195	1221	1353	1334	1365	1303	1069	948	1140
	Energy, 1000 MWH	697.5	575.5	620.3	814.1	888.8	908.3	1006.5	992.2	1015.7	969.6	795.3	705.7	9989.5
Fort Peck	Peak Power, MW	201	203	185	179	206	209	210	210	202	194	201	206	210
	Average Power, MW	144	121	102	86	124	112	92	103	139	140	126	124	120
	Energy, 1000 MWH	107.2	90.2	76.2	64.1	92.1	83.6	68.3	76.4	103.4	103.9	93.4	91.9	1050.8
Garrison	Peak Power, MW	373	372	369	340	384	421	444	440	378	375	404	392	444
	Average Power, MW	280	210	193	233	284	266	304	303	340	309	272	269	277
	Energy, 1000 MWH	208.3	156.0	143.4	173.7	211.7	197.8	226.3	225.8	252.6	230.1	202.1	199.8	2427.6
Oahe	Peak Power, MW	683	700	657	643	662	711	706	697	650	652	688	691	711
	Average Power, MW	245	208	219	338	340	361	429	407	377	353	279	264	324
	Energy, 1000 MWH	182.3	154.8	162.6	251.6	253.0	268.4	318.8	302.8	280.2	262.7	207.3	196.2	2840.6
Big Bend	Peak Power, MW	532	530	483	473	482	503	508	513	485	499	524	546	546
	Average Power, MW	96	78	82	124	119	125	146	142	135	135	113	107	119
	Energy, 1000 MWH	71.1	58.2	60.7	92.3	88.9	92.8	108.6	105.4	100.4	100.7	83.8	79.9	1042.8
Fort Randall	Peak Power, MW	320	346	323	328	359	366	365	362	329	301	291	301	366
	Average Power, MW	116	105	163	219	230	259	279	273	271	258	192	125	211
	Energy, 1000 MWH	86.6	77.8	121.4	163.3	171.0	192.3	207.8	202.8	201.3	192.1	142.9	92.8	1852.1
Gavins Point	Peak Power, MW	80	79	111	112	112	111	111	113	115	115	115	83	115
	Average Power, MW	57	52	75	93	97	99	103	106	105	108	88	61	89
	Energy, 1000 MWH	42.2	38.4	56.0	69.1	72.2	73.3	76.7	79.0	77.8	80.1	65.8	45.0	775.5

Note: Each annual peak power value is the maximum of the 12 monthly values (based on average annual values for the 73-year modeling period).

Table A-13. Summary of Monthly and Annual Power Data for 2025 Depletion and Sedimentation Conditions (Partial Period).
(Based on average annual values for the 1930-2002 modeling period minus 1934-1942)

2025		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
System	Peak Power, MW	2194	2197	2097	2045	2172	2288	2310	2301	2128	2104	2190	2186	2310
	Average Power, MW	935	776	835	1091	1191	1221	1353	1335	1358	1293	1065	946	1138
	Energy, 1000 MWH	695.9	577.5	621.2	811.9	886.2	908.8	1006.8	993.3	1010.0	962.1	792.7	704.2	9970.3
Fort Peck	Peak Power, MW	201	203	185	179	206	209	211	211	202	194	201	206	211
	Average Power, MW	143	122	103	87	122	111	92	104	140	137	126	125	120
	Energy, 1000 MWH	106.6	90.4	76.9	65.1	90.5	82.7	68.4	77.2	103.9	101.7	93.4	92.8	1049.6
Garrison	Peak Power, MW	375	373	370	341	385	422	444	440	379	376	405	394	444
	Average Power, MW	283	214	196	230	286	270	308	302	333	302	271	269	277
	Energy, 1000 MWH	210.5	159.0	145.6	171.3	212.7	200.7	229.3	224.7	247.4	224.7	201.5	200.3	2427.7
Oahe	Peak Power, MW	683	699	657	643	662	711	707	698	650	651	687	690	711
	Average Power, MW	242	207	217	338	339	360	427	409	377	354	278	262	324
	Energy, 1000 MWH	180.3	154.4	161.8	251.2	251.9	267.7	317.3	304.1	280.3	263.5	207.2	194.6	2834.3
Big Bend	Peak Power, MW	532	530	483	473	482	503	508	513	485	499	524	546	546
	Average Power, MW	95	78	81	124	119	124	145	142	135	136	113	107	119
	Energy, 1000 MWH	70.3	58.1	60.5	92.2	88.6	92.5	108.1	105.8	100.5	101.1	83.8	79.3	1040.8
Fort Randall	Peak Power, MW	320	346	323	328	359	366	365	362	329	301	291	301	366
	Average Power, MW	116	104	162	219	229	258	278	272	269	257	190	124	211
	Energy, 1000 MWH	86.2	77.3	120.7	163.0	170.5	192.0	207.2	202.6	200.4	191.3	141.6	92.4	1845.0
Gavins Point	Peak Power, MW	81	79	111	112	112	111	111	113	115	115	115	83	115
	Average Power, MW	56	51	75	93	97	98	103	106	104	107	88	60	88
	Energy, 1000 MWH	42.0	38.2	55.7	69.1	72.0	73.1	76.5	78.9	77.5	79.9	65.2	44.9	772.9

Note: Each annual peak power value is the maximum of the 12 monthly values (based on average annual values for the 73-year modeling period).

Table A-14. Summary of Monthly and Annual Power Data for 2030 Depletion and Sedimentation Conditions (Partial Period).
(Based on average annual values for the 1930-2002 modeling period minus 1934-1942)

2030		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
System	Peak Power, MW	2194	2197	2097	2045	2173	2289	2311	2302	2129	2105	2190	2186	2311
	Average Power, MW	933	777	845	1094	1187	1219	1349	1319	1361	1300	1055	937	1136
	Energy, 1000 MWH	693.9	577.8	628.5	813.6	882.9	907.0	1003.5	981.1	1012.3	966.8	785.1	697.2	9949.7
Fort Peck	Peak Power, MW	202	204	186	180	206	209	211	211	203	194	201	206	211
	Average Power, MW	143	123	107	89	123	113	89	99	139	138	123	123	120
	Energy, 1000 MW	106.5	91.3	79.6	66.5	91.6	84.4	66.3	73.4	103.6	102.4	91.5	91.6	1048.7
Garrison	Peak Power, MW	376	375	370	341	386	423	446	442	380	377	407	396	446
	Average Power, MW	285	218	204	230	282	268	307	295	334	302	265	269	277
	Energy, 1000 MW	212.3	161.9	151.5	171.0	210.2	199.2	228.7	219.6	248.4	224.8	197.0	200.3	2424.9
Oahe	Peak Power, MW	681	698	656	643	662	711	707	698	649	651	685	688	711
	Average Power, MW	239	205	217	338	337	358	427	406	378	358	279	257	323
	Energy, 1000 MW	178.1	152.3	161.2	251.7	251.1	266.5	317.4	302.1	281.5	266.3	207.3	191.6	2827.1
Big Bend	Peak Power, MW	532	530	483	473	481	503	507	512	485	499	524	546	546
	Average Power, MW	93	77	81	124	119	124	145	141	136	137	113	105	119
	Energy, 1000 MW	69.5	57.4	60.4	92.3	88.3	92.2	108.0	105.1	101.1	102.3	84.0	78.2	1038.7
Fort Randall	Peak Power, MW	321	346	323	328	359	366	365	362	328	301	291	301	366
	Average Power, MW	115	103	162	219	228	258	278	272	269	257	189	123	210
	Energy, 1000 MW	85.7	76.9	120.3	163.0	170.0	191.8	206.7	202.3	200.3	191.3	140.5	91.1	1839.7
Gavins Point	Peak Power, MW	81	79	111	112	112	111	111	113	115	115	115	83	115
	Average Power, MW	56	51	75	93	97	98	103	106	104	107	87	60	88
	Energy, 1000 MW	41.7	38.0	55.6	69.0	71.9	73.0	76.3	78.7	77.4	79.8	64.7	44.3	770.5

Note: Each annual peak power value is the maximum of the 12 monthly values (based on average annual values for the 73-year modeling period).

Table A-15. Summary of Monthly and Annual Power Data for 2050 Depletion and Sedimentation Conditions (Partial Period).
(Based on average annual values for the 1930-2002 modeling period minus 1934-1942)

2050		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
System	Peak Power, MW	2203	2206	2105	2053	2180	2297	2319	2310	2136	2109	2195	2196	2319
	Average Power, MW	912	761	833	1090	1174	1212	1355	1336	1370	1314	1029	902	1128
	Energy, 1000 MWH	678.6	566.3	619.7	810.8	873.2	901.5	1008.4	994.2	1019.3	977.3	765.5	670.9	9885.5
Fort Peck	Peak Power, MW	202	204	186	180	207	210	211	211	203	194	202	207	211
	Average Power, MW	138	123	106	89	118	110	90	103	138	134	125	121	119
	Energy, 1000 MWH	102.5	91.3	79.1	66.0	88.0	81.9	67.1	76.6	103.0	99.9	93.1	89.9	1038.5
Garrison	Peak Power, MW	379	377	373	344	390	427	450	445	384	380	410	399	450
	Average Power, MW	284	215	195	228	278	268	315	308	331	301	260	269	276
	Energy, 1000 MWH	211.5	159.9	144.9	169.5	206.5	199.1	234.4	228.8	246.6	224.2	193.8	199.9	2419.0
Oahe	Peak Power, MW	686	703	661	647	666	715	711	703	654	654	688	692	715
	Average Power, MW	231	197	216	339	338	358	427	409	389	374	273	243	322
	Energy, 1000 MWH	172.2	146.7	160.7	252.2	251.3	266.3	318.0	304.0	289.2	278.0	202.8	181.0	2822.3
Big Bend	Peak Power, MW	531	529	483	473	481	502	507	512	486	500	524	546	546
	Average Power, MW	89	74	80	124	118	123	145	141	140	143	111	99	118
	Energy, 1000 MWH	66.6	54.8	59.9	91.9	87.6	91.5	107.6	105.0	103.8	106.7	82.3	73.3	1031.0
Fort Randall	Peak Power, MW	323	347	323	328	359	367	365	362	326	298	289	303	367
	Average Power, MW	114	102	161	218	227	256	276	271	268	254	177	114	207
	Energy, 1000 MWH	84.7	76.0	119.7	162.3	168.6	190.5	205.6	201.7	199.4	189.2	131.8	84.9	1814.7
Gavins Point	Peak Power, MW	80	79	111	112	112	111	111	113	115	115	115	83	115
	Average Power, MW	55	50	74	93	96	97	102	105	104	107	83	56	87
	Energy, 1000 MWH	41.1	37.5	55.4	68.9	71.1	72.2	75.7	78.1	77.2	79.2	61.8	41.8	760.1

Note: Each annual peak power value is the maximum of the 12 monthly values (based on average annual values for the 73-year modeling period).

Table A-16. Summary of Monthly and Annual Power Data for 2070 Depletion and Sedimentation Conditions (Partial Period).
(Based on average annual values for the 1930-2002 modeling period minus 1934-1942)

2070		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
System	Peak Power, MW	2218	2219	2118	2065	2193	2311	2331	2323	2150	2121	2204	2208	2331
	Average Power, MW	891	742	823	1093	1167	1223	1382	1346	1395	1347	1022	877	1130
	Energy, 1000 MWH	662.8	552.2	612.3	813.1	868.6	909.8	1028.3	1001.6	1037.7	1002.4	760.3	652.5	9901.6
Fort Peck	Peak Power, MW	203	205	187	181	208	210	212	212	203	195	203	207	212
	Average Power, MW	133	120	105	90	124	113	91	104	137	135	124	123	119
	Energy, 1000 MWH	98.9	89.1	78.2	67.2	92.0	83.7	68.0	77.4	101.8	100.4	92.0	91.7	1040.3
Garrison	Peak Power, MW	384	382	378	350	396	435	456	451	390	386	415	404	456
	Average Power, MW	280	214	185	231	269	273	320	305	334	312	263	272	277
	Energy, 1000 MWH	208.4	159.0	137.9	172.0	199.9	203.1	237.9	226.9	248.2	231.8	196.0	202.2	2423.3
Oahe	Peak Power, MW	692	711	667	653	672	721	718	710	661	660	693	698	721
	Average Power, MW	225	188	217	340	338	362	442	416	406	391	271	230	325
	Energy, 1000 MWH	167.1	140.2	161.6	252.9	251.7	269.2	329.1	309.2	301.9	291.0	201.7	170.9	2846.6
Big Bend	Peak Power, MW	530	528	483	472	480	501	504	511	487	500	524	545	545
	Average Power, MW	86	70	80	123	117	123	147	142	145	150	110	92	118
	Energy, 1000 MWH	63.9	52.0	59.6	91.4	86.8	91.6	109.7	105.8	107.8	111.3	81.8	68.7	1030.3
Fort Randall	Peak Power, MW	324	348	323	328	359	367	366	363	326	298	288	305	367
	Average Power, MW	113	101	161	216	225	256	280	274	270	254	172	107	206
	Energy, 1000 MWH	83.9	75.0	119.7	161.1	167.6	190.4	208.0	204.0	200.8	189.0	128.1	79.6	1807.1
Gavins Point	Peak Power, MW	80	79	111	112	112	111	111	113	115	115	116	83	116
	Average Power, MW	54	50	74	92	95	97	102	105	104	106	82	53	86
	Energy, 1000 MWH	40.5	36.9	55.3	68.5	70.6	71.8	75.7	78.2	77.3	78.8	60.8	39.5	753.9

Note: Each annual peak power value is the maximum of the 12 monthly values (based on average annual values for the 73-year modeling period).

Table A-17. Summary of Monthly and Annual Power Data for 2090 Depletion and Sedimentation Conditions (Partial Period).
(Based on average annual values for the 1930-2002 modeling period minus 1934-1942)

2090		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
System	Peak Power, MW	2224	2224	2123	2070	2199	2317	2339	2331	2157	2124	2207	2214	2339
	Average Power, MW	865	729	814	1090	1151	1231	1392	1352	1421	1371	1011	839	1127
	Energy, 1000 MWH	643.9	542.6	605.8	811.3	856.0	915.9	1035.8	1005.8	1057.5	1019.7	752.0	624.6	9871.0
Fort Peck	Peak Power, MW	204	206	188	181	208	211	212	212	204	195	203	208	212
	Average Power, MW	130	118	104	95	126	117	97	107	131	132	125	121	119
	Energy, 1000 MWH	96.5	87.9	77.7	70.4	93.5	86.9	72.5	79.3	97.4	97.8	93.1	90.0	1043.0
Garrison	Peak Power, MW	385	383	379	351	399	439	460	455	393	388	417	406	460
	Average Power, MW	280	217	182	228	261	274	323	310	334	314	263	270	277
	Energy, 1000 MWH	208.0	161.7	135.7	169.7	194.1	203.9	240.2	230.3	248.5	233.5	196.0	201.0	2422.5
Oahe	Peak Power, MW	695	714	671	657	675	724	721	713	666	662	693	699	724
	Average Power, MW	213	180	215	340	334	366	444	415	429	411	270	213	325
	Energy, 1000 MWH	158.7	134.1	160.0	253.0	248.7	272.2	330.1	308.9	319.0	305.6	200.5	158.6	2849.5
Big Bend	Peak Power, MW	529	528	483	471	479	500	504	513	488	500	524	545	545
	Average Power, MW	81	66	79	122	114	123	147	142	153	157	109	85	117
	Energy, 1000 MWH	60.3	49.5	58.9	90.7	85.1	91.6	109.6	105.8	113.9	117.0	81.4	63.5	1027.3
Fort Randall	Peak Power, MW	327	348	323	328	360	368	366	362	324	296	288	307	368
	Average Power, MW	109	99	159	214	222	256	280	274	271	252	165	100	204
	Energy, 1000 MWH	81.2	73.4	118.6	159.5	165.1	190.3	208.1	203.8	201.6	187.7	122.7	74.2	1786.1
Gavins Point	Peak Power, MW	80	79	111	112	112	111	111	113	115	115	116	83	116
	Average Power, MW	53	49	74	91	93	96	101	105	104	105	78	50	85
	Energy, 1000 MWH	39.2	36.2	55.0	68.0	69.5	71.1	75.3	77.8	77.1	78.0	58.2	37.2	742.5

Note: Each annual peak power value is the maximum of the 12 monthly values (based on average annual values for the 73-year modeling period).

Table A-18. Summary of Monthly and Annual Power Data for 2110 Depletion and Sedimentation Conditions (Partial Period).
(Based on average annual values for the 1930-2002 modeling period minus 1934-1942)

2110

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
System	Peak Power, MW	2229	2229	2128	2075	2204	2324	2345	2337	2161	2127	2210	2218	2345
	Average Power, MW	841	703	807	1079	1151	1219	1410	1354	1452	1384	1002	813	1122
	Energy, 1000 MWH	625.6	523.0	600.5	803.1	856.7	906.7	1048.7	1007.5	1080.4	1029.7	745.5	604.8	9832.1
Fort Peck	Peak Power, MW	204	207	189	183	209	211	213	212	204	196	204	208	213
	Average Power, MW	127	116	107	96	128	115	99	108	133	130	123	121	119
	Energy, 1000 MWH	94.1	86.4	79.5	71.3	95.2	85.4	73.8	80.3	98.9	96.8	91.2	89.7	1042.4
Garrison	Peak Power, MW	389	386	382	353	403	443	464	458	397	392	422	410	464
	Average Power, MW	281	221	184	222	262	274	334	307	332	306	260	275	277
	Energy, 1000 MWH	209.0	164.1	137.1	165.5	194.6	204.1	248.6	228.2	247.3	227.9	193.7	204.3	2424.6
Oahe	Peak Power, MW	694	715	672	658	676	726	723	716	666	661	690	697	726
	Average Power, MW	201	166	210	337	334	361	449	417	449	429	274	198	325
	Energy, 1000 MWH	149.6	123.2	156.5	250.6	248.1	268.2	333.8	310.5	334.0	319.4	203.5	147.1	2844.7
Big Bend	Peak Power, MW	528	527	483	471	478	501	504	512	488	500	524	545	545
	Average Power, MW	76	61	77	120	114	121	148	142	160	165	111	79	117
	Energy, 1000 MWH	56.6	45.5	57.4	89.6	84.7	90.2	110.4	105.8	119.2	122.7	82.9	58.9	1023.9
Fort Randall	Peak Power, MW	329	349	323	329	360	367	366	362	324	294	288	309	367
	Average Power, MW	105	93	156	213	222	253	279	275	274	250	159	94	201
	Energy, 1000 MWH	78.3	69.2	115.9	158.3	164.9	188.3	207.2	204.9	203.6	185.8	118.0	69.7	1764.3
Gavins Point	Peak Power, MW	80	79	111	112	112	111	111	113	115	115	116	83	116
	Average Power, MW	51	46	73	91	93	95	101	104	104	104	76	47	84
	Energy, 1000 MWH	37.8	34.6	54.0	67.8	69.2	70.4	74.9	77.7	77.3	77.1	56.2	35.2	732.2

Note: Each annual peak power value is the maximum of the 12 monthly values (based on average annual values for the 73-year modeling period).