Red River Valley Water Supply Project

Analysis of Missouri River Effects

Missouri River Basin Water Management Division
Northwestern Division
Corps of Engineers

September 2006

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EXECUTIVE SUMMARY

Future depletions of water from the Missouri River are going to affect the amount of water that moves through the Missouri River Mainstem Reservoir System (Mainstem Reservoir System). One such potential depletion of water could be through a trans-basin diversion to the Red River Valley in North Dakota and Minnesota. The U.S. Department of Interior, Bureau of Reclamation (Reclamation) recently completed a Draft Environmental Impact Statement (DEIS) on the Red River Valley Water Supply Project (RRVWSP) with several cooperating agencies, including the U.S. Army Corps of Engineers (Corps).

For the DEIS, an analysis of the effects of the diversion of water to the Red River Valley for the RRVWSP on Missouri River flows, reservoir levels, and impacts to the various economic uses and environmental resources was completed on a 73-year period of analysis (1930-2002). The focus of the analysis for the Corps' assistance was on the average annual effects over the entire period of analysis for a set of 2002 depletion conditions, 2050 depletion conditions, and two RRVWSP alternatives, each with two levels of water use, or scenarios.

Following the coordination of the DEIS with the Tribes, Federal and State agencies, and interested public, Reclamation asked the Corps to conduct another analysis of the effects of water withdrawals from two Missouri River sites for three alternatives to be included in the array of alternatives to be presented in its Supplemental DEIS (SDEIS) for the RRVWSP. The full period of analysis would be the same; however, emphasis would be placed on analyzing the effects of the water withdrawals during a drought like that of the 1930s (1930-1941). This focus was selected because the modeling conducted by the Corps was set up such that the forecasted volume of water was used in each year of the modeling period, which is not very likely. A repeat of the 1930s drought is the most likely situation where this forecasted volume of water would be used each year. Historically, the Red River Valley experienced a coincidental drought during the same period that the Missouri River Basin experienced this drought.

The Corps followed the same basic process used in the initial analysis for Reclamation in that its Daily Routing Model was used to develop hydrologic, hydropower, and navigation data for use in the economic and environmental impacts models developed for it Missouri River Master Water Control and Update Study (Master Manual Study). Several additional analyses using various modeling techniques were also completed to address what the Corps considered to be special concern by interests in the Missouri River Basin.

The Corps was asked to analyze three alternatives for providing water to the Red River Valley during drought periods from two locations on the Missouri River. These three alternatives withdrew water from either Lake Sakakawea or from Missouri River just downstream from Bismarck, North Dakota. The volume of water for these alternatives ranged from about 60,000 acre-feet per year to just over 80,000 acre-feet per year. Two additional simulations were conducted. The first was for current conditions under the water control plan in the 2004 Revision of the Missouri River Master Water Control Manual, and the second simulation was for 2050 conditions in the Missouri River Basin, which includes increased depletions of 557,500 acre-feet over current conditions. This second simulation represents the No Action alternative for the Red River Valley Water Supply Project analysis of the three alternatives withdrawing water from the Missouri River.

In general, most of the effects of the water withdrawals to the Red River Valley for the RRVWSP are relatively small because the volume of water to be withdrawn is small. Even though the current conditions model simulation determined that there would be 1 non-navigation year, the additional 557,500 acre-feet of forecasted Missouri River Basin depletions between 2002 and 2050 resulted in a second non-navigation year. Adding an additional up to 80,000 acre-feet of Missouri River withdrawal for the Red River Valley did not add a third non-navigation year during the 1930s drought; therefore, the effects of the No Action alternative and the three alternatives diverting Missouri River water to the Red River Valley on Missouri River Basin uses and resources are very similar except for a relatively large reduction in riverine tern and plover habitat. Ongoing requirements and efforts to create additional tern and plover habitat are factors that reduce the negative aspect of this loss of habitat due to Missouri River regulation and flow impacts.

INTRODUCTION

The U.S. Department of Interior, Bureau of Reclamation (Reclamation) and the State of North Dakota were tasked to "jointly prepare and complete a draft environmental impact statement concerning all feasible options to meet the comprehensive water quality and quantity needs of the Red River Valley and the options for meeting those needs including delivery of water from the Missouri River to the Red River Valley…" (Section 8(C)(2)(A) of the Dakota Water Resources Act of 2000). For this Draft Environmental Impact Statement (DEIS), Reclamation requested the assistance of the U.S. Army Corps of Engineers (Corps) to analyze the effects of some of the options for delivery of water from the Missouri River on Missouri River uses and resources. A report was submitted by the Corps to Reclamation in August 2005 that evaluated the average annual effects for a repeat of the period 1930-2002 for two alternatives with two forecasted water use scenarios under current (2002) Missouri River depletion levels and 2050 depletion levels. The data in the report were used for the DEIS that was released for public review in December 2005.

Following the DEIS, Reclamation asked the Corps again for assistance as it initiated efforts to prepare a Supplemental Draft Environmental Impact Statement (SDEIS) for the Red River Valley Water Supply Project (RRVWSP). For this second effort, Reclamation requested an analysis of three alternatives that would withdraw water from the Missouri River for transfer to the Red River Valley. It also requested that the analysis of effects focus on a repeat of the drought of the 1930s (1930-1941) with some analysis provided for the full period of analysis of 1930-2002. To provide a basis for comparison, two additional model simulations of alternatives were completed. These two alternatives included Current conditions (2002) for the Corps Missouri River Master Water Control Manual Water Control Plan and No Action (includes an additional 402,200 acre-feet of Missouri River Basin depletions between 2002 and 2050 under the same Water Control Plan).

The analysis of the withdrawals on Missouri River uses and resources relied on the models developed for the Missouri River Master Manual Review and Update Environmental Impact Statement (Master Manual EIS) completed by the Corps in March 2004. These models included the Daily Routing Model (hydrologic, hydropower, and navigation outputs) and the many economic use and environmental resource models developed for the Master Manual EIS. The Corps' August 2005 report entitled "Red River Valley Water Supply Project – Effects of Alternatives Depleting Water from the Missouri River on Missouri River Uses and Resources" summarizes many of these models. Additional models used for this report that were not summarized in that report will be discussed in some detail in this report.

MISSOURI RIVER AFFECTED ENVIRONMENT

Chapter 3 of the Master Manual EIS is entitled "Description of Existing Environment". This chapter provides all of the necessary information on the Missouri River affected environment for the RRVWSP SDEIS.

SUMMARY OF ALTERNATIVES ANALYZED

A base simulation of the current water control plan for the Missouri River was completed for the RRVWSP to provide the basis for current conditions on the Missouri River. This simulation was completed using the revised Missouri River Basin depletions computed by Reclamation based on the 2002 level of water development within the Missouri River Basin. These depletions were down slightly from those used in the Daily Routing Model for the Master Manual EIS to reflect the water use changes that have occurred in the basin since the previous depletions analysis was completed in 1987. For the RRVWSP analysis, the base simulation will be referred to as Current conditions.

A second simulation was run with an additional 557,500 acre-feet of Missouri River depletions forecasted between 2002 and 2050. This alternative is referred to as No Action in the RRVWSP SDEIS. This alternative will be used to provide a basis for

presenting the relative effects of the three SDEIS alternatives that would use Missouri River water to partially meet the forecasted 2050 water needs in the Red River Valley.

The three alternatives that would withdraw water from the Missouri River to be included in the array of alternatives to No Action in the RRVWSP Supplemental are summarized in Table 1. Because these alternatives' effects would be compared to the No Action alternative that represents 2050 conditions, they were modeled with their respective depletion amount plus the 557,500 acre-feet of forecasted Missouri River in-basin depletions.

Table 1. Missouri River source alternatives evaluated for the RRVWSP SDEIS.

Alternative	Report Acronym	Withdrawal Location	Volume of Water Diverted Annually*
Garrison Diversion Unit Import Pipeline	GDUIP	Lake Sakakawea	59,777 acre-feet
Missouri River to Red River Import Pipeline	MRRRIP	Downstream from Bismarck, ND	62,622 acre-feet
Garrison Diversion Unit Import to Sheyenne River	GDUISR	Lake Sakakawea	80,239 acre-feet

* All three alternatives were modeled under 2050 conditions, which included an additional 557,500 acre-feet of depleted water due to actions within the Missouri River Basin from current conditions (2002) plus the listed amount for each RRVWSP alternative. Depletion numbers were provided to the Corps with a monthly breakdown, with the basis for these depletion numbers by Reclamation included in its SDEIS.

COMPARATIVE ANALYSIS OF THE EFFECTS OF THE RRVWSP ALTERNATIVES

The results of the comparative analysis of RRVWSP alternatives on Missouri River uses and resources are initially presented on an individual use or resource basis. A summary table will be provided at the end of the report that provides some perspective on the overall impacts among the alternatives for all of the uses and resources. Results from two periods of analysis are discussed. To provide some additional perspective relative to the values presented on the Missouri River uses and resources in the DEIS, data will be presented on the total 1930-2002 simulation period. However, as stated on page 3 of the "Executive Summary, Draft Environmental Impact Statement, Red River Valley Water Supply Project", the primary focus of the Corps' analysis will be "on impacts that would occur during a drought similar to that of the 1930s." Also, most of the comparisons for the SDEIS will be among the No Action and the three RRVWSP SDEIS alternatives that rely on the Missouri River as their source of water to divert to the Red River Valley. For this section of the report, these four alternatives will commonly be referred to as the 2050 RRVWSP SDEIS alternatives.

HYDROLOGIC EFFECTS

Before addressing the uses and resources that were evaluated, some data on the hydrologic outputs from the Daily Routing Model are appropriate to provide some perspective on how the Current modeling results completed for the RRVWSP compare to that conducted for the Corps' Master Manual EIS. This section also discusses how the Current modeling results compare to the hydrologic modeling for the four 2050 RRVWSP SDEIS alternatives and how the No Action alternative's hydrology compares to the other three 2050 RRVWSP SDEIS alternatives.

Figure 1 presents the total Missouri River Mainstem System storage levels during the drought of the 1930s and the subsequent 2 years of the recovery period. This figure shows that the amount of water in storage for a repeat of the 1930s drought is less for the Corps' Master Manual EIS simulation. This results because the total Missouri River depletion amounts are greater for the Master Manual EIS simulation than they are for the RRVWSP Current simulation. The Missouri River Master Manual used data that was updated to 1987 while the RRVWSP used data updated to 2002. The present-level depletions for 2002 were actually less than those found for 1987. The difference reflects the water use changes that have occurred in the basin since this previous depletions analysis. These changes were due to decreases in withdrawals for irrigation between 1987 and 2002. This is important in that the effects identified for the RRVWSP Current simulation will be different than those shown for the same drought period in the Master Manual EIS studies. One notable difference is the number of non-navigation years, with the Master Manual simulation having 4 years when the Mainstem System storage is less than 31 million acre-feet (MAF) on March 15 (1935, 1937, 1938, 1941) and the RRVWSP Current simulation having only 1 non-navigation year (1937).

Figure 2 shows the total Missouri River System storage levels for the RRVWSP Current conditions and the four 2050 RRVWSP SDEIS alternatives (No Action and three Missouri River source alternatives) over the same 15-year period as shown in Figure 1. This second storage plot shows that the differences between the Current conditions and the No Action alternative are considerably less than the differences shown in Figure 1. This indicates that the difference in depletion amounts between those used for the Corps' Master Manual EIS and the RRVWSP modeling are considerably more than the 557,500 acre-feet difference between the Current and No Action values. In fact, the storage differences among the three Missouri River water use alternatives are less than the thickness of the line in the figure for the Current values.

Figure 3 shows the differences in the amount of water in System storage for each of the three RRVWSP Missouri River water use alternatives and the No Action alternative (zero line on the plot). It shows that the differences range from an initial value of zero to about 400,000 acre feet by the end of 1941 for the GDUIP alternative (Import alternative) that uses about 60,000 acre-feet per year to about 500,000 acre-feet for the GDUISR alternative (Import to the Sheyenne River alternative) that uses about 80,000 acre-feet per

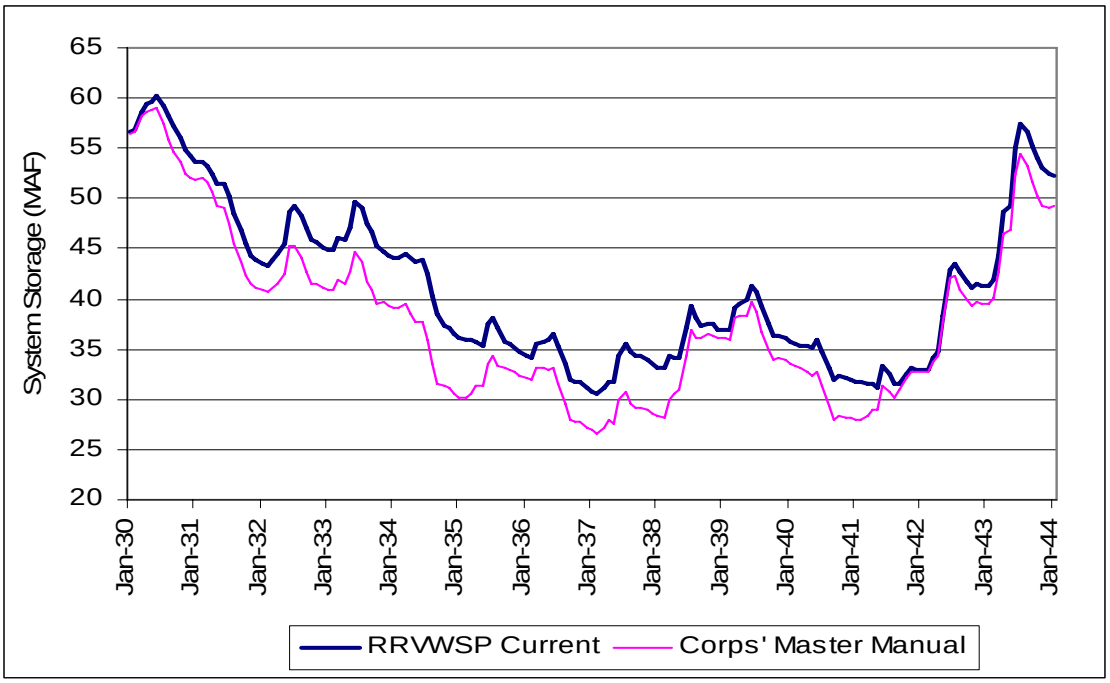

Figure 1. Comparison of the RRVWSP Current simulation storage levels for a repeat of the drought of the 1930s and subsequent recovery period with the Corps' Master Manual EIS simulation storage levels during the same period.

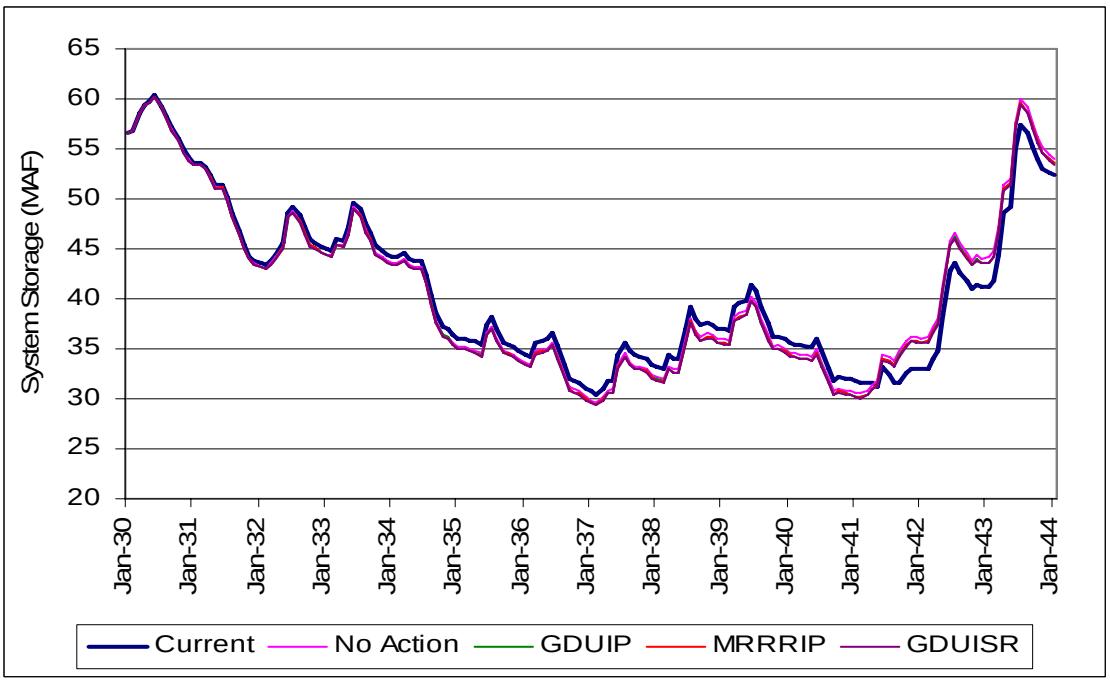

Figure 2. Comparison of the RRVWSP Current simulation storage levels for a repeat of the drought of the 1930s and subsequent recovery period with those of the 2050 RRVWSP SDEIS alternatives simulation storage levels during the same period.

year. The model incorporates these higher depletion values into the regulation decisions following the Master Manual criteria, but the change in storage is less than the accumulated depletion amounts. For example, the GDUISR alternative uses just over 80,000 acre-feet per year more than the No Action alternative, which equates to about 1,000,000 acre-feet over 12 years, but the storage difference is slightly less than 500,000 acre-feet by the end of 1941, the twelfth year of the 1930s drought. The drought conservation criteria of the Corps' Master Manual Water Control Plan save the difference, about 50 percent of the use during that 12-year period. This is reflected primarily in navigation season lengths between the No Action and GDUISR alternatives. To provide some perspective on reservoir-related impacts, the maximum approximated 500,000 acre-feet difference from the No Action alternative equates to a stage difference of around 1 foot in the upper three reservoirs on March 1, when System storage is balanced among these reservoirs during a drought.

One final factor needs to be discussed before going into the Missouri River use and resource impacts. The Current conditions simulation has 1 non-navigation year; however, the No Action and other three 2050 RRVWSP SDEIS alternatives have 2 non-navigation years. This would lead one to believe up front before any of the analyses are even completed that the differences between the No Action and each of the three RRVWSP alternatives will, therefore, be very small, with the differences being related to relatively small differences in the navigation season lengths for the Lower Missouri River downstream from the Missouri River Mainstem Reservoir System and the differences in the reservoir reaches being related to the relatively small differences in the amount of water stored in the System and reservoir level changes among the alternatives.

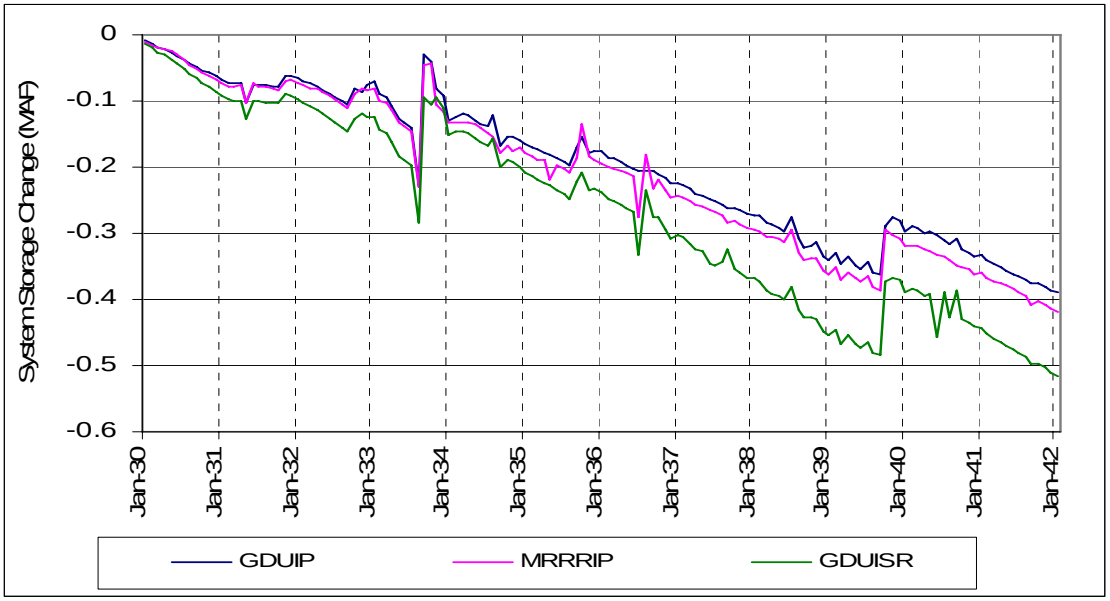

Figure 3. Differences between the No Action alternative and the other three 2050 RRVWSP SDEIS alternatives relying on Missouri River water in terms of the amount of water stored in the Missouri River Mainstem Reservoir System.

FLOOD CONTROL

Flood control benefits were computed for the riverine reaches from Fort Peck Dam to the mouth of the Missouri River and the four largest reservoirs on the Mainstem Reservoir System. Average annual benefits are presented in Table 2 for both the 1930-1941 and 1930-2002 periods of analysis for the Current conditions and four 2050 RRVWSP SDEIS alternatives. Table 2 includes some aggregation of the reach data. Figure 4 includes the average annual total flood control benefits for the Current, No Action, and three other 2050 RRVWSP SDEIS alternatives. Annual values for the five simulations for the 1930-1941 period of analysis are presented in Figure 5.

Three conclusions can be drawn from the data presented in Table 2. First, the average annual flood damages that would have happened had the Mainstem Reservoir System not been in place in the river reaches were lower for the 1930s drought period of 1930-1941 than for the full period of analysis of 1930-2002. Second, the differences for the total column among the four 2050 RRVWSP SDEIS alternatives are only $0.02 million for the 1930's drought, which is equivalent to a percentage change of 0.01 percent. The differences among the alternatives for the full period of analysis from 1930 to 2002 are a little larger in magnitude at from -$0.03 million to $0.19 million, which represent a percentage change of -0.01 to 0.50 percent. Third, the changes among the four 2005 RRVWSP SDEIS alternatives in the 1930s drought were on the two river reaches while the changes for the full period of analysis were on all three sub-reaches included in Table 2.

Table 2 and Figure 4 show that the future depletions will generally increase the flood control benefits for a repeat of the 1930s drought. The table shows the same would also be true for the full period of analysis from 1930 to 2002. Figure 5 shows that the flood control benefits range annually from no benefits to over $650 million a year; however, there is essentially no difference among the four 2050 RRVWSP SDEIS alternatives in all years.

Table 2. Average Annual Flood Control Benefits ($ million).

	Total	Reservoirs	Upper River	Lower River
		1930-1941		
Current	167.08	0.00	64.51	102.57
No Action	167.27	0.00	64.54	102.73
GDUIP	167.25	0.00	64.51	102.74
MRRRIP	167.25	0.00	64.51	102.74
GDUISR	167.25	0.00	64.51	102.74
		1930-2002		
Current	426.56	-0.64	91.75	335.46
No Action	427.31	-0.65	91.75	336.21
GDUIP	427.28	-0.64	91.66	336.26
MRRRIP	427.50	-0.63	91.76	336.37
GDUISR	427.42	-0.62	91.76	336.28

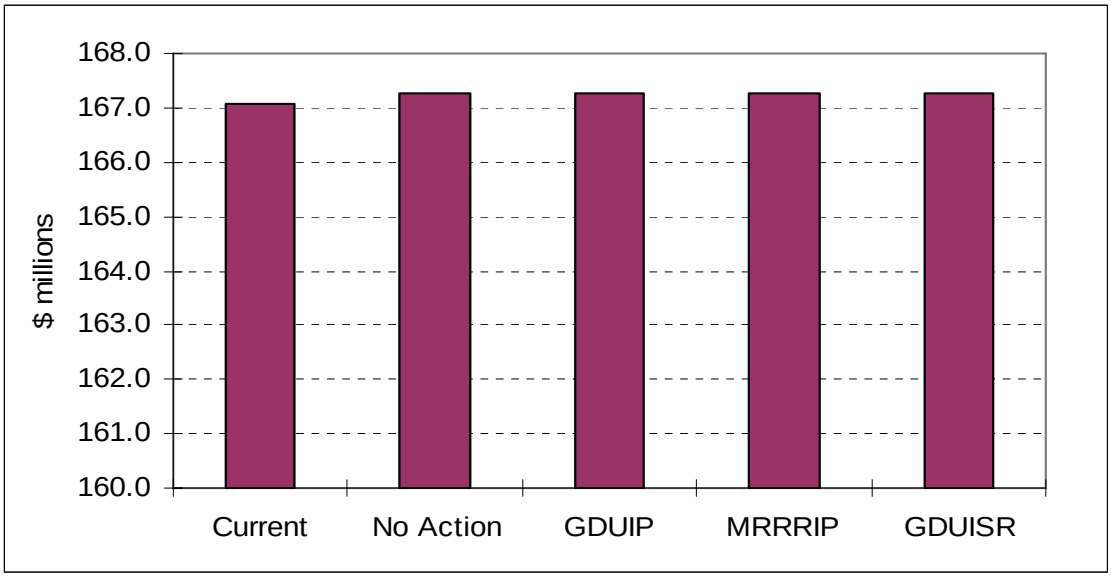

Figure 4. Average annual total flood control benefits, 1930-1941.

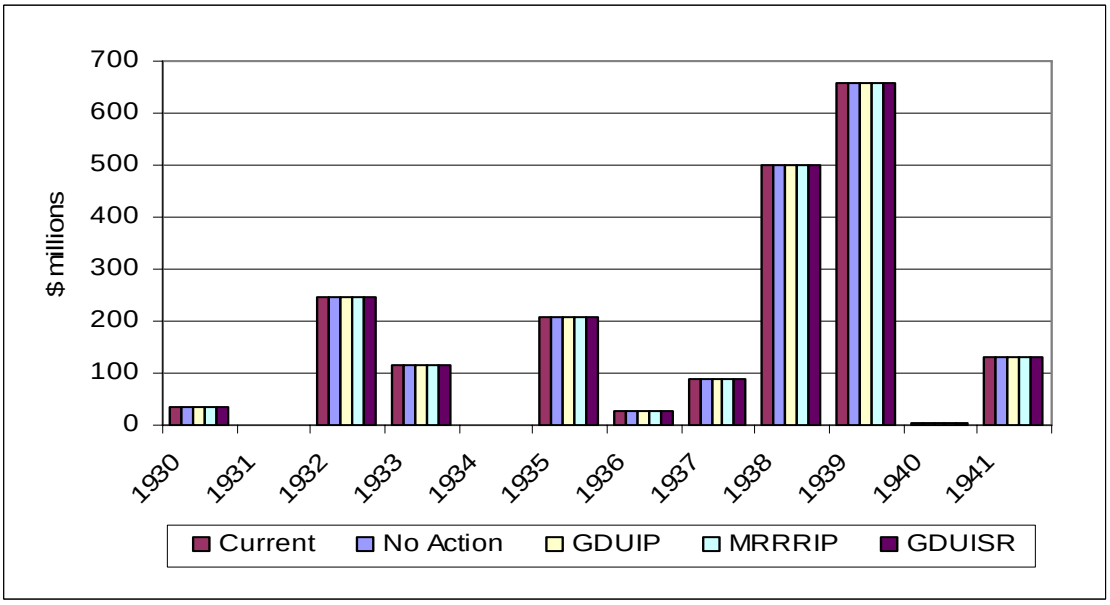

Figure 5. Annual total flood control benefits, 1930-1941.

MISSOURI RIVER NAVIGATION

Navigation occurs on the Missouri River from Sioux City, Iowa to the mouth near St. Louis, Missouri. The average annual total navigation benefits for both periods of analysis are presented in Table 3. Figure 6 includes the total average annual values for the Current conditions and the four 2050 RRVWSP SDEIS alternatives for the 1930-1941 period. Annual values for the Current conditions and the four 2050 RRVWSP SDEIS alternatives for the 1930-1941 period of analysis are presented in Figure 7.

Table 3. Average Annual Total Missouri River Navigation Benefits ($ millions).

	1930-1941	1930-2002
Current	1.76	8.57
No Action	2.07	8.54
GDUIP	2.08	8.55
MRRRIP	2.07	8.55
GDUISR	2.07	8.55

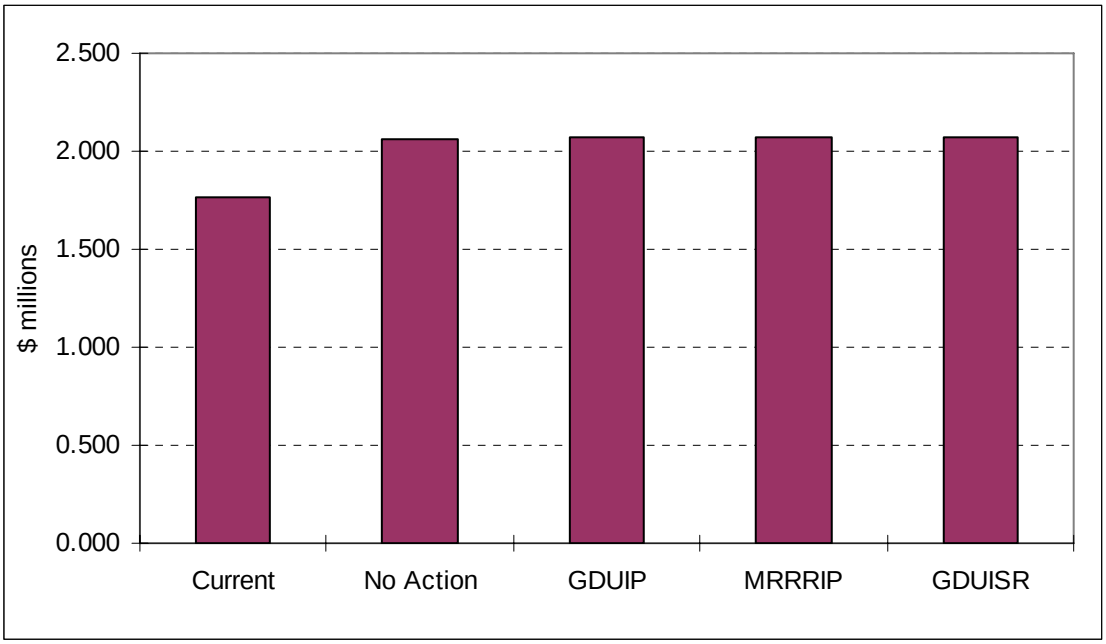

Figure 6. Average annual total Missouri River navigation benefits, 1930-1941.

Table 3 and Figure 6 show that the navigation benefits go up from the lower value for the Current conditions for the four 2050 RRVWSP SDEIS alternatives. This increase is due to the additional non-navigation year (for a total of 2 non-navigation years in all four RRVWSP SDEIS alternatives) that occurs in 1941 for these four alternatives, based on the Daily Routing Modeling assumptions used in the RRVWSP analysis of Missouri River effects. This additional non-navigation year results in an additional approximately $0.3 million of average annual navigation benefits on the Missouri River over the 12-year drought period for all four of the 2050 RRVWSP SDEIS alternatives. The major portion of these additional benefits occurs in 1941, as shown in Figure 7, for these three alternatives. This is due to the assumption that there would be no navigation operations and maintenance costs on the Missouri River navigation channel in a non-navigation year. These costs are usually to repair any damage to the ends of structures that may have occurred during and after the previous year's navigation season, and they would not occur if no navigation is anticipated in a given year. Also, flows may not be adequate to allow the equipment to work from barges in the channel as the flows would drop to those

required for water supply and thermal powerplant cooling in the non-navigation year. The total benefits drop below zero in some of the minimum navigation service years, also as shown in Figure 7, due to the fact that the operations and maintenance costs assumed in the economic computations equal or exceed the direct navigation benefits in minimum service years. The shorter the navigation season is, the greater the likelihood that these costs will exceed the direct benefits. The annual Missouri River navigation benefits in a full service year, whether 8 or 8.33 months in length, are over $15 million, as shown in Figure 7 in 1930.

Navigation benefits for the four 2050 RRVWSP SDEIS alternatives are essentially the same, as shown in both Table 3 and Figure 6. When percent changes are computed, they range from 0.39 to 0.54 percent greater for the three alternatives using Missouri River water as a supplemental source when compared to value for the No Action alternative.

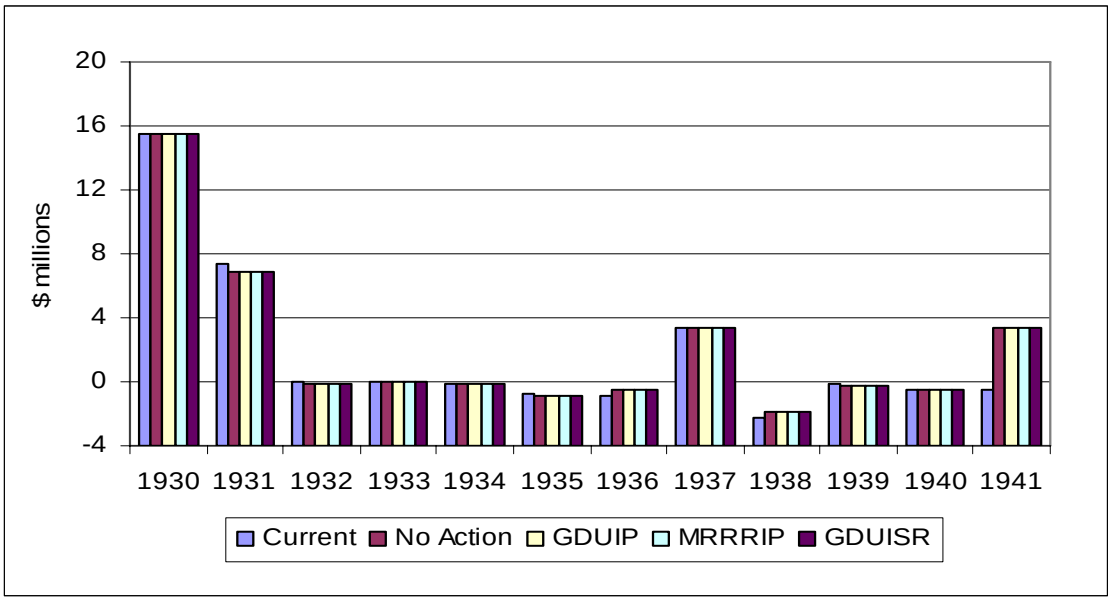

Figure 7. Annual total Missouri River navigation benefits, 1930-1941.

Table 4 presents the Missouri River navigation season lengths for the 12 years of the 1930s drought. Increases in the annual water use of the four 2050 RRVWSP SDEIS alternatives result in a relatively small reduction of navigation season length, as evidenced by the shorter season lengths in most years and the total number of months navigation is provided over the entire period. To better understand what the effect is on season length, Figure 8 was prepared. Using the summed monthly data from Table 4 and an average of 30.5 days in a navigation season month, this figure shows that there is a very good relationship between the total number of days of navigation in the 12-year period and the amount of water use, or Missouri River depletion, of the four 2050 RRVWSP SDEIS alternatives. The slope of the line equates to a reduction of approximately 92 days of navigation season length for every million acre-feet of depletions over the 12-year period for an increase of water use over 557,500 acre-feet (0.56 million acre-feet) resulting from the three RRVWSP SDEIS alternatives using Missouri River water as a supplemental source during extended droughts like that of the

1930s. Since only a fraction of a million acre-feet of water is used by each of the three alternatives, the effect on navigation season length is less than an average of about 2 days every 3 years over the 12 year period (maximum effect = 92 X 0.08 X 1/12 = 0.64).

Table 4. Missouri River Navigation Season Lengths (months).

	Current	No Action	GDUIP	MRRRIP	GDUISR
1930	8	8	8	8	8
1931	7.99	7.94	7.92	7.92	7.91
1932	7.4	7.32	7.3	7.3	7.29
1933	7.62	7.5	7.48	7.47	7.46
1934	7	7	7	7	7
1935	6.25	6.06	6.02	6.02	6.01
1936	6.07	6	6	6	6
1937	0	0	0	0	0
1938	6.16	6	6	6	6
1939	7	6.83	6.76	6.76	6.73
1940	6	6	6	6	6
1941	6	0	0	0	0

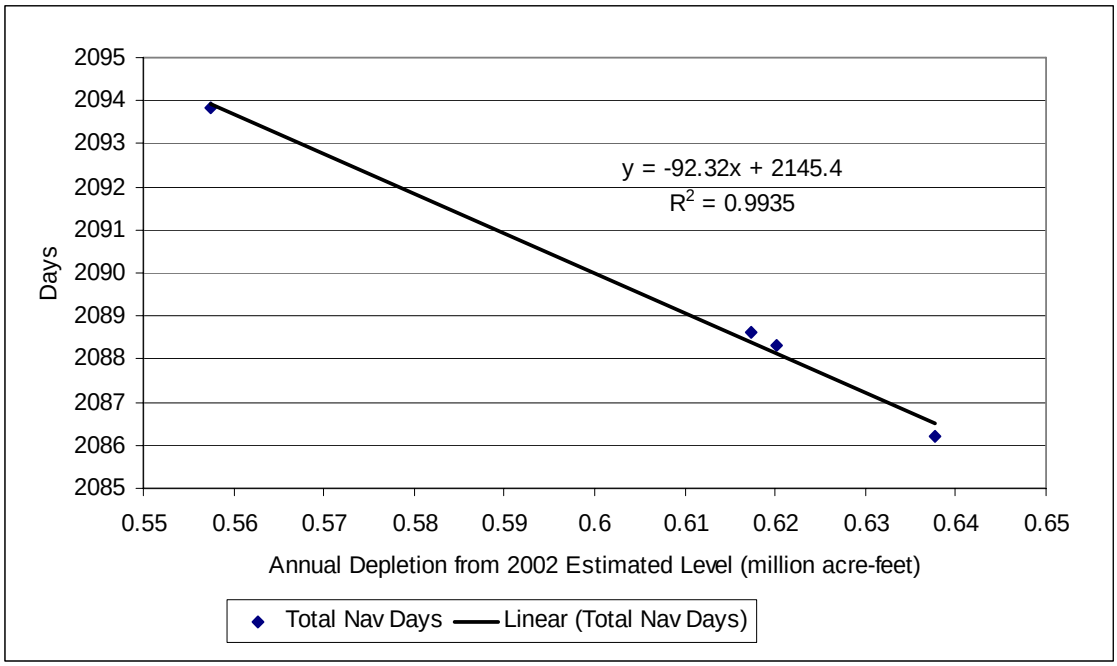

Figure 8. Number of navigation days in the 12-year period from 1930 to 1941 versus the amount of depletions for four 2050 RRVWSP SDEIS alternatives.

MISSISSIPPI RIVER NAVIGATION

Releases from Gavins Point Dam are essentially the same for all four 2050 RRVWSP SDEIS alternatives during the 1930s drought as evidenced by the change of Missouri

River navigation season lengths presented in Table 4. When the season lengths of the No Action alternative and the three 2050 RRVWSP SDEIS alternatives are compared, the three alternatives would reduce the season length for 1 day up to 3 days on the Missouri River in 5 years (1931 [1], 1932 [1], 1933 [1], 1935 [2], and 1939 [3]). The rest of each of those 5 years would have similar flows until the release reductions were started from 1 to 3 days earlier leading up to the end of the navigation season on the Missouri River. This translates to the reduction of available water on the Missouri and Mississippi Rivers as water is transferred to the Red River Valley, affecting Mississippi River flows only 8 days out of a 12-year period from 1930 to 1942 (a total of 4,383 days).

Navigation on the Mississippi River would be most severely affected by the 3 days of lower flows from the Missouri River in 1939 because that was the most severe year for increased Mississippi River navigation efficiency costs in the 1930s drought. The reduction of the navigation flows on the Mississippi River of up to 6,000 cubic feet per second over the 3 days would occur when the stages at St. Louis, Missouri are approximately -2 feet, which means that the 6,000 cfs could reduce the stage by less than 1 foot over the 3-day period. The amount of tonnage loaded on the barges would likely be unaffected, and it appears that the tow size may also be unaffected. If these were both the case, the economic impact for the up to 3-day difference in navigation season length in 1939 would be zero. If tow size were affected, the tow size difference would be between 20 barges and 16 barges, which would add some efficiency cost for Mississippi River navigation of $37,000 per day, or about $100,000. These costs would be for the shallow draft movement between St. Louis and Cairo, Illinois. Additional costs may accrue for the movement from Cairo to a deep draft port. If deep draft navigation were affected, some additional costs may also accrue. Overall, however, the costs are likely less than $1 million, which is extremely small when one considers that the annual Mississippi River shallow draft navigation benefits are about $2 billion.

HYDROPOWER

Economic Modeling Benefits

Hydropower is generated at all of the six dams forming the Mainstem Reservoir System on the Missouri River. During drought, generation at all six dams is reduced by either lower releases from the dams only, as is the case for the three smaller, downstream reservoirs (Lewis and Clark Lake, Lake Francis Case, and Lake Sharpe), or by reduced releases and lower reservoir levels, as is the case at the three larger, upstream reservoirs (Lake Oahe, Lake Sakakawea, and Fort Peck Lake). Reductions in the amount of water in Mainstem Reservoir System storage by actions that increase depletions, such as transport of water to the Red River Valley during an extended drought, could have an adverse effect on hydropower. Table 5 presents the hydropower economic benefits in terms of National Economic Development (NED) dollars for both periods of analysis. Figure 9 shows the total 1930s drought values graphically. This figure includes the total average annual values for the four 2050 RRVWSP SDEIS alternatives and the Current (2002) conditions. Annual values for the four RRVWSP SDEIS alternatives at 2050 conditions for the 1930-1941 period of analysis are presented in Figure 10.

Table 5. Average annual hydropower benefits ($ millions).

	Total	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point
				1930-1941			
Current	555.6	49.6	102.7	157.5	109.2	100.1	36.5
No Action	548.2	48.8	101.0	154.8	108.4	99.1	36.0
GDUIP	547.1	48.8	100.3	154.7	108.4	99.0	36.0
MRRRIP	547.3	48.8	100.5	154.6	108.4	99.0	36.0
GDUISR	546.8	48.7	100.0	154.7	108.4	99.0	36.0
				1930-2002			
Current	658.5	63.7	137.8	193.9	113.2	110.2	39.7
No Action	655.7	63.1	136.9	193.2	112.9	110.0	39.6
GDUIP	654.5	63.0	136.3	192.8	112.8	109.9	39.6
MRRRIP	654.7	63.0	136.7	192.7	112.9	109.9	39.6
GDUISR	654.2	63.1	136.3	192.5	112.9	109.8	39.6

Both Table 5 and Figure 9 show that the in-basin combined with the out-of-basin depletions of the four 2050 RRVWSP SDEIS alternatives have an adverse impact on hydropower NED benefits. When compared to the hydropower benefits for the No Action alternative, the losses for the increased depletions of the other three 2050 RRVWSP SDEIS alternatives during the 1930s drought are estimated to be $0.9 million to $1.4 million per year. These losses equate to 0.17 to 0.26 percent change from the benefits of the No Action alternative. For the full, 73-year period of analysis, the differences are somewhat smaller; however, they follow the same basic pattern, as the depletions increase, the total hydropower benefits decrease.

Figure 10 shows the annual values and that the hydropower benefits decline through the first 7 years of the drought as Mainstem System storage declines but increase before decreasing again after 1937, which would be a non-navigation year, which would cause Mainstem System storage to increase in 1938.

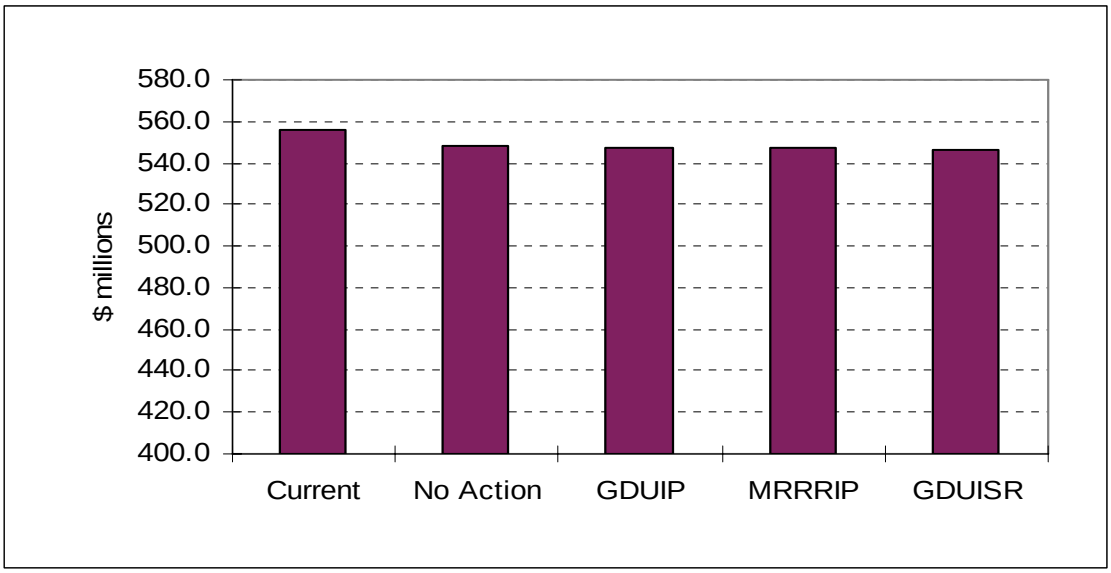

Figure 9. Average annual total hydropower benefits, 1930-1941.

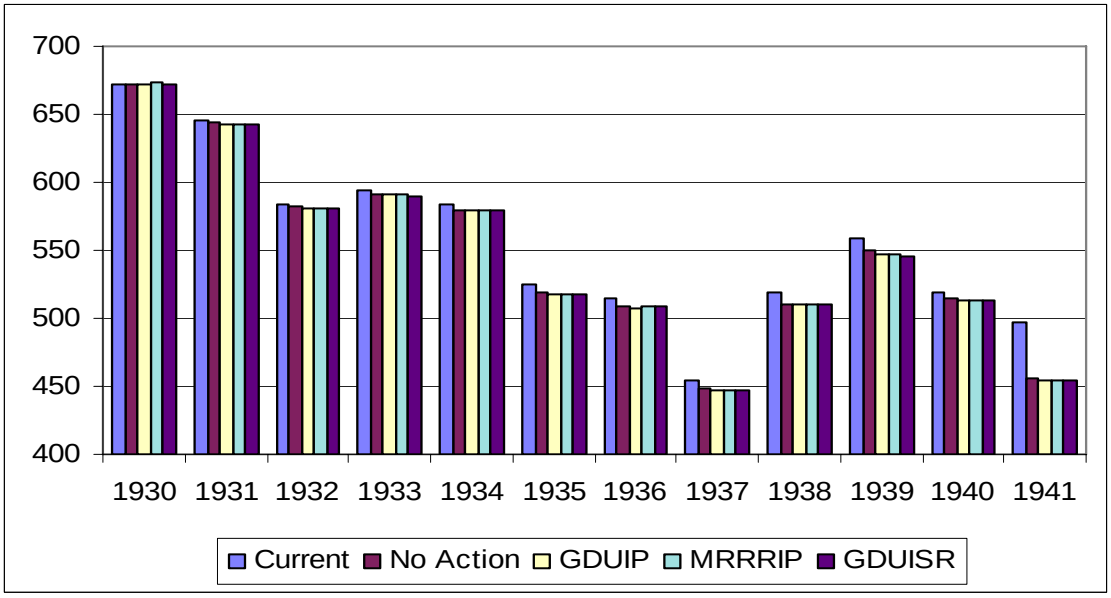

Figure 10. Annual total hydropower benefits, 1930-1941.

Hydropower Marketing Revenues

Reduced annual generation or a redistribution of the annual generation has an impact on the revenues received by the Western Area Power Administration (Western) when it markets the electricity generated at the Corps' Mainstem Reservoir System. To determine the extent of the effects of the water used from the Missouri River for the 2050 RRVWSP SDEIS alternatives, a spreadsheet model developed by Western for the Master Manual EIS was used to compute the net annual energy revenues that Western would accumulate through a drought like that of the 1930s and over the full period of analysis. This spreadsheet model subtracts the amount of firm energy committed each month to

Western's customers from that actually generated on an average annual basis for each month for the period being analyzed. This difference is then multiplied times a rate structure that is based on a marketing forecast. The spreadsheet then sums the pluses (excess energy above the firm amount) and the minuses (energy that needs to be purchased to meet the firm commitment) to arrive at an average annual revenue value for the sales and purchases as Western markets its firm commitment for the period being analyzed. Table 6 presents the results of an analysis using a rate structure used for the Master Manual EIS that relied on the monthly Cinergy Rates of January 30, 2001 (Cinergy provided monthly rate values for the upcoming year at the end of each month.) for both the 1930s drought period and the full period of analysis of 1930-2002.

Table 6. Average annual net hydropower revenues on Western's sales and purchases to meet its firm energy commitments ($ millions)

	1930-1941	1930-2002
Current	-64.51	83.89
No Action	-76.65	79.16
GDUIP	-75.17	77.96
MRRRIP	-74.79	78.21
GDUISR	-74.97	77.24

Table 6 shows first that the revenues during the 1930s drought period are negative meaning that considerable power had to be purchased during such a drought. Second, the figure shows that the Missouri River in-basin depletions would have an average annual impact of about $12 million during a drought like that of the 1930s. These losses of revenue are an indication that the additional non-navigation year of the No Action alternative is an important factor. This is shown on Figure 11 where the two non-navigation years of 1937 and 1941 (both non-navigation years for the No Action alternative and the other three 2050 RRVWSP SDEIS alternatives). When compared to the No Action alternative, a net revenue gain occurs in the 1930s drought period for the addition of the depletions resulting from the implementation of any one of the three RRVWSP SDEIS alternatives that relies on the Missouri River for water. This net gain ranges from about $1.5 million to $1.9 million. Over the full 73-year period of analysis, however, a net revenue loss of about $1.0 million to $1.9 million would occur if the full amount of water were diverted in every year, not just the extended drought years.

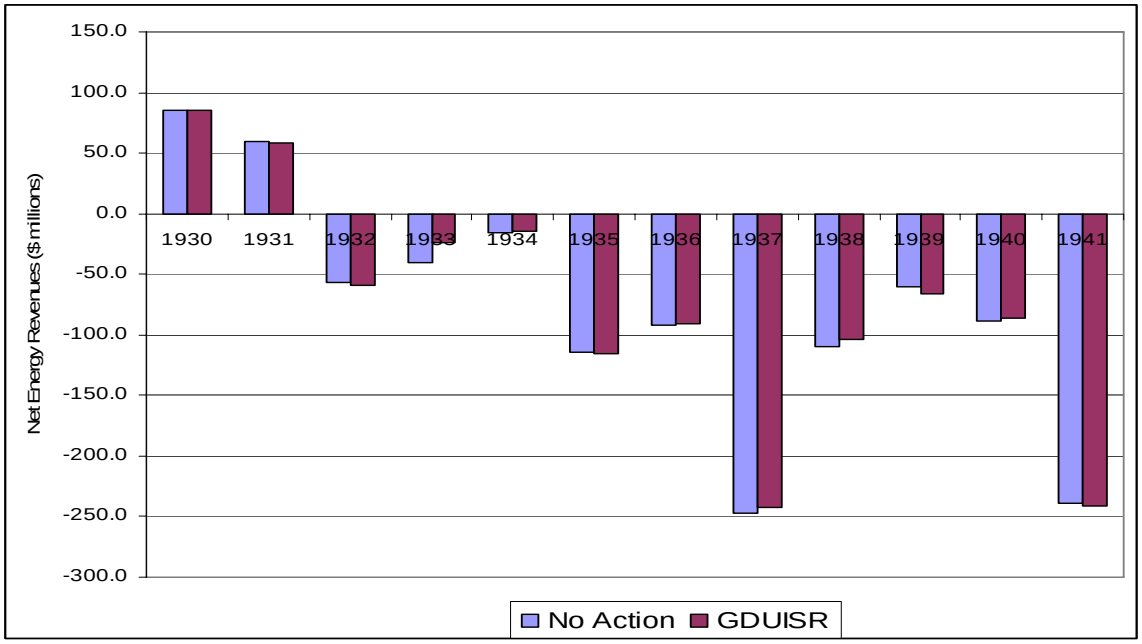

Figure 11. Annual net energy revenues from purchases and sales below and above, respectively, Western's firm energy commitment to its customers for two of the 2050 RRVWSP SDEIS alternatives.

Hydropower and Thermal Generation Capacity at Risk

The above discussion has identified that hydropower benefits and revenues decrease during extended droughts such as the 1930s drought. Thermal generation along the mainstem of the Missouri River is also adversely affected when flows are diminished below levels that can fully accept the waste heat that is in the water discharged back to the river after it is used for cooling the generators. If the flow is diminished too much, the primary solution is to reduce generation to limit the amount of waste heat. The average annual amount of hydropower generation capacity that falls below the summer marketing capacity by Western of 2070 megawatts (MW) is listed in Table 7. This table also lists the amount of thermal generation that is at risk on average in the summers during the 1930 drought. These maximum-day values were computed by pulling data from the water supply model on lost generation instead of the net economic cost of the lost generation. Also, the model had to be run on a daily time step to accomplish this task of computing capacity at risk. The value used from this more intense water supply modeling is the highest daily value during the period being modeled, in this case, mid-June through mid-September. Using the two capacity values, a sum is computed to arrive at the total generation capacity that may be at risk during a drought like the 1930s drought, should both the thermal and hydropower maximum reductions occur on the same day. One can generally see that the four 2050 RRVWSP SDEIS alternatives with the second non-navigation year would have greater amounts of thermal generation capacity at risk than under Current conditions. The values for the hydropower capacity at risk are essentially the same for Current conditions and the four 2050 RRVWSP SDEIS alternatives except for the highest water use alternative, the one that would divert water from Lake Sakakawea and move it to the Sheyenne River, which is 8 MW higher than the

Current conditions. The total capacity-at-risk values are essentially the same among the four 2050 RRVWSP SDEIS alternatives.

Table 7. Missouri River mainstem capacity at risk from mid-June through mid-September, 1930-1941 (MW).

	Hydropower	Thermal	Total
Current	54	309	363
No Action	55	480	536
GDUIP	57	476	533
MRRRIP	57	475	533
GDUISR	62	472	534

The average annual values, however, do not provide a representative picture of what Western, the thermal generating utilities, and the consumers of electricity (those delivering the electricity to the ultimate users) will be dealing with on an annual basis. Figures 12, 13, and 14 provide this perspective. These three figures show the annual hydropower, thermal, and total capacity at risk, based on the assumptions used for this analysis. The hydropower at risk increases as the drought persists. The thermal generation has the highest amount of capacity at risk in the non-navigation years when river flows would be the lowest in the summer. Because the thermal numbers are greater, the total numbers are greatest in the non-navigation years, and these totals exceed 2000 MW.

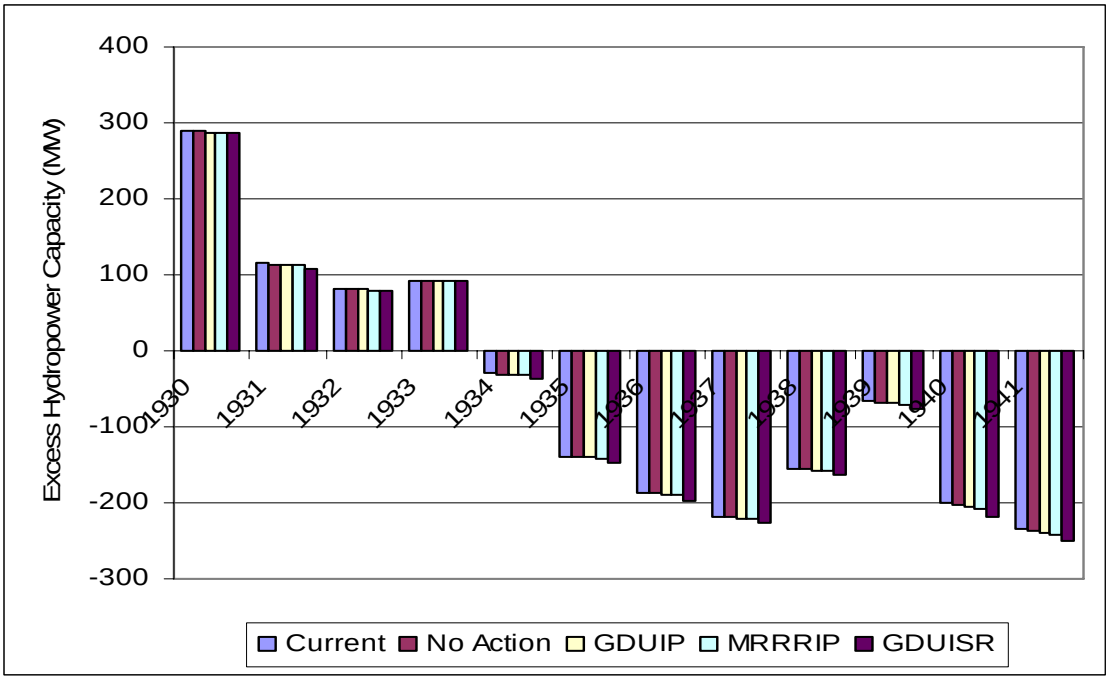

Figure 12. Annual hydropower capacity in excess of Western's summer marketable capacity from mid-June through mid-September, 1930-1941.

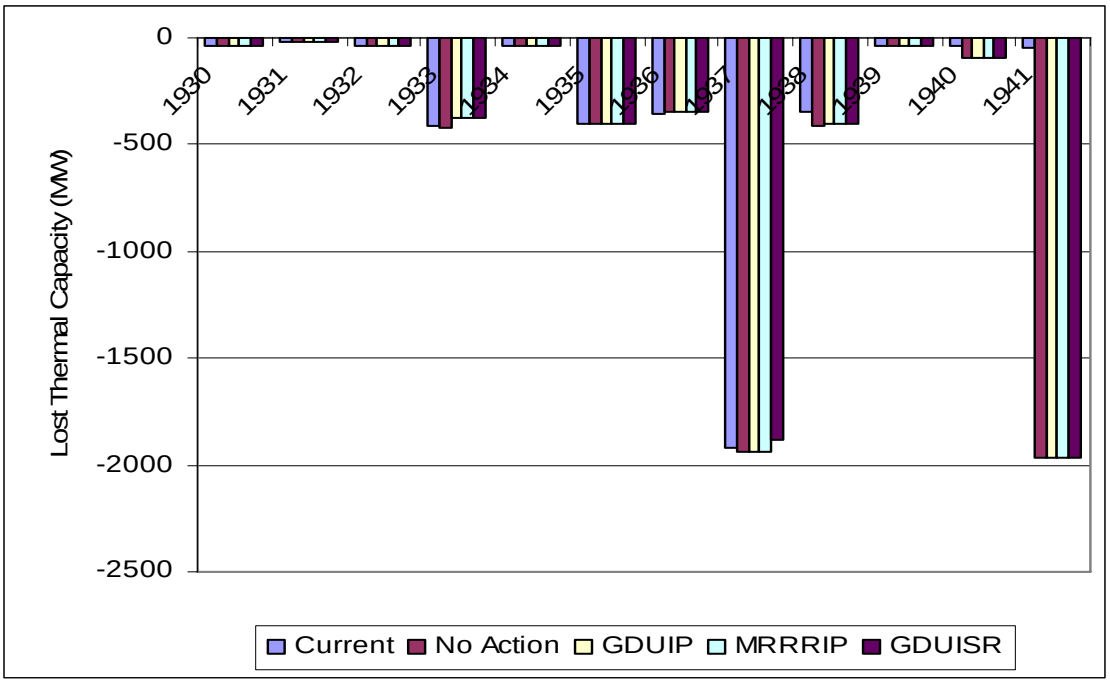

Figure 13. Annual thermal generating capacity at risk from mid-June through mid-September, 1930-1941.

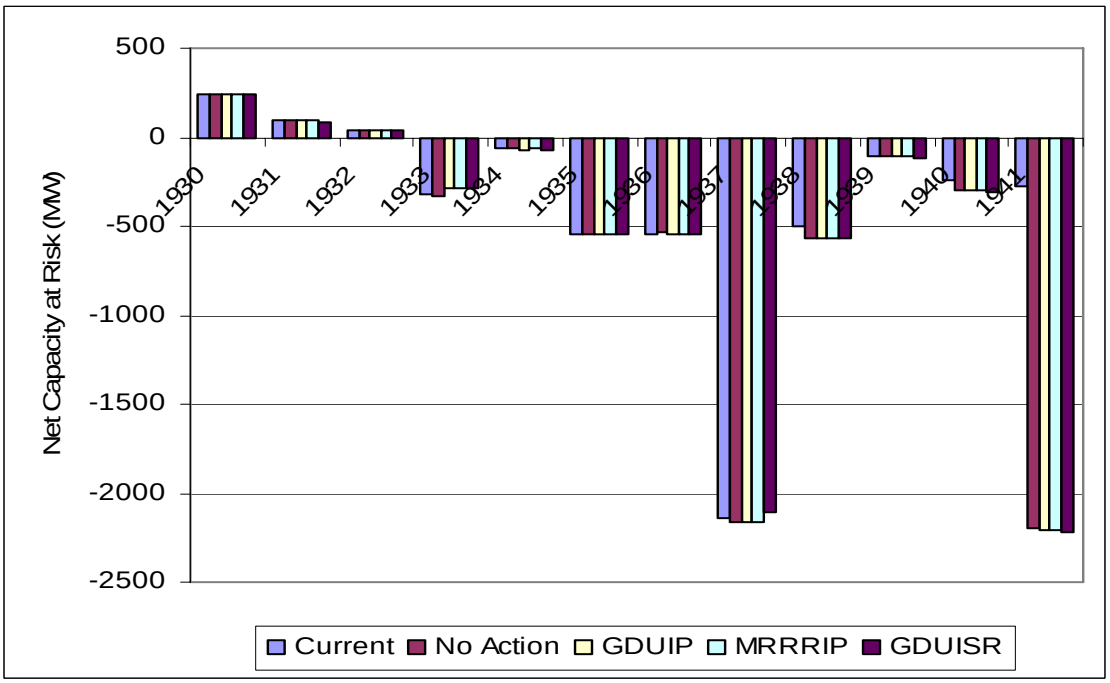

Figure 14. Annual combined hydropower and thermal generating capacity at risk from mid-May through mid-September, 1930-1941.

Hydropower and Thermal Generation Energy at Risk

Generation of electricity is reduced from the Mainstem Reservoir System as capacity is diminished when the reservoir levels drop and releases from the reservoirs are lowered during extended droughts. Reduced releases within and from the System result in lower flows the river reach below Garrison Dam and downstream from the Mainstem Reservoir System on the Lower River in which to dissipate heat from the generators in those two reaches. In extremely warm summer periods, the temperature of the receiving stream may exceed 85 degrees Fahrenheit, and the amount of water temperature increase allowed is reduced as all heat sources must not raise the temperature above 90 degrees.

The effect of the drought of the 1930s on energy generation limitations, or energy at risk, was evaluated for the RRVWSP alternatives because water use from these alternatives would reduce the amount of water moving through and downstream from the Mainstem Reservoir System during an extended drought like that of the 1930s. The average annual energy at risk is presented in Table 8. This table shows that the four 2050 RRVWSP SDEIS alternatives have greater amounts of energy at risk relative to the Current conditions. The hydropower values are the energy generation marketed by Western minus the firm commitment made to Western's customers for the months of mid-June (1/2 of the June monthly value) through mid-September (1/2 of the September monthly value). A negative number means that, on average, not enough energy is generated to meet the firm commitments.). The thermal values are the cutbacks in generation required to comply with the thermal discharge permits for the hottest time of the year, mid-June through mid-September. When combined, the No Action alternative has the highest amount of energy at risk by a factor of over two times the value of the Current conditions and a maximum of 30 gigawatt-hours (GWh) over the energy-at-risk value for the three other 2050 RRVWSP SDEIS alternatives that would transfer Missouri River water to the Red River Valley.

Table 8. Missouri River mainstem energy at risk from mid-June through mid-September, 1930-1941 (GWh).

	Hydropower	Thermal	Total
Current	-10	148	137
No Action	46	274	320
GDUIP	28	268	296
MRRRIP	27	267	294
GDUISR	27	263	290

This average annual analysis does not give a total picture for the variability and the worst year that could occur in a drought like that of the 1930s. Figures 15, 16, and 17 show the amount of energy that would need to be purchased (negative numbers on the figures) to either meet Western's firm energy commitments to its customers or by the utilities purchasing power from the Missouri River mainstem thermal powerplants when the powerplants cannot operate at full capacity. Hydropower energy at risk is greatest in the non-navigation years (1937 and 1941) for all four of the 2050 RRVWSP SDEIS

alternatives. Similarly, the thermal energy at risk is greatest in the non-navigation years; therefore, the combined energy-at-risk values occur in the non-navigation years. The loss of energy availability could exceed 2,000 GWh in the non-navigation years.

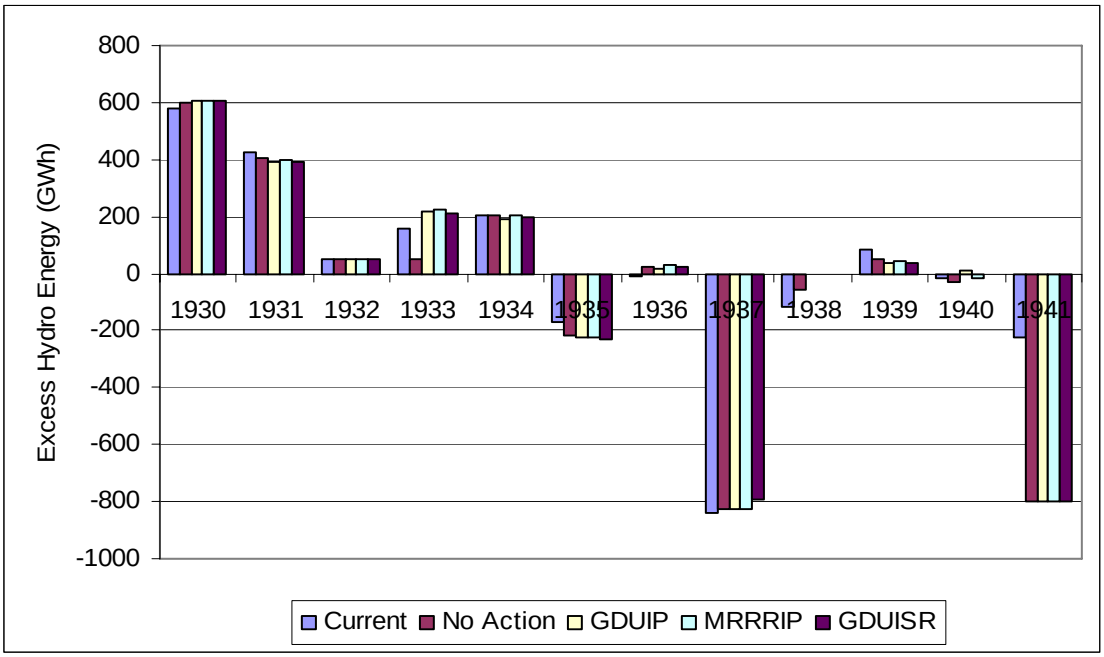

Figure 15. Annual hydropower mid-June through mid-September energy in excess of Western's firm energy commitments for those months, 1930-1941.

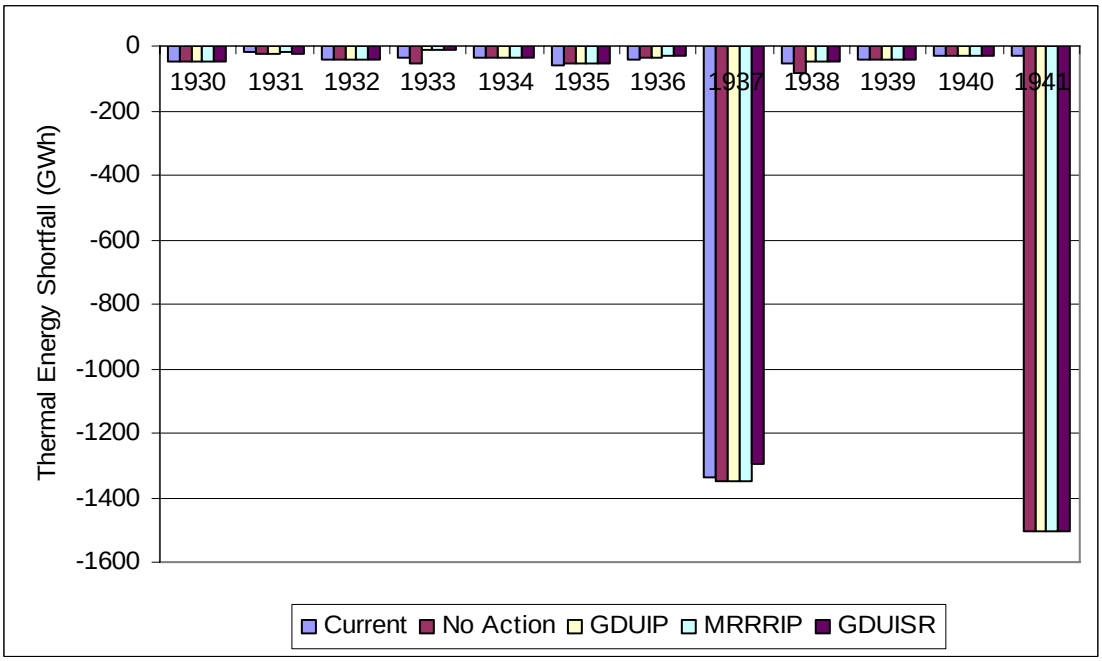

Figure 16. Annual thermal mid-June through mid-September energy at risk, 1930-1941.

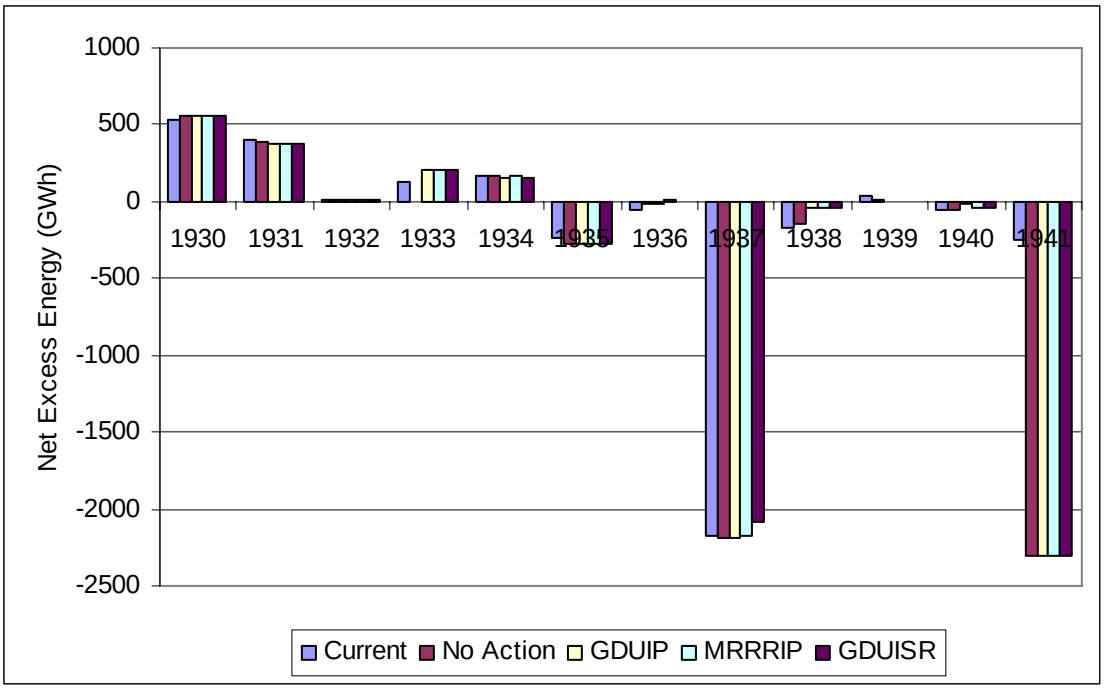

Figure 17. Annual combined energy at risk from mid-June through mid September, 1930-1941.

WATER SUPPLY

An important benefit of the Mainstem Reservoir System is the availability of water at more than 1,600 intake facilities along lake and river reaches from Fort Peck Lake to St. Louis. Economic benefits accrue to the use of water for thermal powerplants, agriculture, public and private drinking water, and other industrial uses of water not served by public systems.

Table 9 presents the average annual water supply benefits for both the 1930s drought and the 1930-2002 periods of analysis. To provide a more visual perspective of the changes in the total 1930-1941 water supply benefits, Figure 18 was prepared. This figure shows the average annual benefits for 1930-1941 period of analysis. The No Action alternative differs from the other three 2050 RRVWSP SDEIS alternatives by $0.6 million to $0.7 million, which equates to a percentage difference from No Action of -0.11 to -0.14 percent. Figure 19 shows that the benefits for the four 2050 RRVWSP SDEIS alternatives vary in some of the 1930s drought years, with the greatest difference occurring in 1937.

As the reservoir levels drop, some intakes are more likely to lose their access to water from the lake. A special analysis identified the municipal intakes at greatest risk of losing water access and if there was a difference among the alternatives if this access was lost on Lakes Oahe and Sakakawea. This analysis found that only one intake would lose its access, and this access was lost under Current conditions and all of the 2050 alternatives. This intake is the Lake Sakakawea intake for Parshall, North Dakota, and it

would need to be lowered so that it could be fully functional at water levels as low as 1795 feet mean sea level.

Table 9. Average annual water supply benefits ($ millions).

	Total	Lakes	Upper River	Lower River
		1930-1941		
Current	565.6	16.2	95.5	453.9
No Action	555.3	16.1	93.5	445.7
GDUIP	554.7	16.2	92.9	445.6
MRRRIP	554.6	16.0	92.9	445.6
GDUISR	554.7	16.2	92.9	445.6
		1930-2002		
Current	613.0	20.5	96.0	496.6
No Action	611.2	20.5	95.6	495.1
GDUIP	611.0	20.5	95.4	495.1
MRRRIP	610.9	20.4	95.5	495.1
GDUISR	611.0	20.5	95.4	495.1

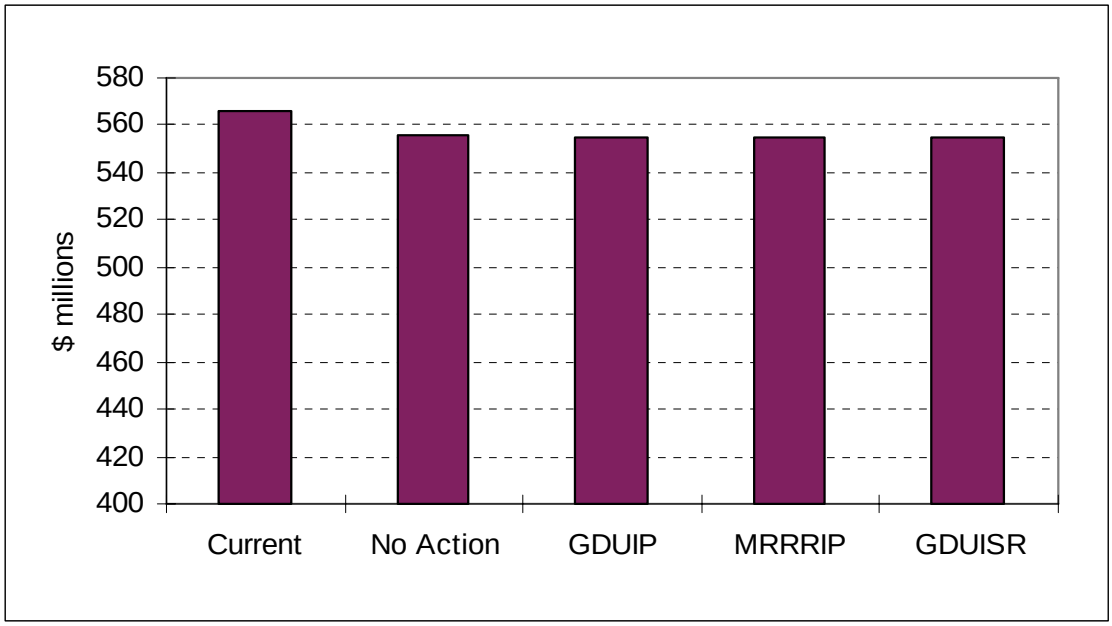

Figure 18. Average annual total water supply benefits, 1930-1941.

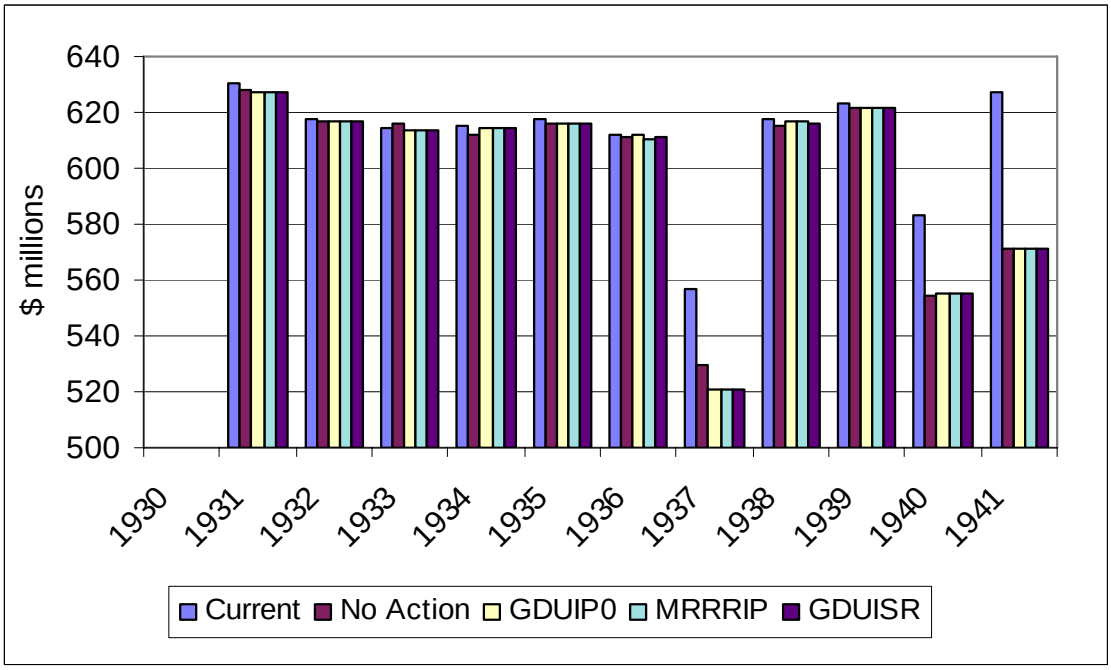

Figure 19. Annual total water supply benefits, 1930-1941. (Note that the benefits for 1930 do not appear on the figure because the water supply economics modeling assumes replacement of facilities occurs in year 1 and every 30 years subsequently.)

RECREATION

Recreation benefits were computed for all reaches of the Missouri River from Fort Peck Lake to the mouth. These benefits are summarized in Table 10 and Figure 20. Changes in total recreation benefits during a drought like that of the 1930s increase from $1.0 million to $2.5 million from the No Action alternative to the other three 2050 RRVWSP SDEIS alternatives. In terms of percentage differences from the No Action alternative, these three alternatives result in increases in recreation benefits of 1.44 to 3.97 percent.

The annual total recreation benefits are shown in Figure 21. There are some differences among the RRVWSP alternatives on an annual basis. These differences are sporadic from year to year with the greatest differences occurring the last 3 years of the drought. These variations indicate that they are due to the intrasystem regulation of the upper three reservoirs, as is indicated in Table 10, where the increases occur only at the upper three reservoirs. Figures 22 through 24 show the annual values for each of the upper three reservoirs, and the increased benefits occur most noticeably at Lake Sakakawea in the latter years of the drought. These differences may be due to higher replacement costs for some of the boat ramps as the reservoir recovered to its highest elevation since early in the drought at the beginning of 1939, which may have triggered some of these replacement costs.

Table 10. Average annual recreation benefits ($ millions).

	Total	Upper 3 Reservoirs	Lower 3 Reservoirs	Upper River	Lower River
		1930-1941			
Current	71.2	19.5	27.8	4.5	19.3
No Action	71.5	19.9	28.0	4.5	19.0
GDUIP	72.5	21.0	28.0	4.5	19.0
MRRRIP	74.0	22.5	28.0	4.5	19.0
GDUISR	73.9	22.4	28.0	4.5	19.0
		1930-2002			
Current	87.4	34.3	28.8	4.5	19.7
No Action	87.5	34.4	28.8	4.5	19.7
GDUIP	87.6	34.5	28.8	4.5	19.7
MRRRIP	87.9	34.8	28.9	4.5	19.7
GDUISR	87.8	34.7	28.9	4.5	19.7

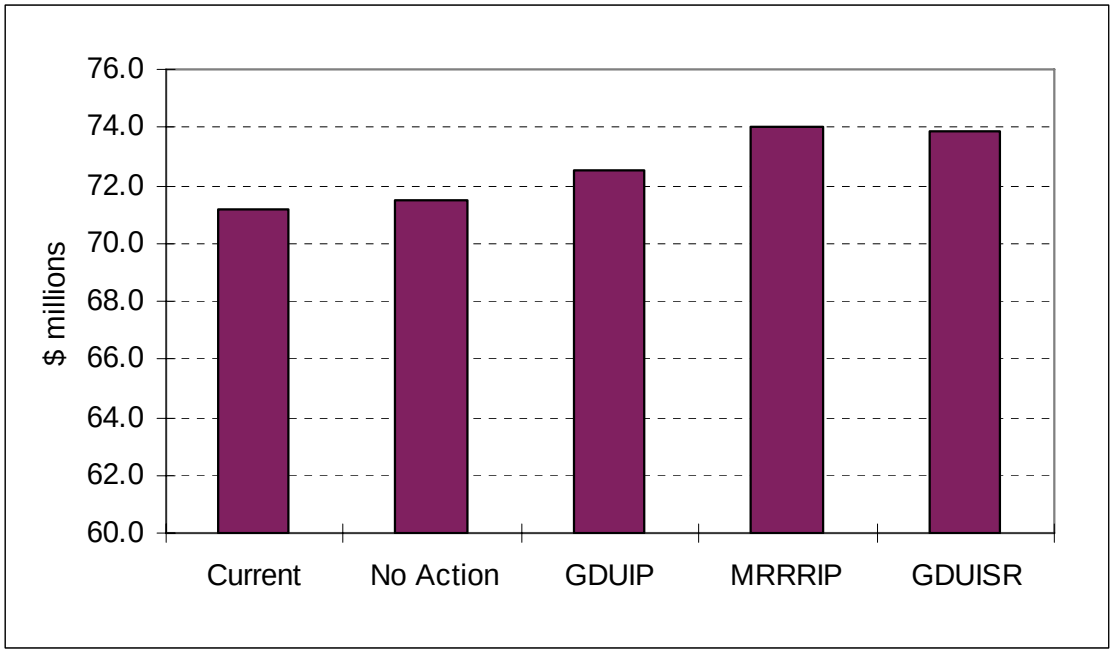

Figure 20. Average annual total recreation benefits, 1930-1941.

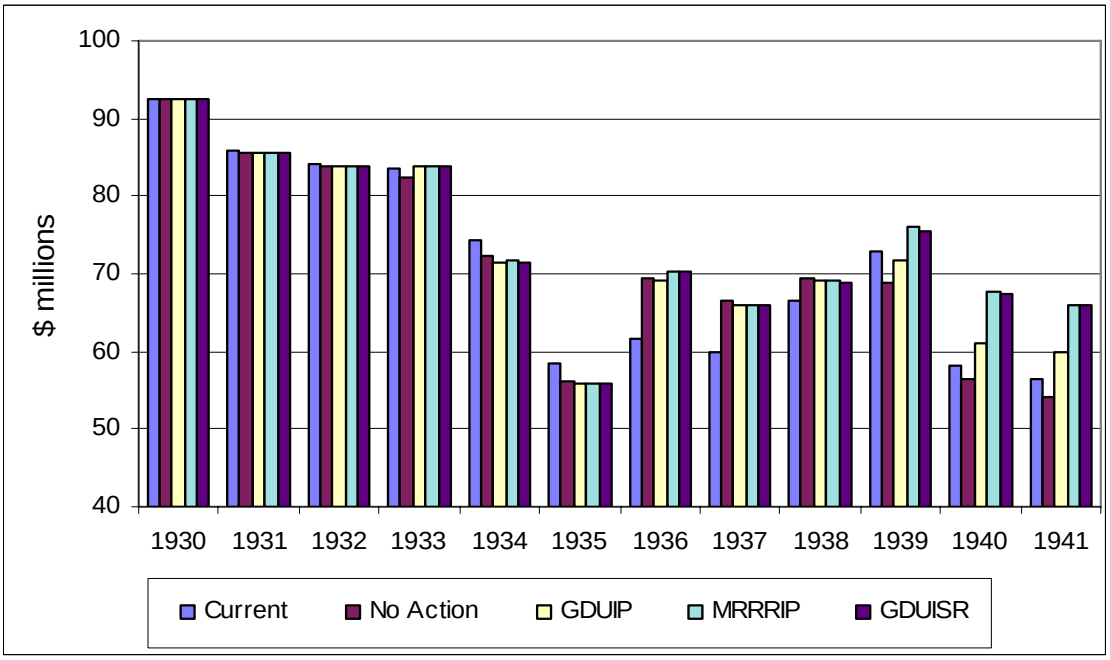

Figure 21. Annual total recreation benefits, 1930-1941.

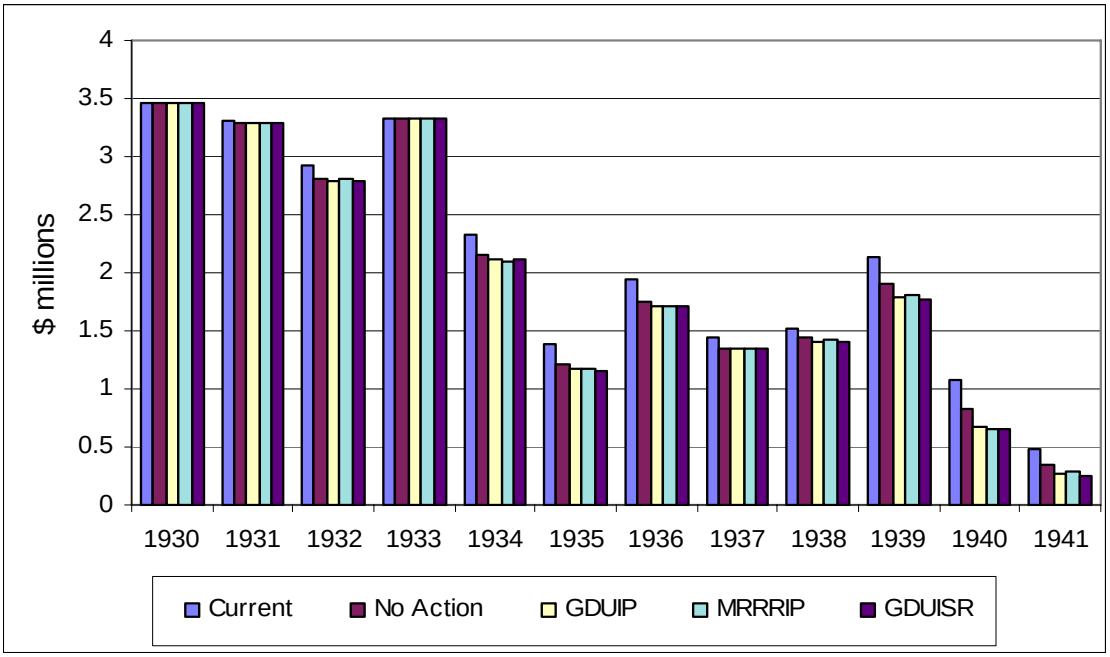

Figure 22. Annual Fort Peck Lake recreation benefits, 1930-1941.

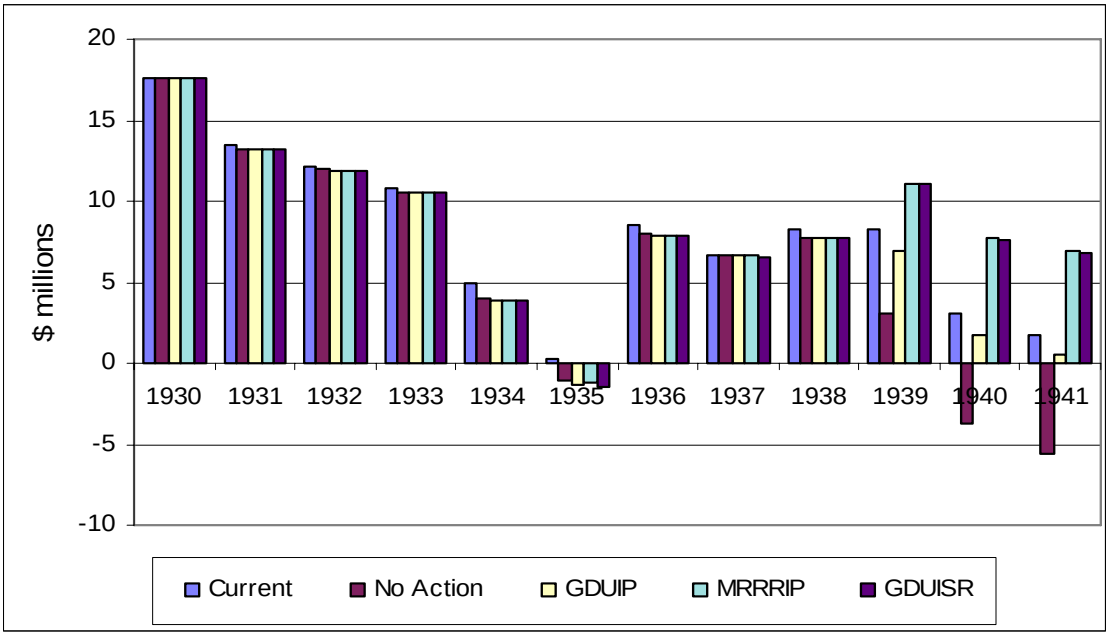

Figure 23. Annual Lake Sakakawea recreation benefits, 1930-1941.

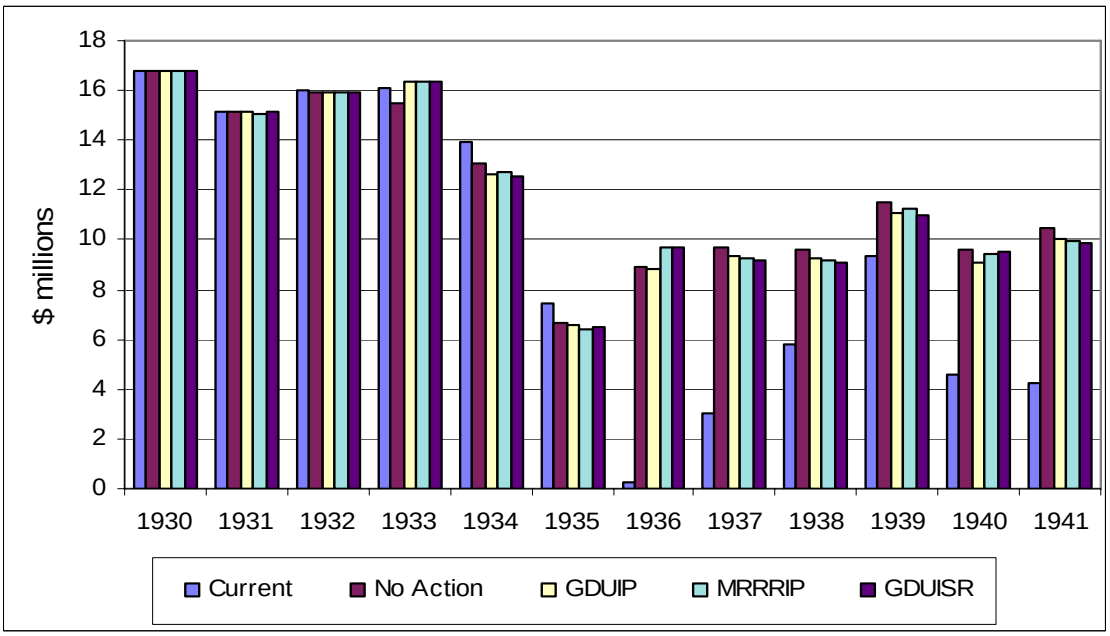

Figure 24. Annual Lake Oahe recreation benefits, 1930-1941.

RESERVOIR COLDWATER FISH HABITAT

Various coldwater fish species in the three larger reservoirs of the Mainstem Reservoir System require temperature and dissolved oxygen criteria that meet their habitat requirements. Table 11 and Figure 25 show the average annual reservoir coldwater fish habitat values for the 1930s drought. The table also includes the values for the 73-year

period of analysis from 1930 to 2002. Annual values for this habitat are the minimum volume of this habitat in the July through October timeframe of each year.

Both Table 11 and Figure 25 show that the reservoir coldwater fish habitat will diminish in the future for both periods of analysis as the result of depletions occurring, whether they are from uses within or external to the Missouri River Basin. Compared to the amount of habitat for the No Action alternative, the three 2050 RRVWSP SDEIS alternatives that rely on Missouri River water have reduced amounts of coldwater fish habitat. The reductions for the 1930s drought period range from 0.07 to 0.10 MAF of total habitat. This range equates to percentage differences from the No Action alternative of -1.77 to -2.46 percent.

The reach data in Table 10 also show variability as the depletions increase above those of the No Action alternative. Coldwater fish habitat in Lake Sakakawea actually increases; where as, this habitat decreases in Fort Peck Lake and Lake Oahe on an average annual basis during a repeat of the 1930s drought. Even with these changes, the main concern with reservoir coldwater habitat is complete loss of this habitat during an extended drought because that could lead to a loss of one or more fish species, including the critical forage fish species in one or more of the reservoirs. The annual total values shown in Figure 26 do not show a complete loss of the coldwater habitat in the reservoirs. Figures 27, 28, and 29 present the annual reservoir coldwater habitat values for Lake Sakakawea, Fort Peck Lake, and Lake Oahe, respectively. This order was chosen because this is the order in which these reservoirs are likely to lose the coldwater habitat.

Table 11. Average annual reservoir coldwater fish habitat (MAF).

	Total	Fort Peck Lake	Lake Sakakawea	Lake Oahe
		1930-1941		
Current	4.40	1.57	0.64	2.19
No Action	4.28	1.55	0.59	2.14
GDUIP	4.20	1.43	0.64	2.13
MRRRIP	4.18	1.42	0.63	2.13
GDUISR	4.21	1.44	0.65	2.12
		1930-2002		
Current	9.71	3.61	2.61	3.48
No Action	9.65	3.58	2.60	3.46
GDUIP	9.57	3.51	2.60	3.45
MRRRIP	9.55	3.52	2.58	3.45
GDUISR	9.58	3.53	2.61	3.44

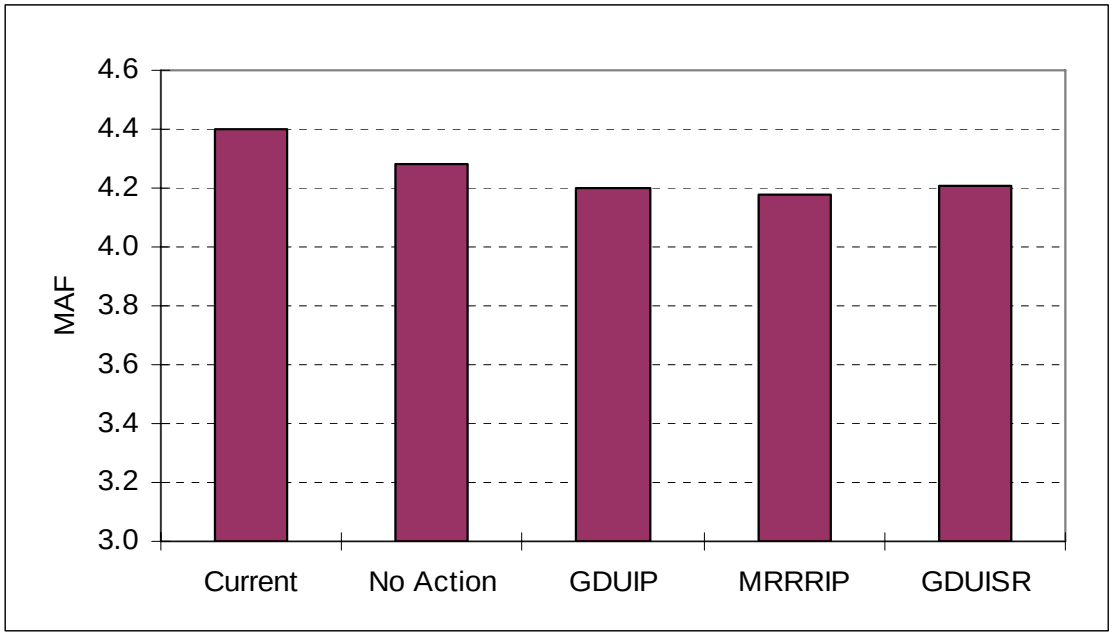

Figure 25. Average annual total reservoir coldwater fish habitat, 1930-1941.

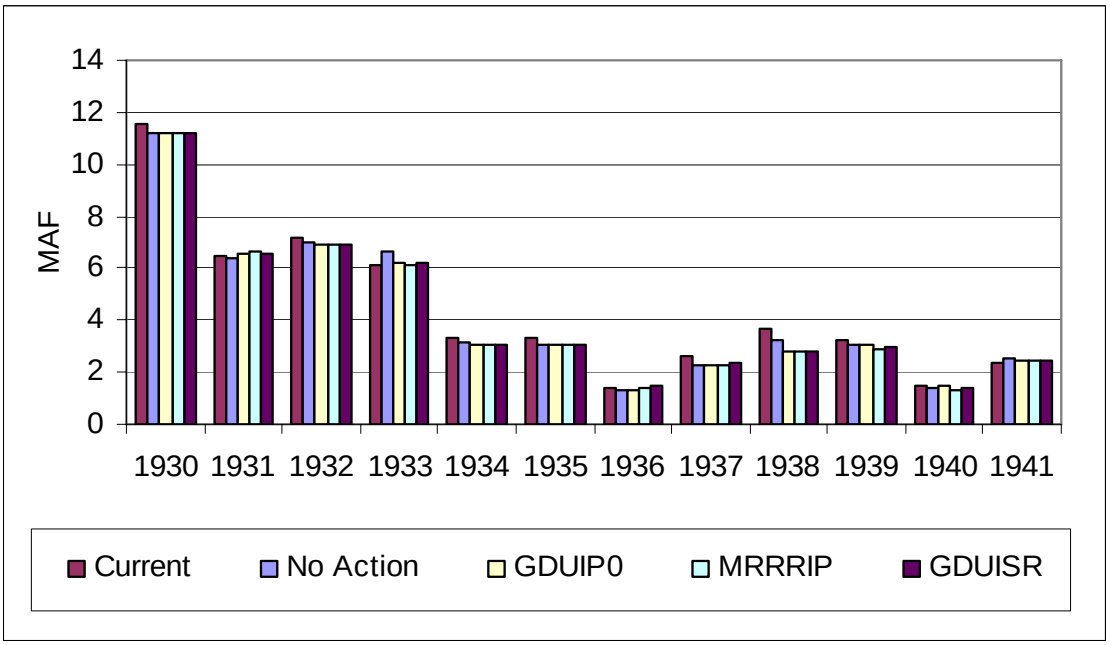

Figure 26. Annual total reservoir coldwater fish habitat, 1930-1941.

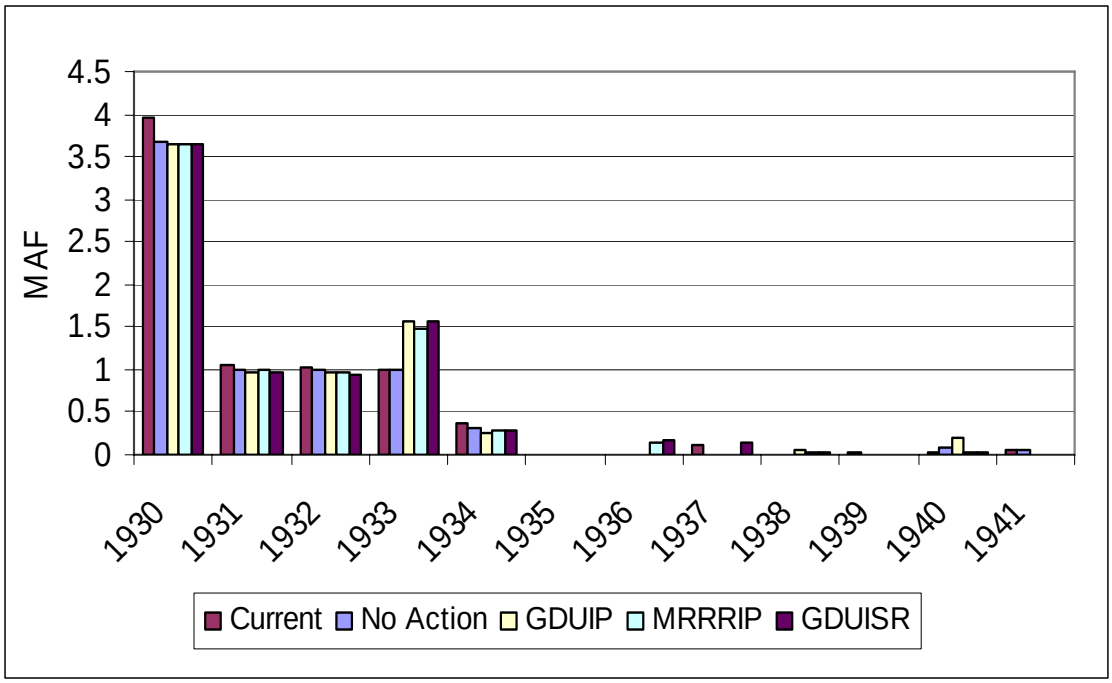

Figure 27. Annual Lake Sakakawea coldwater fish habitat, 1930-1941.

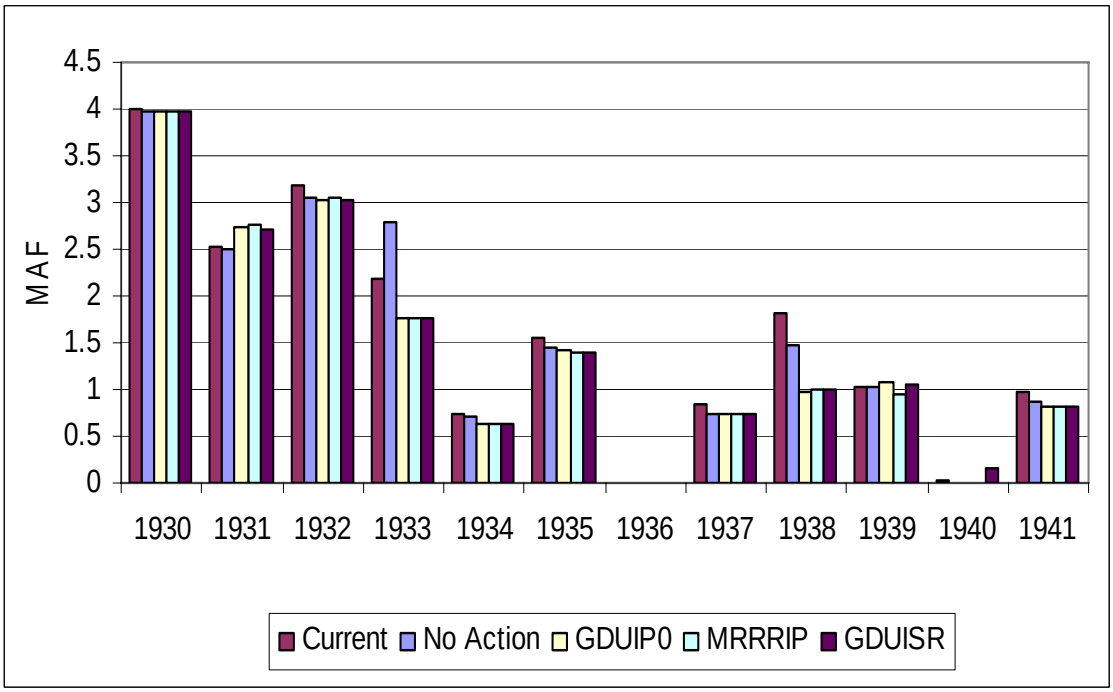

Figure 28. Annual Fort Peck Lake coldwater fish habitat, 1930-1941.

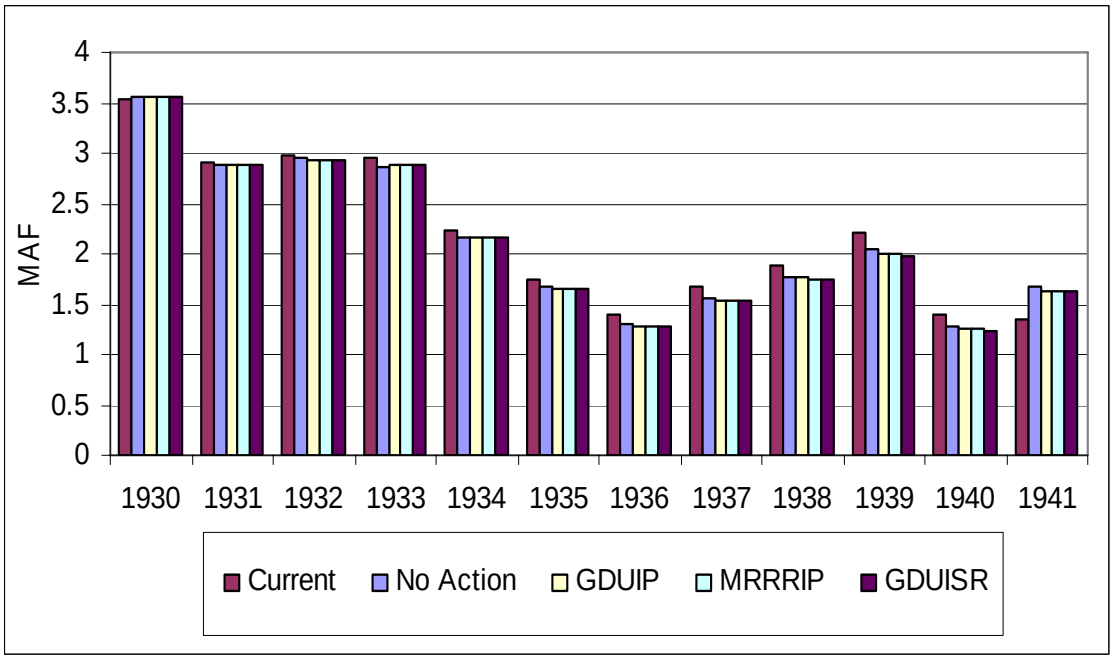

Figure 29. Annual Lake Oahe coldwater fish habitat, 1930-1941.

The coldwater habitat is completely lost in Lake Sakakawea and Fort Peck Lake sometime during the drought under all of the alternatives, including Current conditions. This habitat is lost from 1935 through 1941 in Lake Sakakawea under all alternatives and in 1936 and 1940 for Fort Peck Lake under all alternatives. Only Lake Oahe is able to maintain a minimum of over 1 MAF of this habitat through the entire drought for all of the alternatives. The Corps is currently involved with detailed modeling of the three reservoirs, and one hypothesis is that the depth of water withdrawal is an important factor in affecting the order of losing this critical habitat in all three reservoirs, with Lake Oahe being the reservoir to retain some habitat longest in an extended drought (based on the Master Manual modeling and the untested hypothesis for the uncompleted, more detailed modeling). There is no difference among the alternatives in terms of when and for how long this habitat is completely lost in two of the three reservoirs during a repeat of the 1930s drought.

RIVERINE COLDWATER FISH HABITAT

Coldwater habitat for river fish occurs downstream from Fort Peck and Garrison Dams. The average annual values for this habitat for the alternatives are shown in Table 12 and Figure 30. Values for the 1930s drought and the 73-year modeling period are shown in the table, and only the drought values are plotted on the figure. Also, the values are the average miles of river that meet the criteria in the April through September timeframe.

Values in the table and figure for the 1930-1941 drought period show that the average annual miles of coldwater habitat will generally increase in an extended drought as the depletions increase above the Current conditions. This, however, is not the same result

for the full period of analysis from 1930 through 2002, when the total amount of riverine coldwater fish habitat is greatest under Current conditions.

A trend also exists for the changes in the amount of total habitat as the amount of water diverted to use in the Red River Valley increases among the alternatives. Compared to the values for the No Action alternative, the total values increase by 0.02 to 0.23 miles, which equates to a percentage difference of from 0.01 to 0.15 percent. On a reach basis, the direction of change from the No Action alternative varies. It increases for the Fort Peck reach and decreases for the Garrison reach. This pattern is generally consistent for the drought and full period of analysis.

Table 12. Average annual riverine coldwater fish habitat (miles).

	Total	Fort Peck	Garrison
		1930-1941	
Current	150.72	117.30	33.42
No Action	150.77	116.94	33.83
GDUIP	150.79	118.15	32.64
MRRRIP	150.86	118.33	32.54
GDUISR	151.00	118.67	32.33
		1930-2002	
Current	183.28	138.55	44.73
No Action	183.07	138.54	44.53
GDUIP	183.01	138.89	44.12
MRRRIP	182.36	138.45	43.91
GDUISR	182.79	138.85	43.94

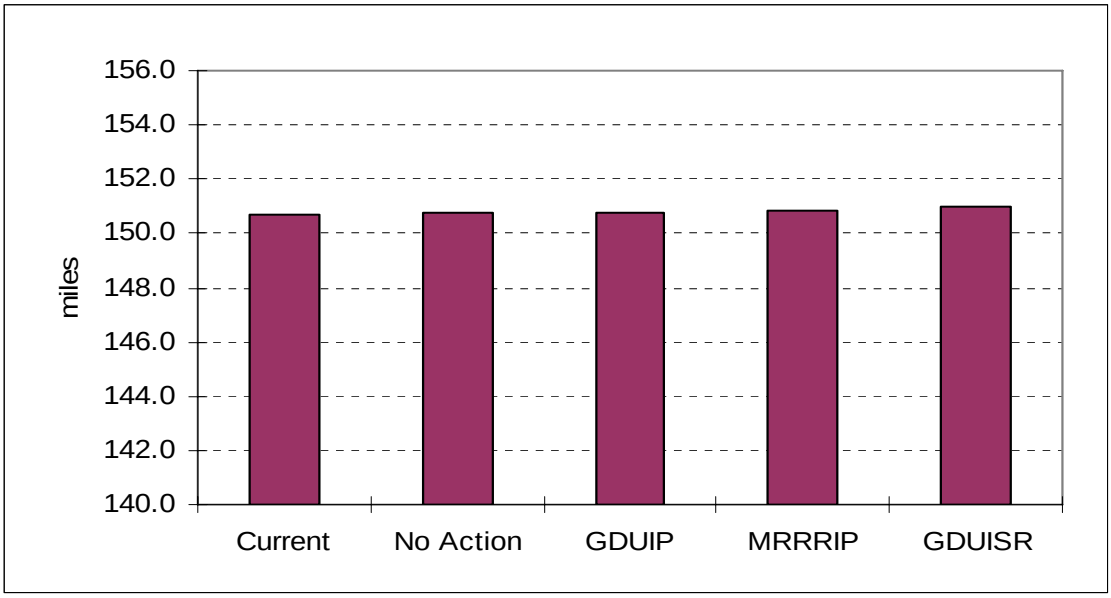

Figure 30. Average annual total riverine coldwater fish habitat, 1930-1941.

Annual values for riverine coldwater fish habitat for the 1930s drought period are shown on Figure 31. This figure shows that the number of miles of riverine coldwater fish habitat diminishes from about 220 miles quickly in a drought, and stays in the range of 130 to 170 miles in the last 11 years of the 12-year drought. There is little variation among the alternatives in any year, with the greatest difference being about 20 to 30 miles. These small differences, however, account for the differences in the average annual values.

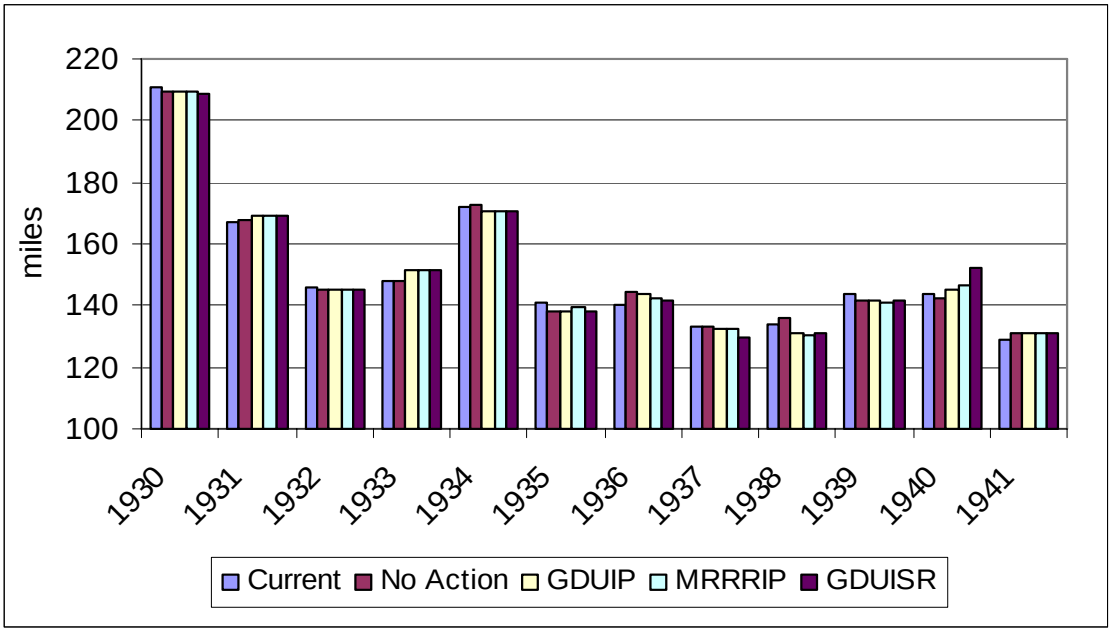

Figure 31. Annual total riverine coldwater fish habitat, 1930-1941.

RIVERINE WARMWATER FISH HABITAT

Warmwater habitat for river fish occurs downstream from Fort Peck, Garrison, and Fort Randall Dams. The average annual values for this habitat for the alternatives are shown in Table 12 and Figure 26. Values for the 1930s drought and the 73-year modeling period are shown in the table, and only the drought values are plotted on the figure. Also, the values are the average miles of river that meet the criteria in the April through August timeframe.

As expected with lower reservoir levels and lower releases during a drought like the 1930s drought, the amount of riverine warmwater fish habitat is higher during the 1930s drought than it averages over a combination of normal, wet, and drought periods, as would occur over the full 73-year period of analysis. For both periods of analysis, the change for the other three 2050 RRVWSP SDEIS alternatives from the No Action alternative is positive for the diversion of water to the Red River Valley. This increase

ranges from 0.04 miles to 0.18 miles for the 1930s drought period. In terms of percent changes from the No Action alternative, this range is an increase of 1.44 to 1.63 percent.

Figure 33 presents the annual average total values for riverine warmwater fish habitat. With the exception of 2 years, 1934 and 1939, the figure shows that as the drought progresses and the reservoir levels drop and releases are reduced, the amount of warmwater habitat generally increases during the drought. The greatest differences between the No Action alternative and each of the three other 2050 RRVWSP SDEIS alternatives in a single year occurred in 1939. This difference was a positive difference, which led to the increase in the average annual values for the warmwater habitat.

Table 13. Average annual riverine warmwater fish habitat (miles).

	Total	Fort Peck	Garrison	Fort Randall
		1930-1941		
Current	72.83	49.44	6.56	16.83
No Action	72.27	50.12	6.73	15.41
GDUIP	73.41	50.13	7.01	16.26
MRRRIP	73.31	49.97	7.08	16.26
GDUISR	73.45	50.20	6.96	16.29
		1930-2002		
Current	50.26	31.91	5.37	12.97
No Action	50.64	31.87	5.79	12.99
GDUIP	50.68	31.84	5.77	13.06
MRRRIP	51.01	32.12	5.77	13.13
GDUISR	50.97	31.95	5.91	13.11

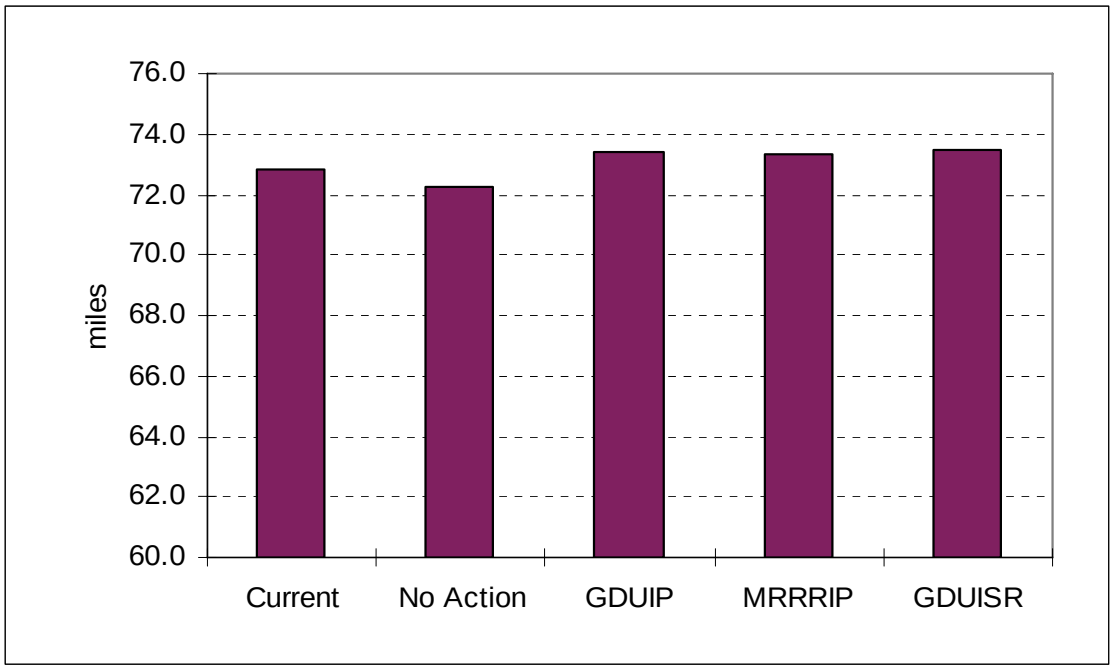

Figure 32. Average annual total riverine warmwater fish habitat, 1930-1941.

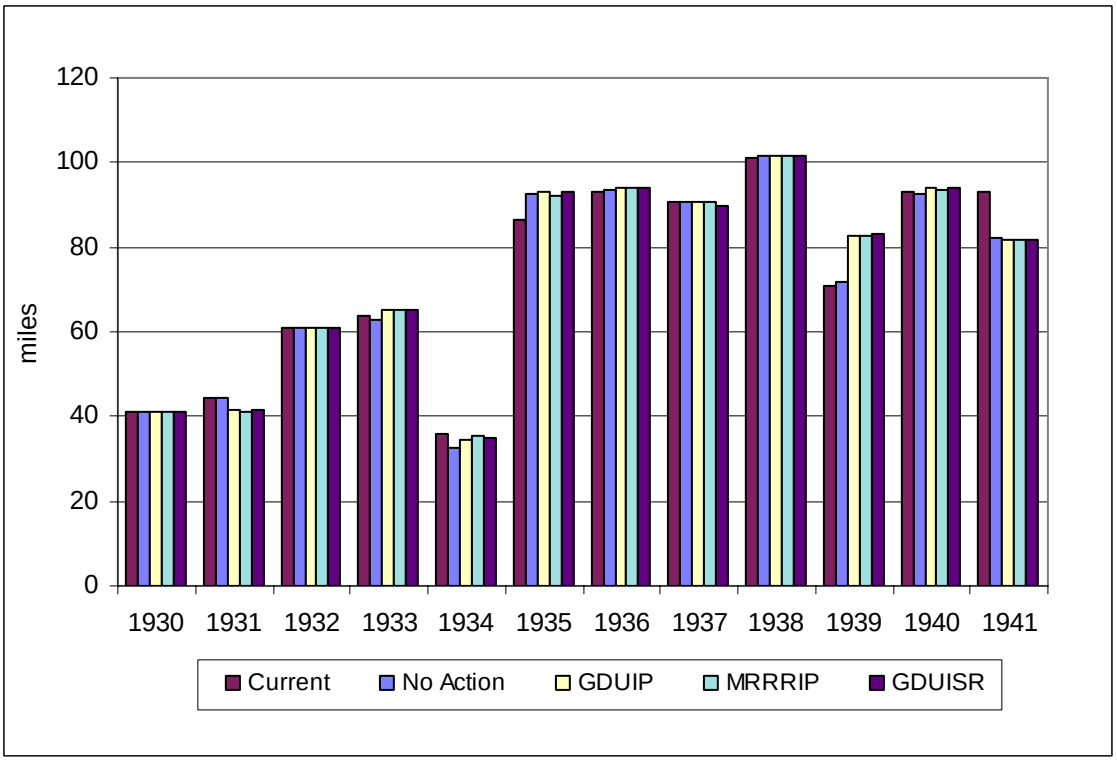

Figure 33. Annual total riverine warmwater fish habitat, 1930-1941.

RESERVOIR YOUNG FISH PRODUCTION

The reservoir young fish production index values are based on regressions of hydrologic factors versus actual young fish production in the six Mainstem Reservoir System reservoirs in the 1980s and early 1990s. Higher index values mean higher young fish production. The average annual total fish production values computed for the two periods of analysis are presented in Table 14, and the 1930-1941 values are shown in Figure 34.

The table and figure show that the differences for the total young fish production index are 0.1 index unit for both periods of analysis. Generally, however, the No Action alternative has the highest index value, meaning that reservoir fish production will be highest under that alternative. On a reservoir basis, the difference among the alternatives is also never more than 0.1 index unit. The increased depletions between the Current conditions to the No Action alternative in 2050 have minimal impact on young fish production in the six Mainstem System reservoirs. The percentage changes between the No Action alternative and each of the three 2050 RRVWSP SDEIS alternatives are reductions of from 0.91 to 1.20 percent.

Figure 35 presents the annual total young fish production index values. The values through the drought drop, increase, and then generally drop again. There is some variation among the four 2050 RRVWSP alternatives with the greatest difference occurring in 1941, a non-navigation year with low flows through the reservoirs.

Table 14. Average annual reservoir young fish production (index).

	Total	Fort Peck Lake	Lake Sakakawea	Lake Oahe	Lake Sharpe	Lake Francis Case	Lewis and Clark Lake
				1930-1941			
Current	1.43	0.23	0.37	0.23	0.23	0.16	0.22
No Action	1.44	0.22	0.38	0.23	0.24	0.15	0.22
GDUIP	1.43	0.22	0.37	0.23	0.24	0.15	0.22
MRRRIP	1.43	0.22	0.37	0.23	0.24	0.15	0.22
GDUISR	1.43	0.22	0.37	0.23	0.24	0.15	0.22
				1930-2002			
Current	2.09	0.53	0.47	0.39	0.27	0.24	0.19
No Action	2.08	0.52	0.47	0.39	0.28	0.23	0.19
GDUIP	2.08	0.51	0.47	0.39	0.28	0.24	0.19
MRRRIP	2.08	0.51	0.47	0.39	0.28	0.24	0.19
GDUISR	2.09	0.51	0.47	0.39	0.28	0.24	0.19

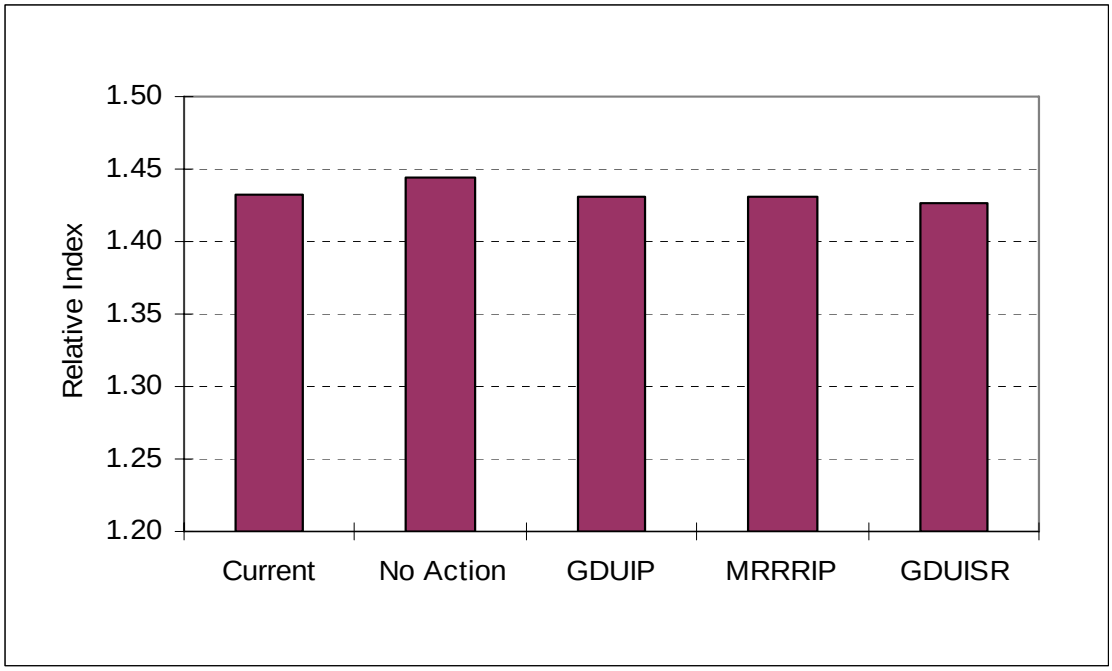

Figure 34. Average annual total young fish production index, 1930-1941.

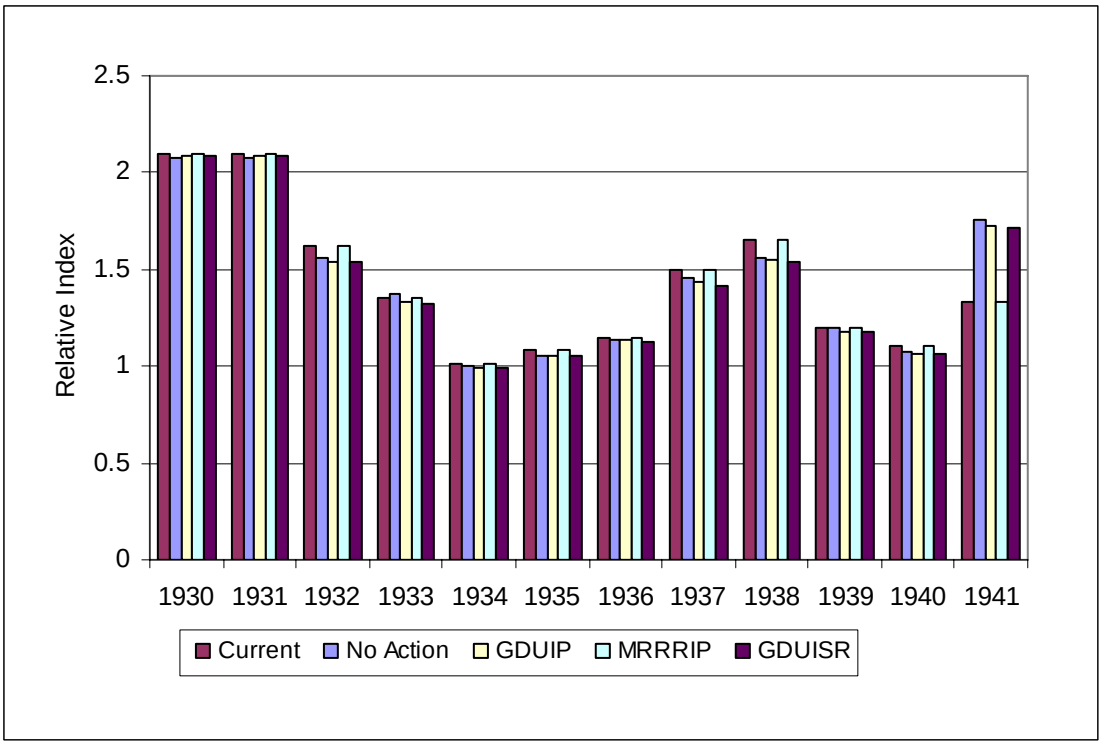

Figure 35. Annual total young fish production index, 1931-1941.

NATIVE RIVER FISH PHYSICAL HABITAT

Construction of the Mainstem Reservoir System has altered the historical flow patterns moving through the various reaches of the Missouri River. Also, the reduction in peak annual flows and other factors have resulted in channel shape and capacity changes. These changes have altered the velocity and depth patterns that occurred throughout the year in the various river reaches. The native river fish physical habitat model computes monthly indices indicating how close channel velocities and/or depths under a water control plan compare to the historic values for each river reach in the Upper (within the Mainstem Reservoir System) and Lower Missouri River (a perfect match would be an index value of 1.0 for that month). Table 15 and Figure 36 show the average annual index values for the 12 years of the 1930s drought. The table also presents the data for the full 73-year period of analysis.

The total physical habitat index values for both periods of analysis follow a similar pattern. As the depletions increase above Current conditions, the physical habitat index values gradually increase, although that increase is relatively small. Generally the physical habitat indices will decrease as the depletions increase between now and 2050. Compared to the No Action alternative, the three 2050 RRVWSP SDEIS alternatives that would rely on the Missouri River for supplemental water would reverse the trend and provide an increase in the physical habitat values. The increases range from 0.17 units to 0.25 units (percent increase range of 0.21 to 0.31 percent). A similar pattern occurs on the Upper River and Lower River reaches as well.

Table 15. Average annual native river fish physical habitat (index).

	Total	Upper River	Lower River
		1930-1941	
Current	81.15	25.41	55.74
No Action	80.78	25.25	55.53
GDUIP	80.95	25.40	55.54
MRRRIP	80.99	25.44	55.54
GDUISR	81.03	25.48	55.55
		1930-2002	
Current	81.11	25.08	56.03
No Action	81.08	25.07	56.01
GDUIP	81.16	25.14	56.02
MRRRIP	81.15	25.13	56.02
GDUISR	81.14	25.12	56.02

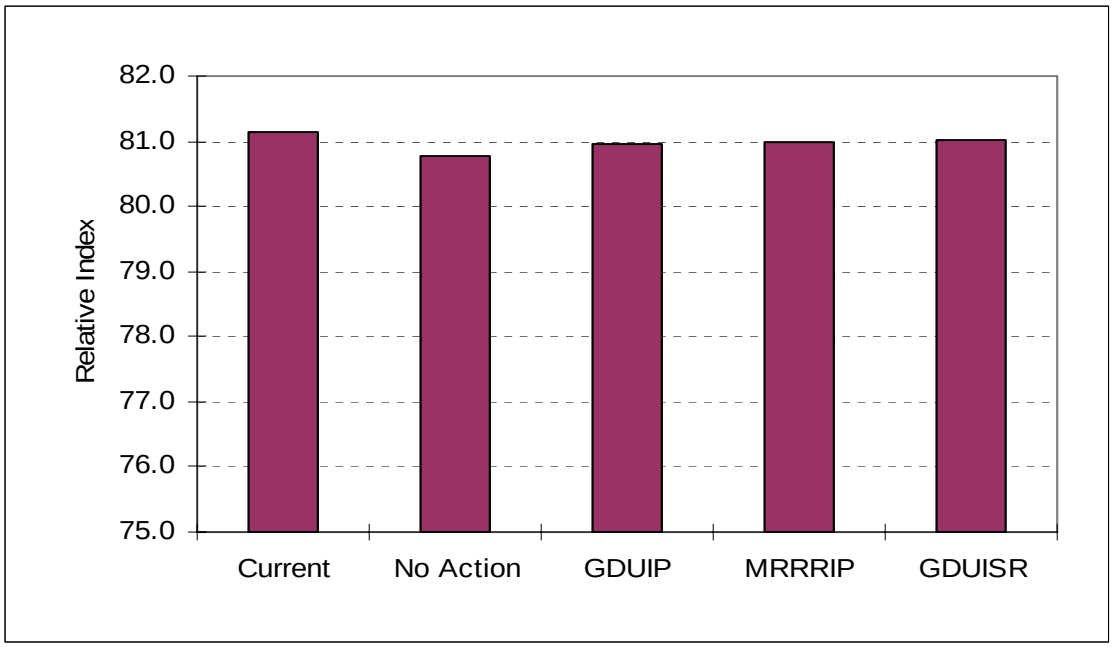

Figure 36. Average annual total native river fish physical habitat index, 1930-1941.

Figure 31 presents the annual total physical habitat values for the 1930s drought period. The values generally remain relatively close together, ranging from 80 to just over 84 on an annual basis. Noticeable differences for the addition of the Red River Valley diversions to the No Action alternative occur in several of the years, with the differences generally being increases.

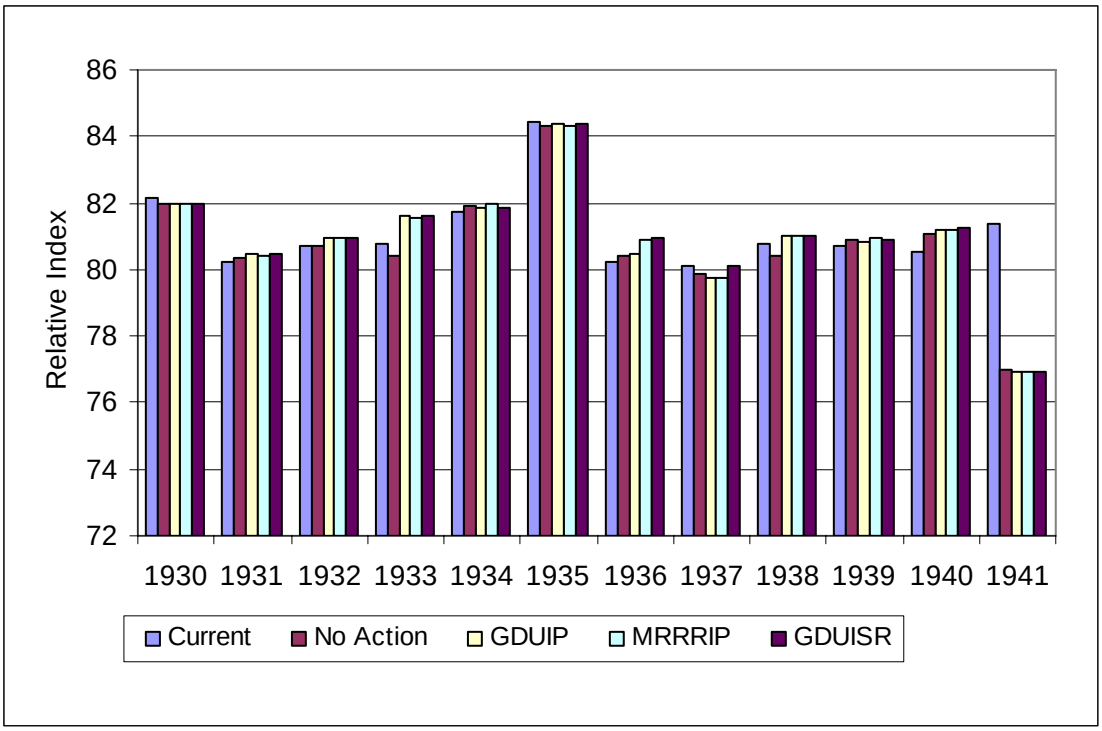

Figure 37. Annual total native river fish physical habitat index, 1930-1941.

RIVERINE TERN AND PLOVER HABITAT

Riverine tern and plover habitat occurs on four reaches of the Missouri River, downstream from Fort Peck, Garrison, Fort Randall, and Gavins Point Dams. Changes to habitat that existed in about the 1991 timeframe were modeled to determine annual values for the number of acres that remained in these reaches as vegetation encroached on bare sand habitat during the summer months and were scoured away by high flows. The modeling did not account for the geomorphic processes that build and erode sandbars and islands or the Corps' habitat construction and vegetation removal efforts that have gone on in recent years. Average annual total habitat values in acres of habitat for the two periods of analysis are presented in Table 16, and the values for the 1930s drought period only are shown on Figure 38.

Tern and plover habitat values decrease as a result of Missouri River depletions resulting between those under the No Action alternative and the three 2050 RRVWSP SDEIS alternatives that would divert water to the Red River Valley. Because the primary habitat losses are in the two intra-System reaches downstream of Fort Peck and Garrison Dam, the reductions for these three alternatives results from how the water is moved among the three upper reservoirs. The losses of total riverine tern and plover habitat range from 121.4 acres to 180.4 acres. Because of the low flows during the droughts, major amount of vegetation encroachment can occur, especially if flows in a given reach are extremely low. This vegetation encroachment would account for the 28 to 42 percent losses of total habitat.

Table 16. Average annual riverine tern and plover habitat (acres).

	Total	Fort Peck	Garrison	Fort Randall	Gavins Point
			1930-1941		
Current	392.9	89.0	274.3	14.6	14.9
No Action	432.3	74.8	324.0	14.6	18.8
GDUIP	310.9	46.3	231.1	14.7	18.8
MRRRIP	296.4	46.3	216.5	14.7	18.8
GDUISR	251.9	46.3	172.1	14.7	18.8
			1930-2002		
Current	384.1	72.2	242.3	37.1	32.4
No Action	363.3	42.7	250.1	36.7	33.7
GDUIP	316.7	34.0	217.8	33.9	31.0
MRRRIP	326.5	35.8	225.6	33.9	31.3
GDUISR	319.3	35.6	217.4	34.5	31.8

Figure 39 presents the annual values through the 1930s drought for the total riverine tern and plover habitat. Habitat increases in 1931 and 1932 in response to the reduction in releases from the Mainstem Reservoir System to serve navigation, which drops to minimum service in the second year of the drought. Continuation of these lower releases eventually leads to less habitat in the next 4 years as vegetation encroaches on the bare sand of the sandbars and islands at the continuing lower flows. Habitat increases dramatically in 1937 for most of the alternatives in response to even lower flows in this non-navigation year for all of the alternatives. The return to minimum service flows in 1938 results in even less habitat than before 1937 as vegetation would have encroached even lower on the sandbars and islands in the non-navigation year. The trend continues downward through 1941 for all of the alternatives with some alternatives having essentially no habitat in some years. Finally, habitat increases again in 1941 when the low flows for the navigation season expose some very low-lying bare sand habitat. The variation among the alternatives follows primarily the pattern for the Garrison downstream reach since it has the greatest habitat acreage and the greatest variability of the four reaches. The Fort Peck reach also shows some habitat reductions as the depletions increase under the three 2050 RRVWSP SDEIS alternatives using Missouri River water.

Ongoing requirements and efforts to create additional tern and plover habitat are factors that reduce the negative aspect of this loss of habitat due to Missouri River regulation and flow impacts, including the effects of actions resulting in additional depletions. The amount of tern and plover habitat is extremely variable as vegetation encroachment and island or sandbar erosion affect the amount of clear sand habitat, the preferred habitat of these two bird species. In the case of the modeling results discussed above, vegetation encroachment is part of the model computations, and the island clearing (vegetation removal) currently being conducted will ensure that the variability the model computes will be diminished for the Garrison and other river reaches showing considerable tern and plover habitat variability.

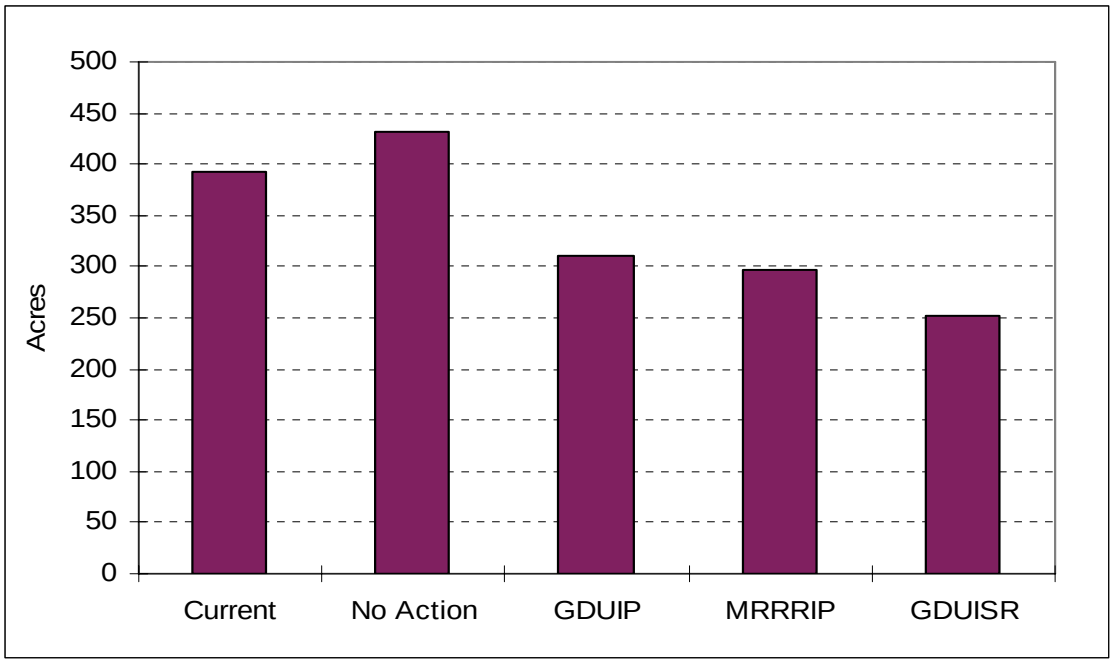

Figure 38. Average annual total riverine tern and plover habitat, 1930-1941.

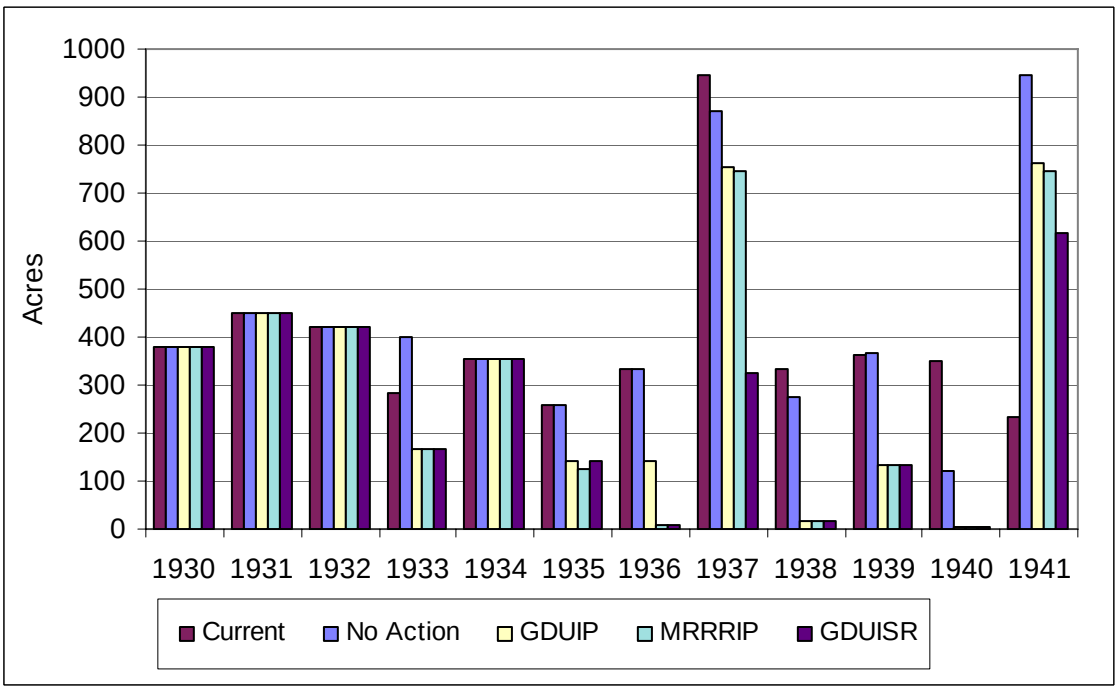

Figure 39. Annual total riverine tern and plover habitat, 1930-1941.

WETLAND HABITAT

Wetland habitat at approximately 40 sites from Fort Peck Lake to the mouth of the Missouri River were surveyed to determine the mix of wetland, riparian, bare sand, and open water habitat within a specific area comprising essentially all of each site surveyed. The effects of rising and falling water levels in the reservoirs and river reaches were modeled to determine potential effects on the mix of these four habitat types. The results of the modeling of the Current conditions and the four 2050 RRVWSP SDEIS alternatives are presented in Table 17 for both periods of analysis for the total and sub-reach data. The total average annual values for the 1930s drought analysis are shown on Figure 40.

Table 17 and Figure 40 show that the total wetland habitat values for the 1930s period of analysis increase from the No Action alternative to the three 2050 RRVWSP SDEIS alternatives that would use supplemental Red River Valley water with diversion of water from the Missouri River. The increases of 2,530 acres to 2,900 acres represent percentage increases of from 2.31 to 2.55 percent over the No Action alternative. The variability follows what is going on with the Upper River and reservoir delta reaches because their values also increase with the additional depletions associated with the three alternatives using Missouri River water. Because these two sets of reaches are the ones primarily affected, the likely cause for the differences is due to the variability throughout the year for intra-system regulation.

Figure 41 presents the annual values for the 1930s drought period. This figure shows variability in every year among the alternatives as there appears to be no set trend among them. Further examination of the delta and river reach breakdowns shows the variability on an annual basis also occurs in the delta and Upper River reaches.

Table 17. Average annual wetland habitat (1000 acres).

	Total	Delta	Upper River	Lower River
		1930-1941		
Current	114.35	37.35	39.72	37.28
No Action	113.82	38.08	39.45	36.29
GDUIP	116.72	39.87	40.56	36.29
MRRRIP	116.46	39.61	40.56	36.29
GDUISR	116.39	39.57	40.54	36.29
		1930-2002		
Current	151.02	34.64	45.39	70.99
No Action	151.83	34.72	46.31	70.80
GDUIP	151.07	33.95	46.36	70.76
MRRRIP	150.37	33.34	46.41	70.62
GDUISR	151.29	33.91	46.56	70.82

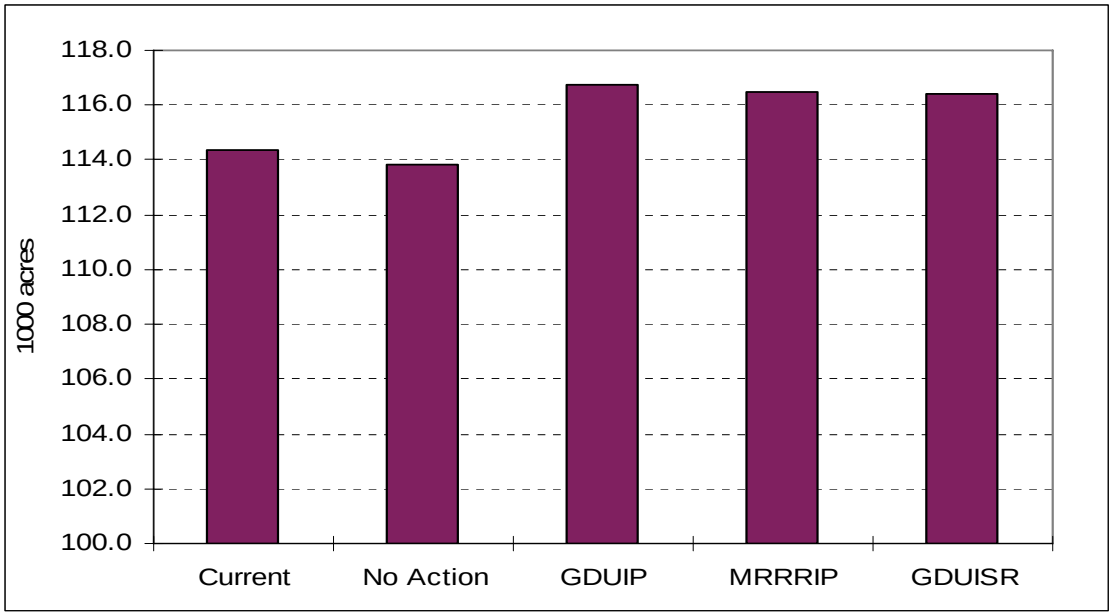

Figure 40. Average annual wetland habitat, 1930-1941.

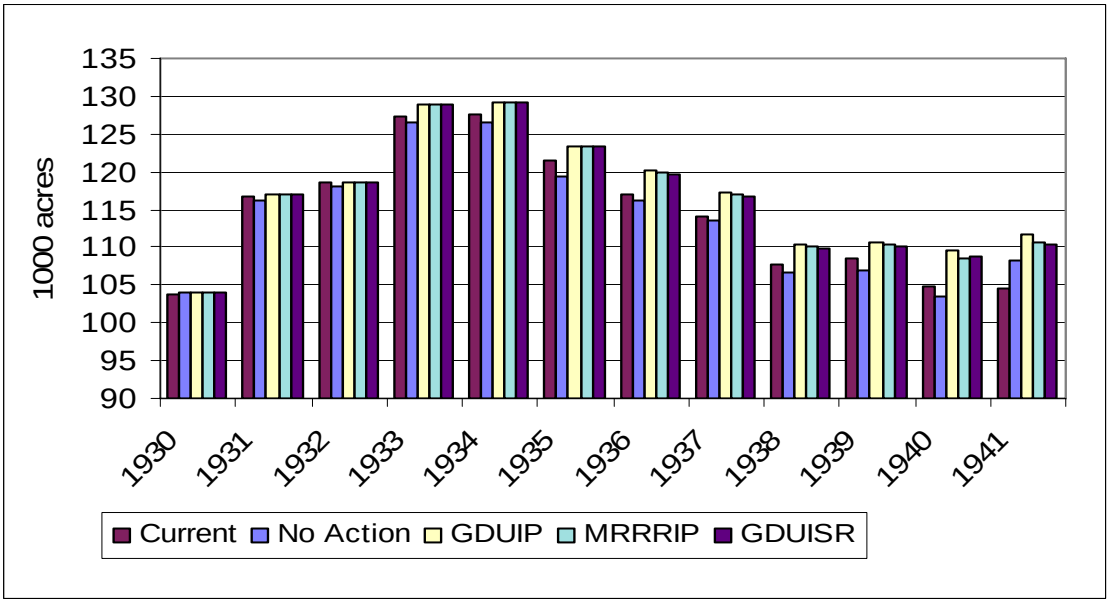

Figure 41. Annual total wetland habitat, 1930-1941.

RIPARIAN HABITAT

Riparian habitat is one of the four habitat types that were measured at the approximately 40 representative sites between the Fort Peck delta and the mouth of the Missouri River. It is the vegetative habitat type that needs the driest conditions. Table 18 and Figure 42 present the data on the riparian habitat values for the Current conditions and the four 2050 RRVWSP SDEIS alternatives.

Both the table and the figure show that, for the 1930s drought period of analysis, the No Action and three other 2050 RRVWSP SDEIS alternatives have a total riparian habitat value that is slightly higher than the Current conditions value. The values for the both periods of analysis are all essentially the same. Even the 1930s drought figures are essentially the same when one considers that the range is about 3,200 acres out of 144,000 acres of habitat. The range of percent differences from the No Action alternative for the three 2050 RRVWSP SDEIS alternatives taking water from the Missouri River to the Red River Valley is -0.09 to +0.13 percent. As with the wetland habitat, the differences for the delta and Upper River reaches account for the total differences among the alternatives.

Figure 43 presents the annual values for riparian habitat. It shows that the riparian habitat initially decreases for all of the alternatives and then increases gradually through the remainder of the drought, which would be expected with the drier conditions in the reservoirs and river reaches. The values in all years for all of the alternatives are essentially the same.

Table 18. Average annual riparian habitat (1000 acres).

	Total	Delta	Upper River	Lower River
		1930-1941		
Current	143.80	14.24	38.83	90.72
No Action	144.28	13.92	38.99	91.37
GDUIP	144.15	14.20	38.59	91.37
MRRRIP	144.47	14.46	38.63	91.37
GDUISR	144.47	14.46	38.63	91.37
		1930-2002		
Current	116.81	13.02	43.76	60.02
No Action	116.93	13.00	43.68	60.25
GDUIP	116.96	12.95	43.59	60.42
MRRRIP	117.17	13.08	43.68	60.40
GDUISR	117.12	13.06	43.68	60.39

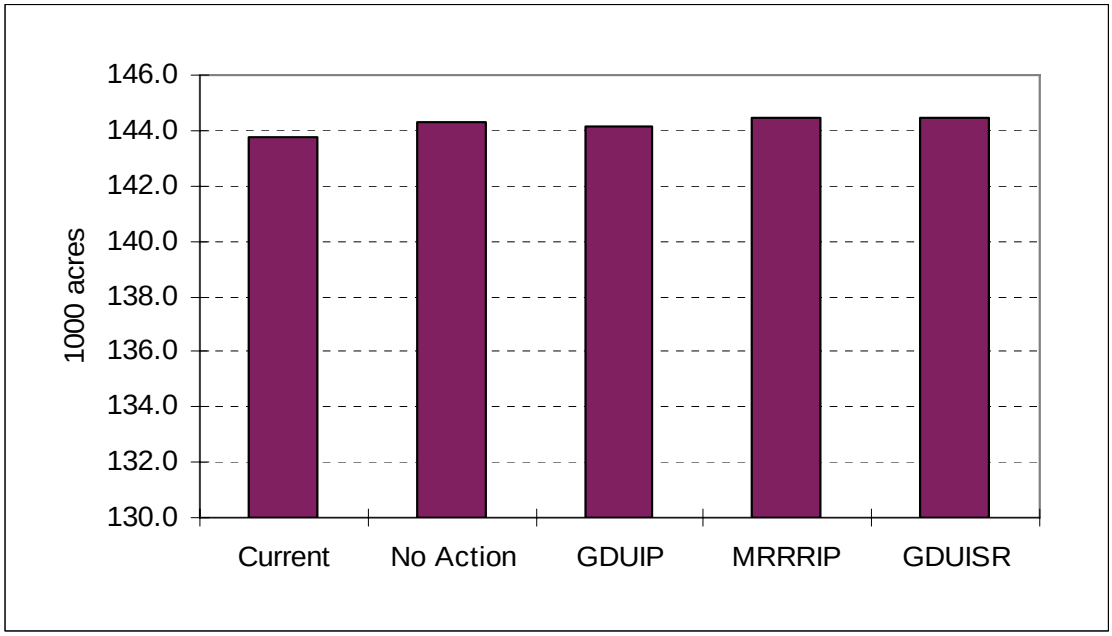

Figure 42. Average annual total riparian habitat, 1930-1941.

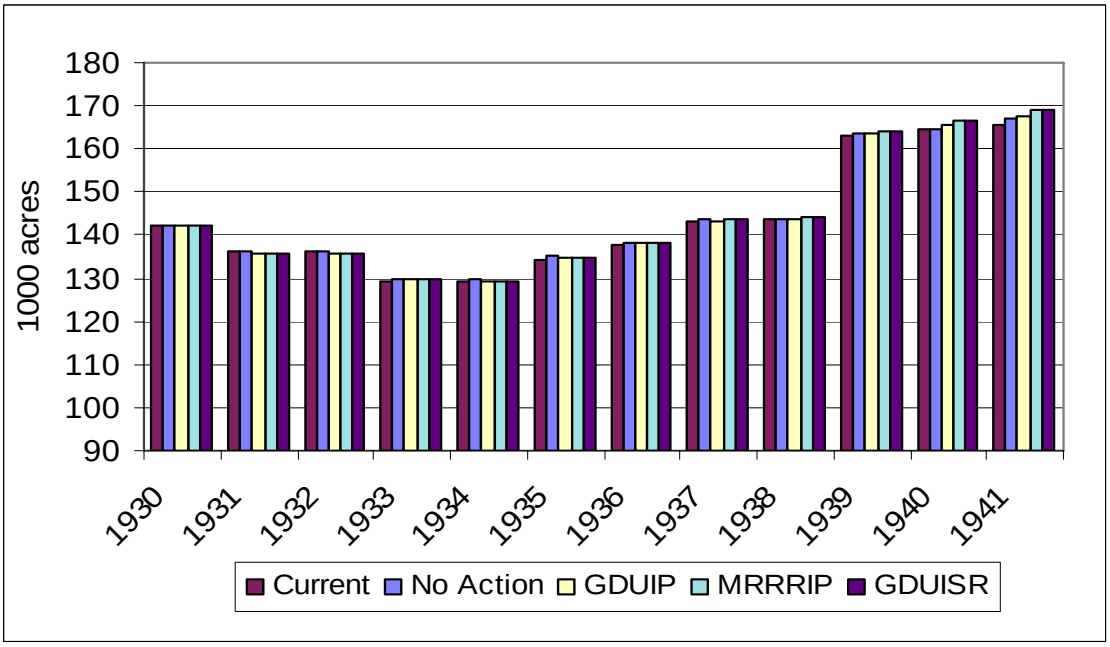

Figure 43. Annual total riparian habitat, 1930-1941.

HISTORIC PROPERTIES

The historic properties analysis focused on the potential erosion of known cultural, prehistoric, and historic sites located along the upper three lakes and Lake Sharpe. To turn the number of "hits" by wave action into a value that an increase reflects a positive

change between alternatives, the summation of months the known sites were susceptible to erosion was converted to an index value. Average annual effects of the alternatives on these sites are listed in Table 19 for both periods of analysis and on Figure 44 for the 1930s drought period of analysis.

The table and figure show that the historic properties index values are generally the same no matter what the additional water use in the Red River Valley is for the four 2050 RRVWSP SDEIS . The maximum difference of 8 units is equivalent to 0.11 percent.

Figure 45 presents the annual index values during the 1930s drought. The values are generally the same in 1930 at just over 3500 units, and they increase over the next 5 years of the drought to about 7500 units. There is limited variability in the four transition years, with the greatest difference being in 1934 with the No Action alternative being noticeably higher than the other three 2050 RRVWSP SDEIS alternatives. By 1935 when the values become about 7500 for the remainder of the 1930 to 1941 period, the water levels in the upper three reservoirs have dropped such that the wave action does not affect the known sites in these reservoirs and the index value is maximized.

Table 19. Average annual historic properties values (index).

	Total	Fort Peck Lake	Lake Sakakawea	Lake Oahe	Lake Sharpe
			1930-1941		
Current	6927	195	3660	2868	204
No Action	6968	196	3668	2900	204
GDUIP	6960	196	3672	2888	204
MRRRIP	6965	196	3673	2892	204
GDUISR	6962	197	3673	2888	204
			1930-2002		
Current	5105	146	2724	2031	204
No Action	5135	148	2744	2039	204
GDUIP	5156	149	2763	2040	204
MRRRIP	5152	149	2761	2038	204
GDUISR	5153	148	2753	2048	204

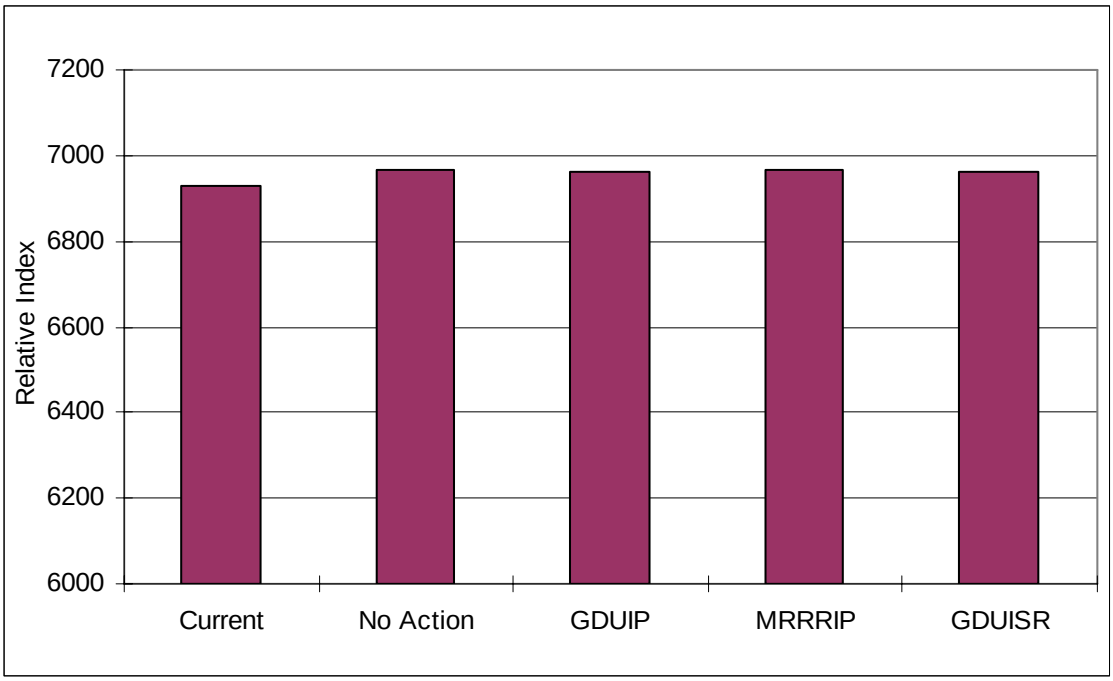

Figure 44. Average annual total historic properties index, 1930-1941.

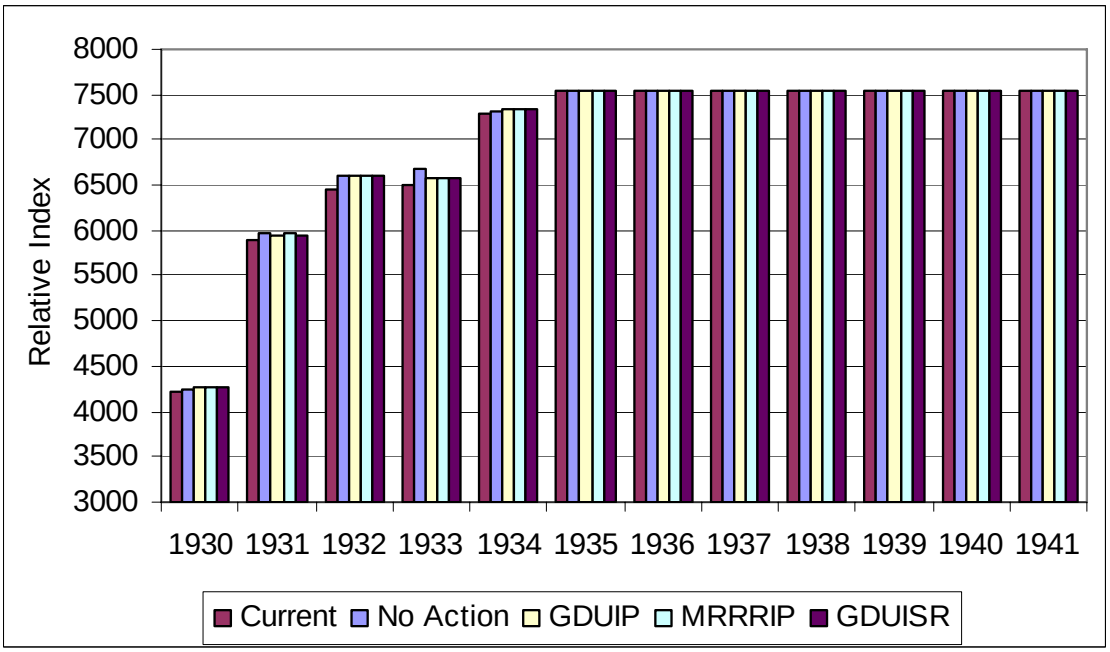

Figure 45. Annual total historic properties index, 1930-1941.

SUMMARY OF THE COMPARATIVE IMPACTS DURING THE 1930s DROUGHT

The individual sections of the comparative analysis of the 2050 RRVWSP SDEIS alternatives have focused on the effects of the alternatives on an economic use or an environmental resource one by one. This section will provide a comparative analysis among all of the economic uses and environmental resources in one table for the 1930s drought period. Table 20 presents the comparison of the three 2050 RRVWSP SDEIS alternatives to the No Action alternative.

Table 20 presents the positive average annual impacts during a repeat of the 1930s drought highlighted in green and the negative impacts highlighted in red, with the raw values without units for the No Action alternative provided in that column. Those values that are not highlighted (round off to zero) are changes between -0.5 and +0.5 percent, meaning those impacts are very small compared to those highlighted. Even though an impact may not be highlighted, the effects of an alternative in that category, no matter how small, may be significant to someone.

Table 20 shows that adding additional depletions to the Missouri River by 2050 above those that would occur within the basin (No Action) by moving less than 100,000 acre-feet of water to the Red River Valley would have negative effects greater than 0.5 percent in only three categories analyzed by the Corps for the RRVWSP SDEIS. These three categories are reservoir coldwater fish habitat, young fish production in the six mainstem System reservoirs, and riverine tern and plover habitat. Positive changes on an average annual basis through the 1930s drought from the No Action alternative would be for Missouri River navigation (one alternative with a change greater than 0.5 percent), hydropower energy revenues, hydropower plus thermal capacity at risk (two of the three alternatives), hydropower plus thermal energy at risk, recreation, riverine warmwater fish habitat, and wetland habitat. Of the positive average annual changes, the hydropower energy revenues, capacity at risk, and energy at risk values were unexpected. Further examination was required to determine what may have caused these results. This examination determined that the net difference between the No Action alternative and the other three 2050 RRVWSP SDEIS alternatives occurred in 1933 due to higher summer releases from the Garrison Dam. These higher releases resulted in more energy during the higher value part of the year regarding the energy revenue difference. It also provided higher flows to eliminate required generation reductions to the thermal powerplants in the Garrison downstream reach. This led to the reduction in the capacity at risk value (positive change). Finally, the additional hydropower energy that summer plus the reduced adverse effects to thermal generation that summer led to a reduction in the energy at risk value (positive change). Whether the difference in releases that summer would have occurred under real-time operations is unknown. Either way, the impact is due to a very small difference in the operation of the Mainstem System, with the effects being positive and the larger percentage differences not being a true indication of how close the three other alternatives are to the No Action alternative.

Table 20. Comparison of three 2050 RRVWSP SDEIS alternatives to No Action, 1930-1941.

	No Action Ave. Ann. Value 1/	Garrison Diversion Unit Import Pipeline (GDUIP)	Missouri River to Red River Import Pipeline (MRRRIP)	Garrison Diversion Unit Import to Sheyenne River (GDUISR)
		Percent Change from No Action Value		
Flood Control	167.3	0	0	0
Navigation	2.07	1	0	0
Hydropower NED	548.2	0	0	0
Hydropower Energy Revenues	-76.7	2	2	2
Hydropower + Thermal Capacity at Risk	535.6	1	1	0
Hydropower + Thermal Energy at Risk	320.4	8	8	10
Water Supply	555.3	0	0	0
Recreation	71.5	1	4	3
Reservoir Coldwater Fish Habitat	4.3	-2	-2	-2
Riverine Coldwater Fish Habitat	150.8	0	0	0
Riverine Warmwater Fish Habitat	72.3	2	1	2
Young Fish Production	1.44	-1	-1	-1
Phy. Hab. for Native River Fish	80.8	0	0	0
Riverine Tern and Plover Habitat	432.3	-28	-31	-42
Wetland Habitat	113.8	3	2	2
Riparian Habitat	144.3	0	0	0
Historic Properties	6968.3	0	0	0

1/ Units vary among the various economic use and environmental resource categories.